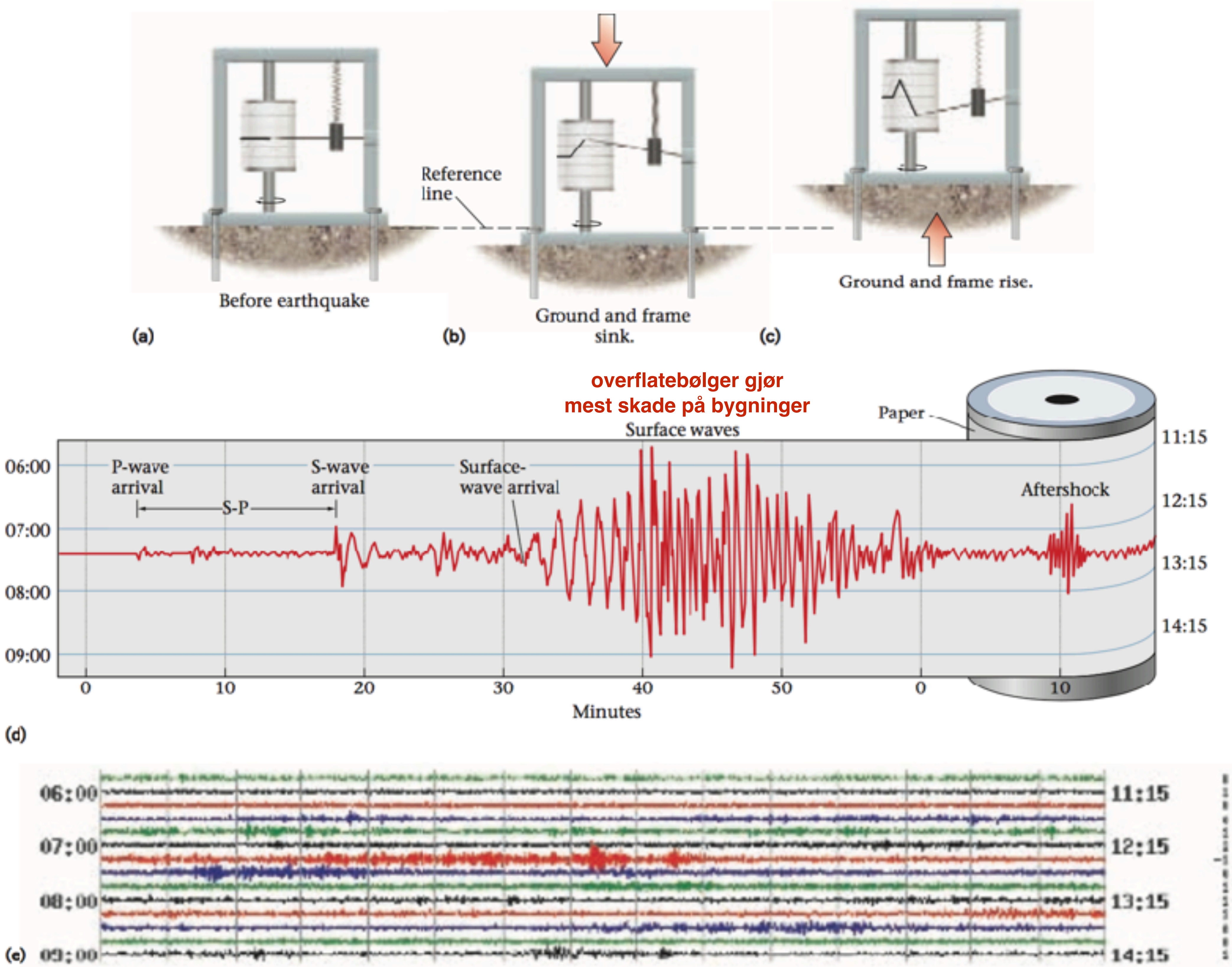


FIGURE 10.14 How a seismograph works (here, a vertical-motion seismograph). **(a)** Before an earthquake, the pen traces a straight line. **(b)** During an earthquake, when the ground and the frame of a seismograph go down, the weight stays in place because of inertia, so the pen rises relative to the paper roll. **(c)** When the ground and the seismograph frame rise, the pen goes down. **(d)** This closeup of the record (seismogram) for a single earthquake shows the signals generated by different kinds of seismic waves. **(e)** Digital seismic record from a seismograph station in Arkansas. The vertical lines represent minutes. Colors have no meaning, they just make the figure more readable. All of the earthquakes shown are small.

Du kan telle sekunder mellom lyn og torden for å bestemme hvor langt vekk lynet er.

Lyn (lys) tar ca. 0 sekunder å reise til deg.
Torden (lyd) tar ca. 3 sekunder å reise hver km.
(Lydhastighet er 343 meter per sekund.)

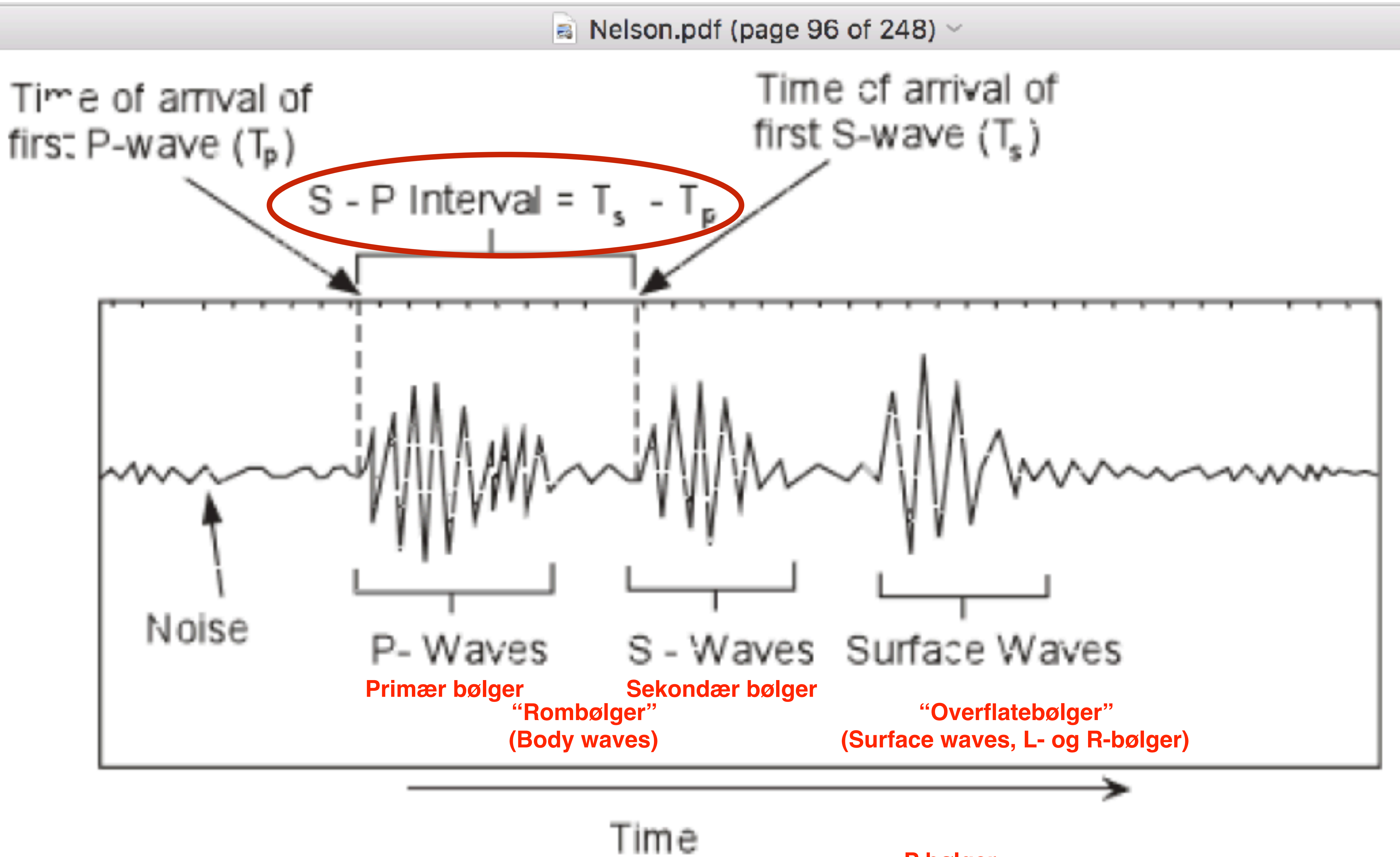
Lightning-Prone States. ...

Superbolts' of lightning strike when ...

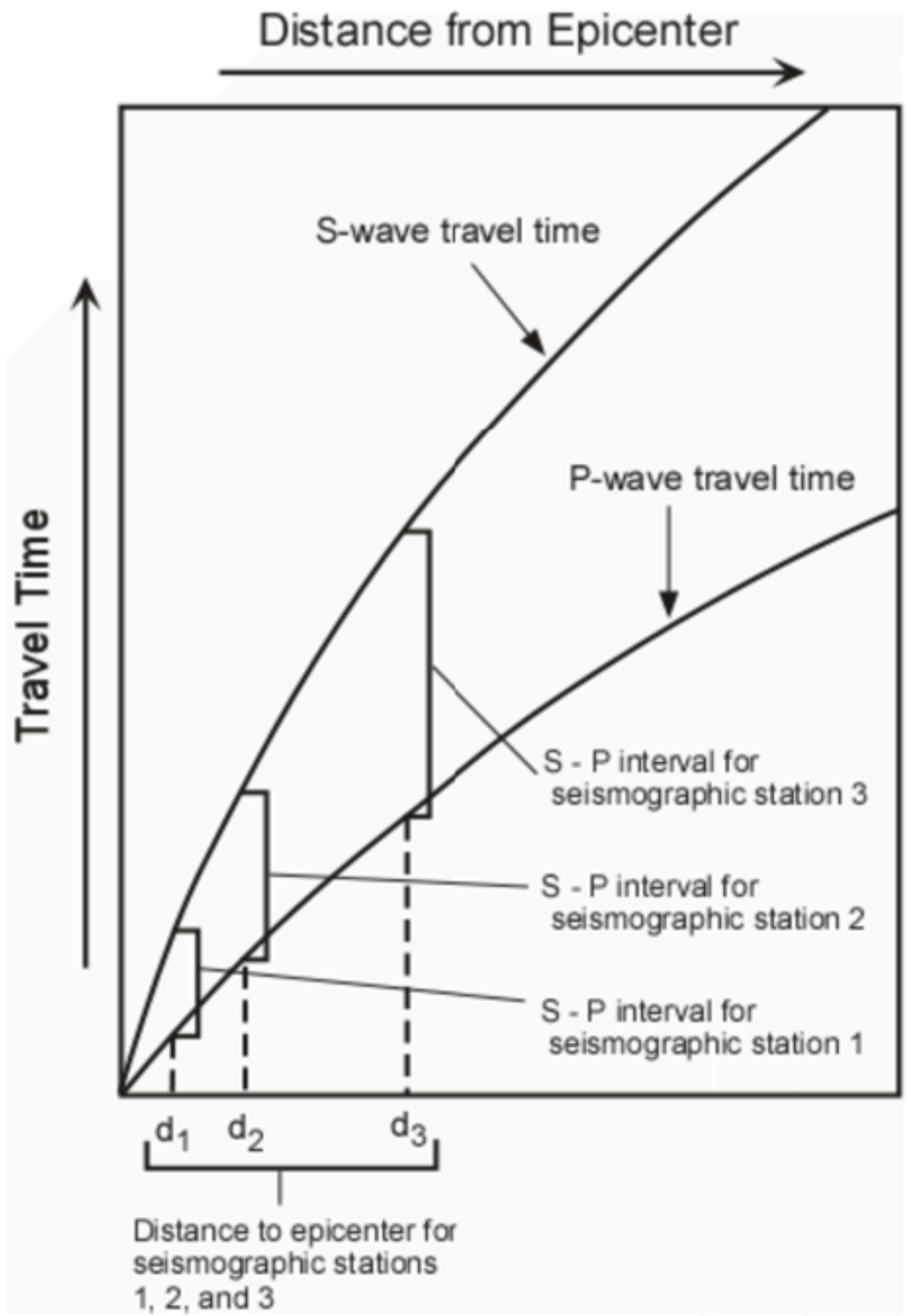
Hvis du teller til 9, er lynet 3 km vekk.

Vi kan kalle denne tid for "*torden-minus-lyn interval*"

Dette er det samme som med jordskjelv:
"*S-minus-P interval*"



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.

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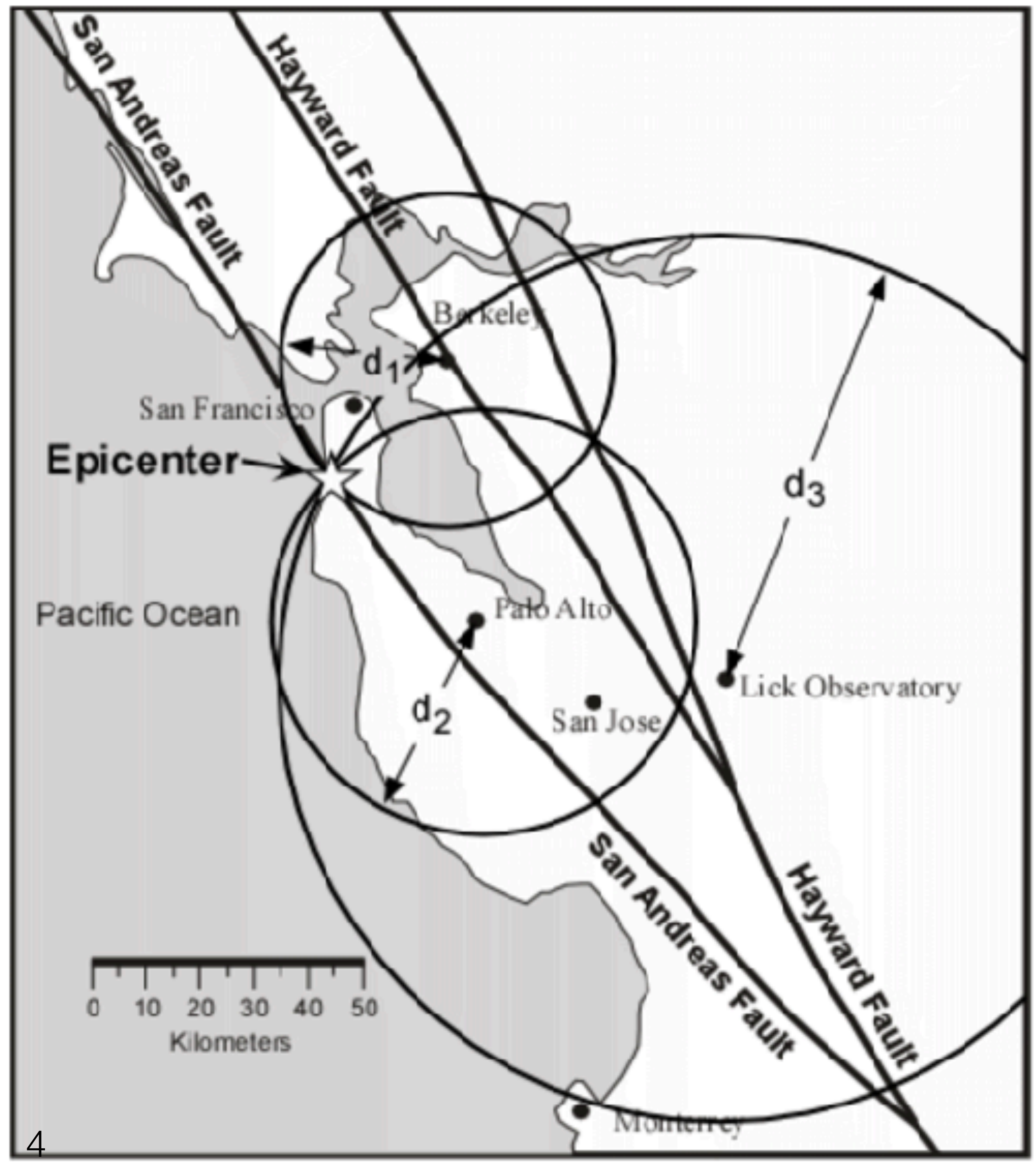
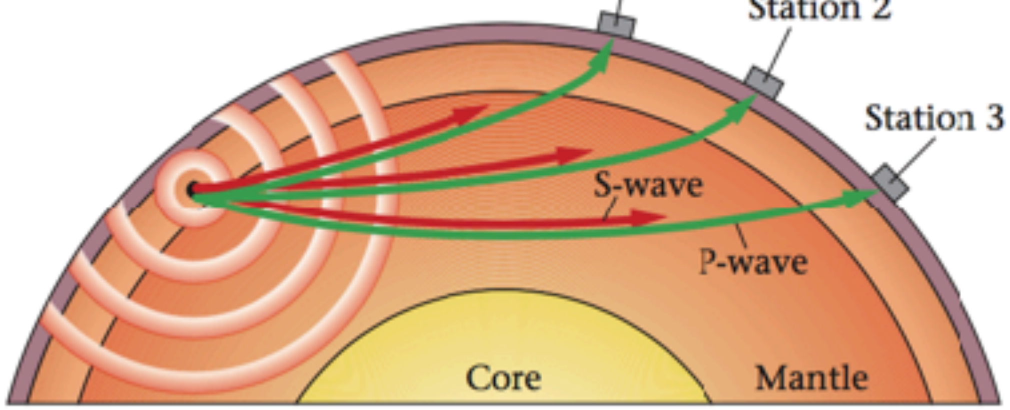


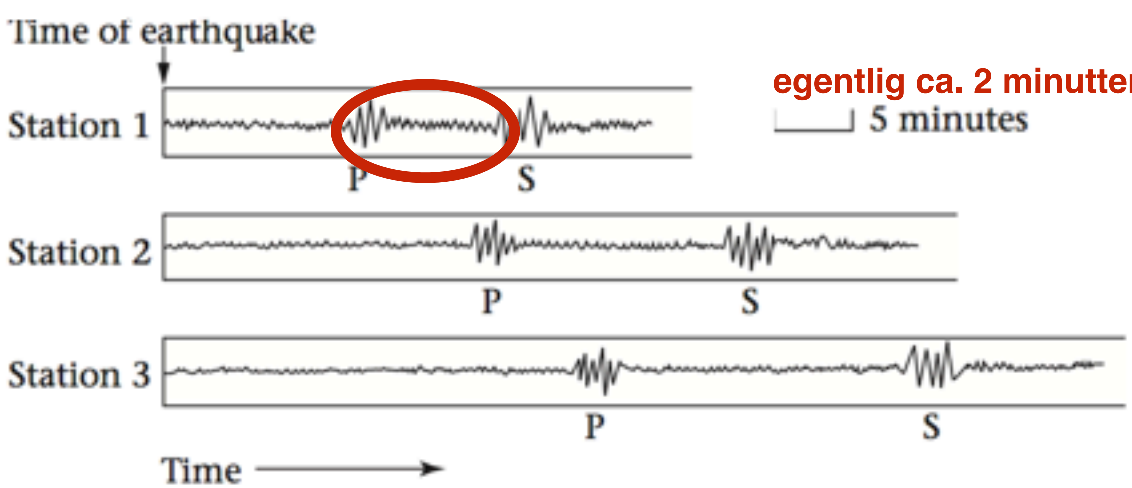
Marshaks forklaring

termine the map position of the epicenter, we use a method called triangulation, by plotting the distance between the epi-

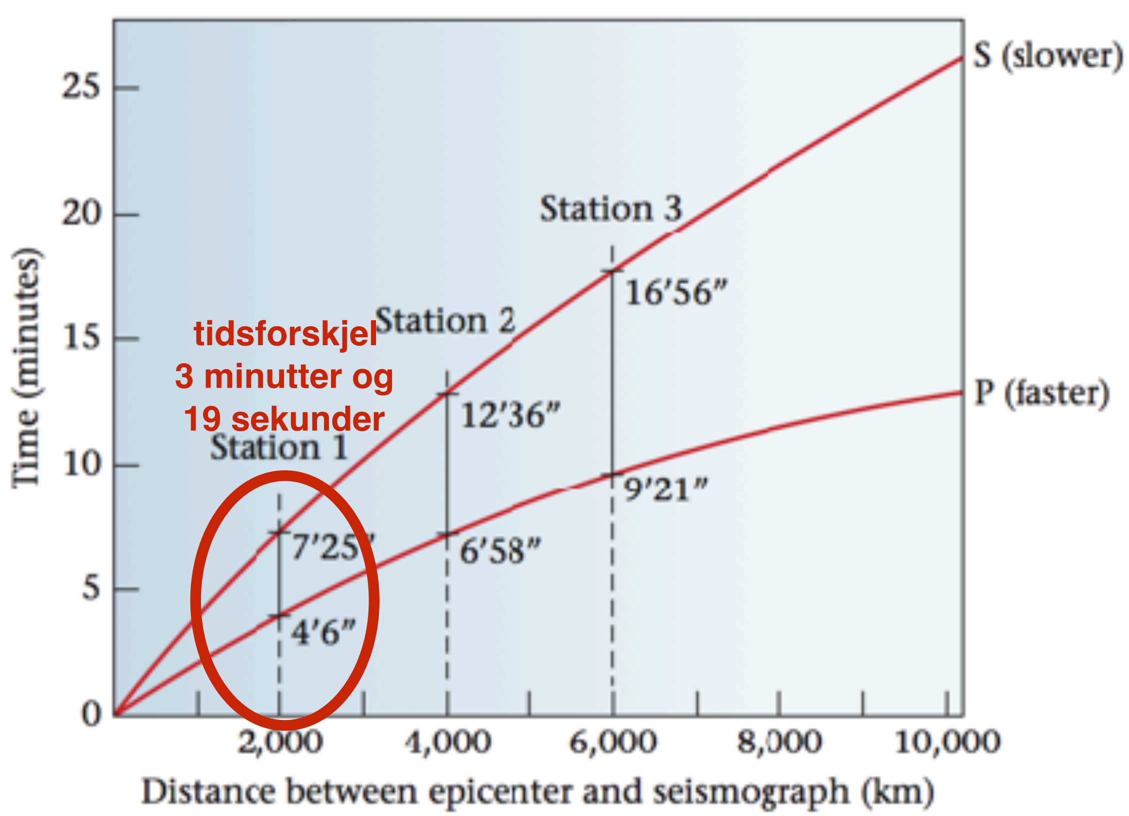
(a)



(b)



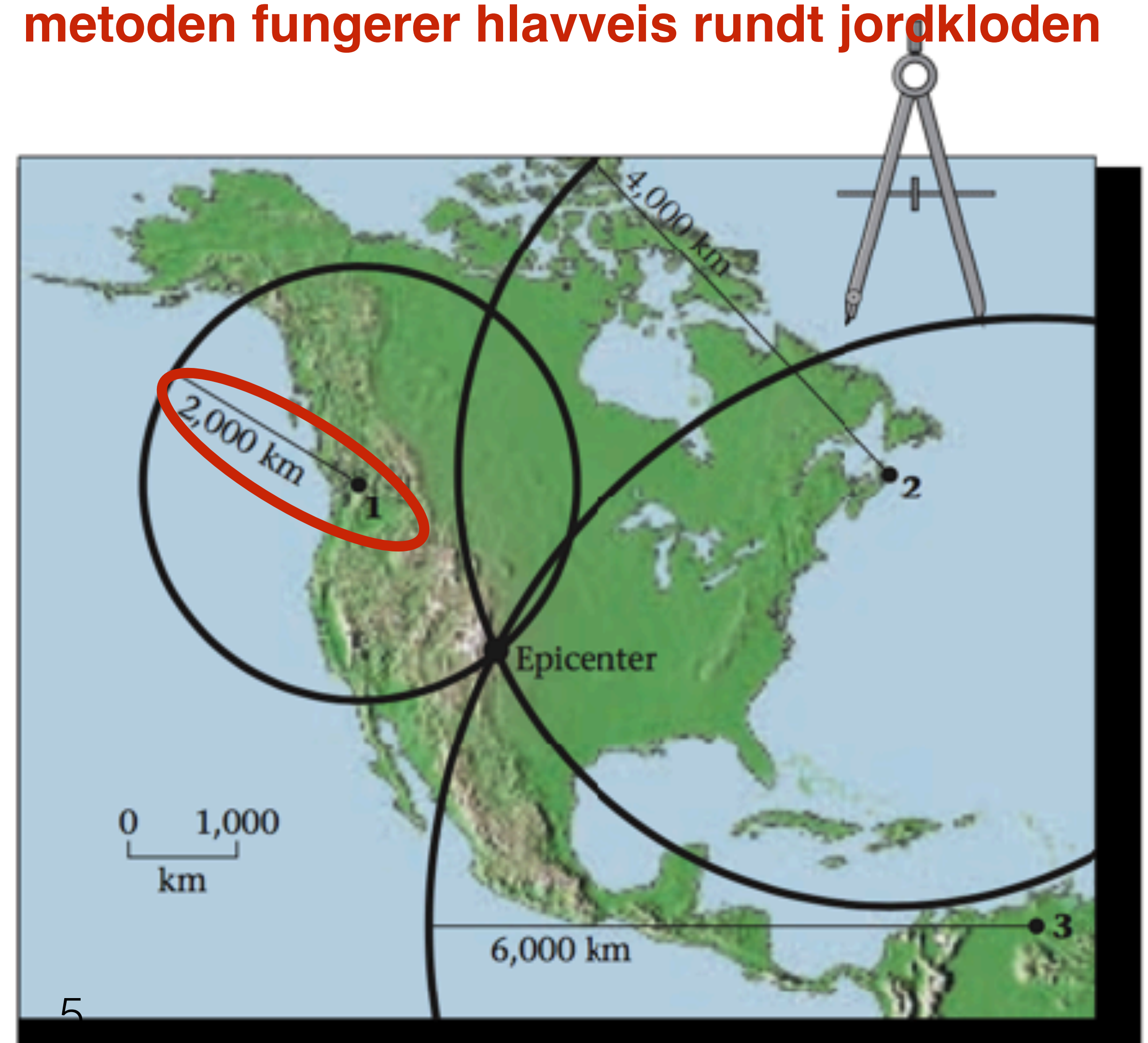
(c)



(d)

FIGURE 10.16 **(a)** Different seismic waves travel at different velocities, like cars racing at different speeds. **(b)** Thus, different waves arrive at different times at seismograph stations. P-waves arrive first, then S-waves. **(c)** The greater the distance between the epicenter and the seismograph station, the greater the time delay between the P-wave and S-wave arrival times. In this example, station 1 is closest to the epicenter, and station 3 is farthest away from it. Note that the P-wave arrives later at station 3 than at station 1, and that the time interval between P- and S-wave arrivals is greater at station 3 than at station 1. Arrivals at station 2 are in between. **(d)** We can represent the contrasting arrival times of P-waves and S-waves on a travel-time curve. **(e)** If an earthquake epicenter lies 2,000 km from station 1, we draw a circle with a radius of 2,000 km around the station. Following the same procedure for stations 2 and 3, we can locate the epicenter: it lies at the intersection point of the three circles.

metoden fungerer hlavveis rundt jordkloden

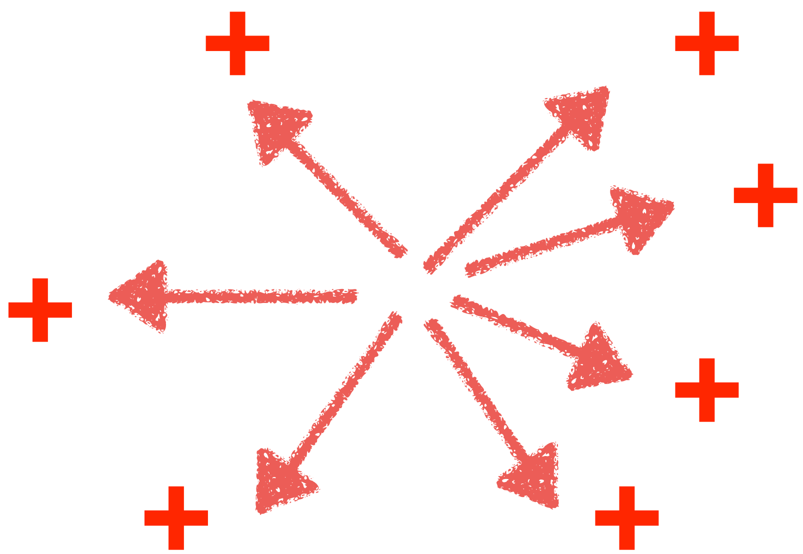


(e)

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.

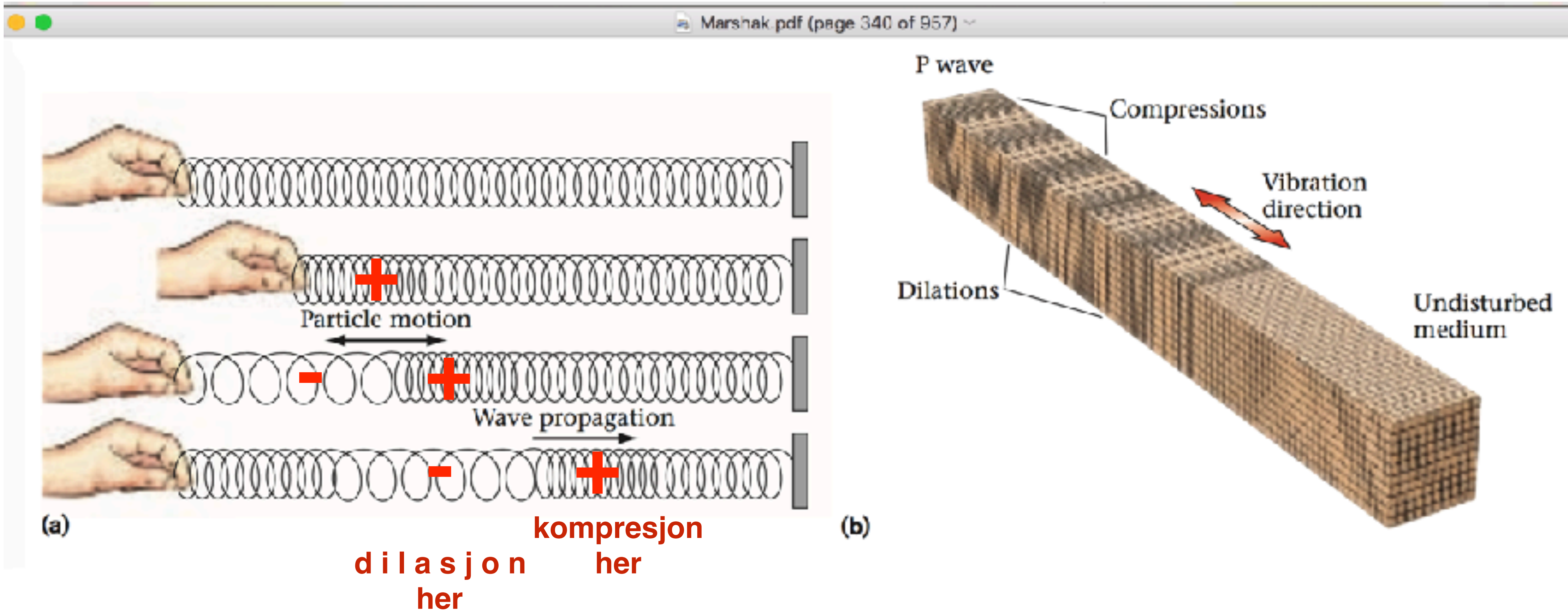


Ved en atombombe test f.eks. i Nord Korea, blir det kompresjon (ekspansjon) i alle retninger.

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

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

FIRST MOTION STUDY



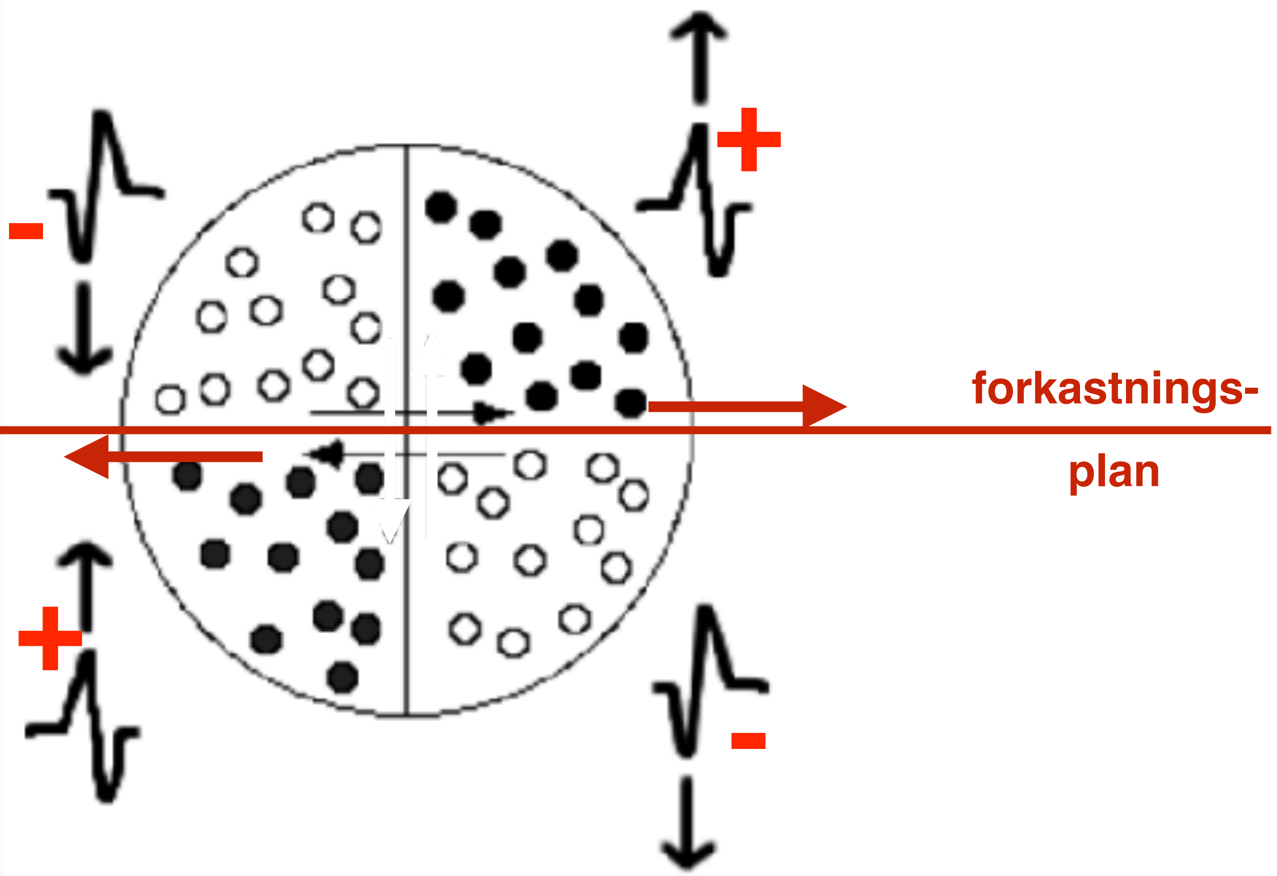
Den "FØRSTE BEVEGELSE" her er kompresjon (+).
Fordi hånden presser fjæren frem (+).

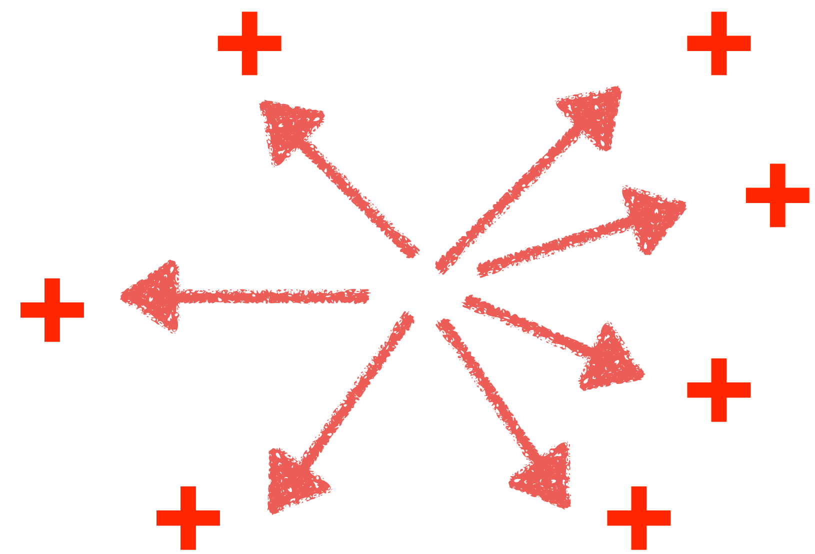
Hvis man drar tilbake i stedet for å presse,
blir første bevegelse dilasjon (-).

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

first motion

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 i Nord Korea,
blir det kompresjon (ekspansjon) i alle retninger.

Alle verdens seismiske stasjoner registrerer
KOMPRESJON som første bevegelse.

Midtpunkt i sirkelen er jordskjelvs Fokus

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

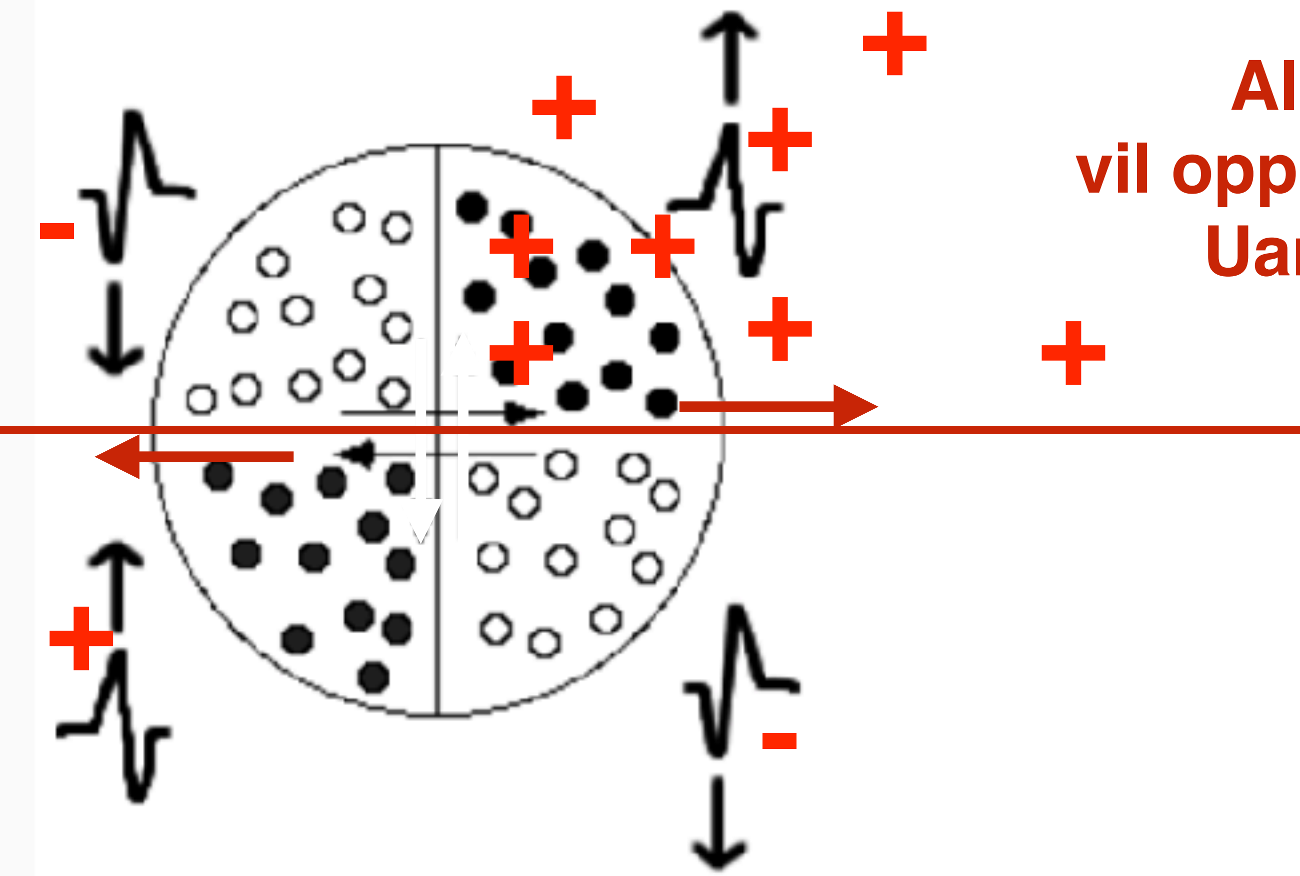
\+ KOMPRESJON

\- DILASJON

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

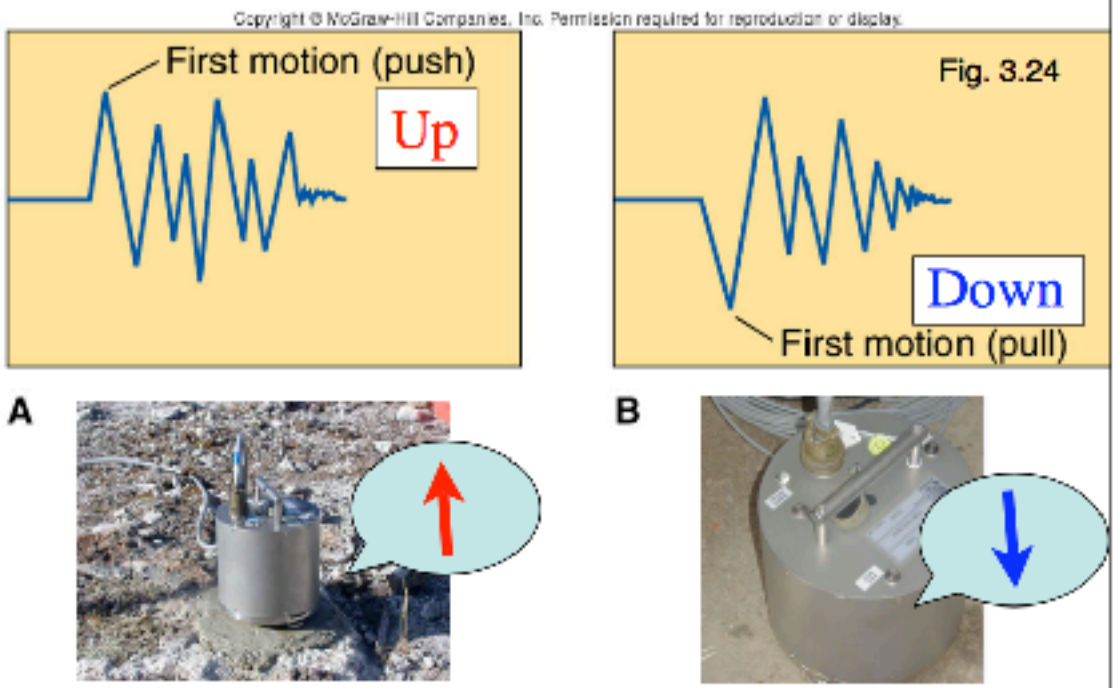
first motion

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.

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



Up - kompresjon
Down - dilasjon

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

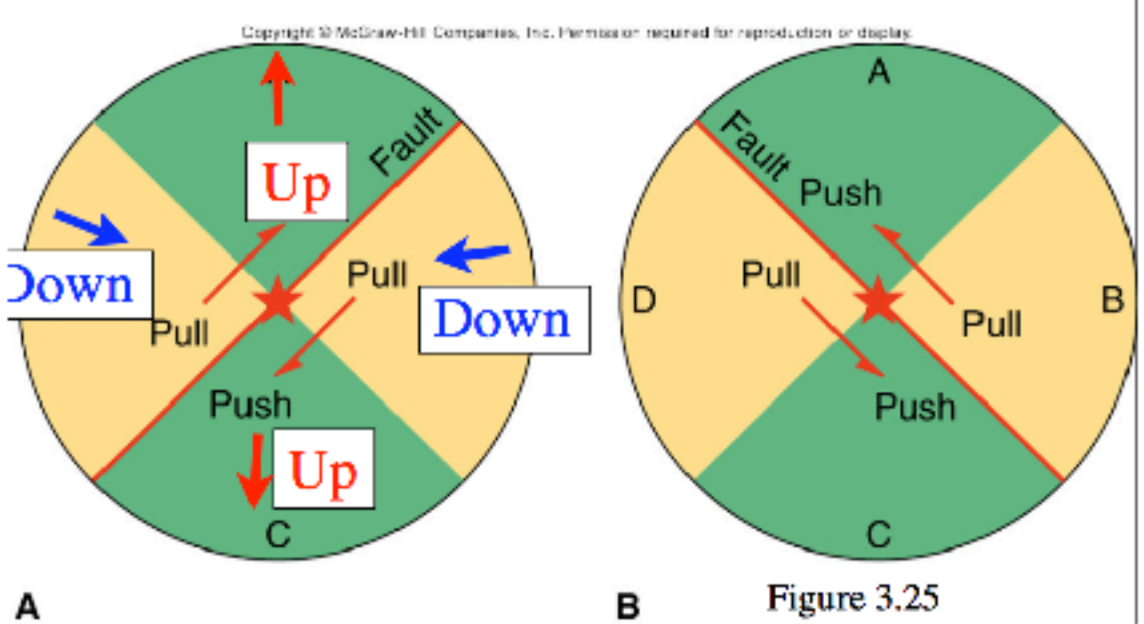
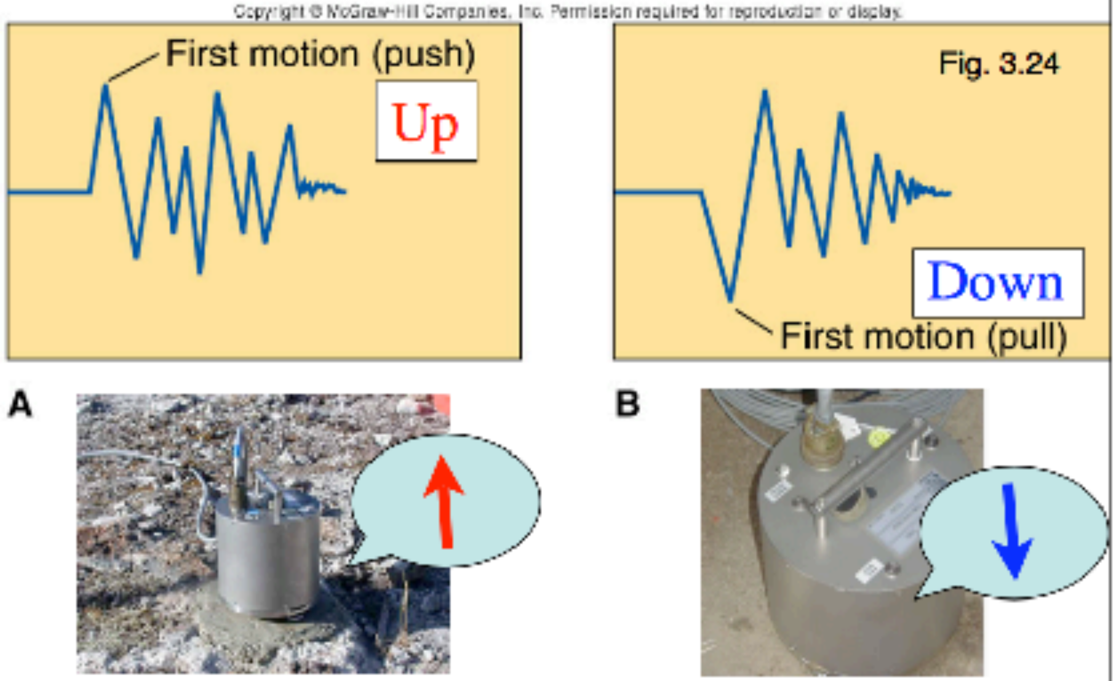


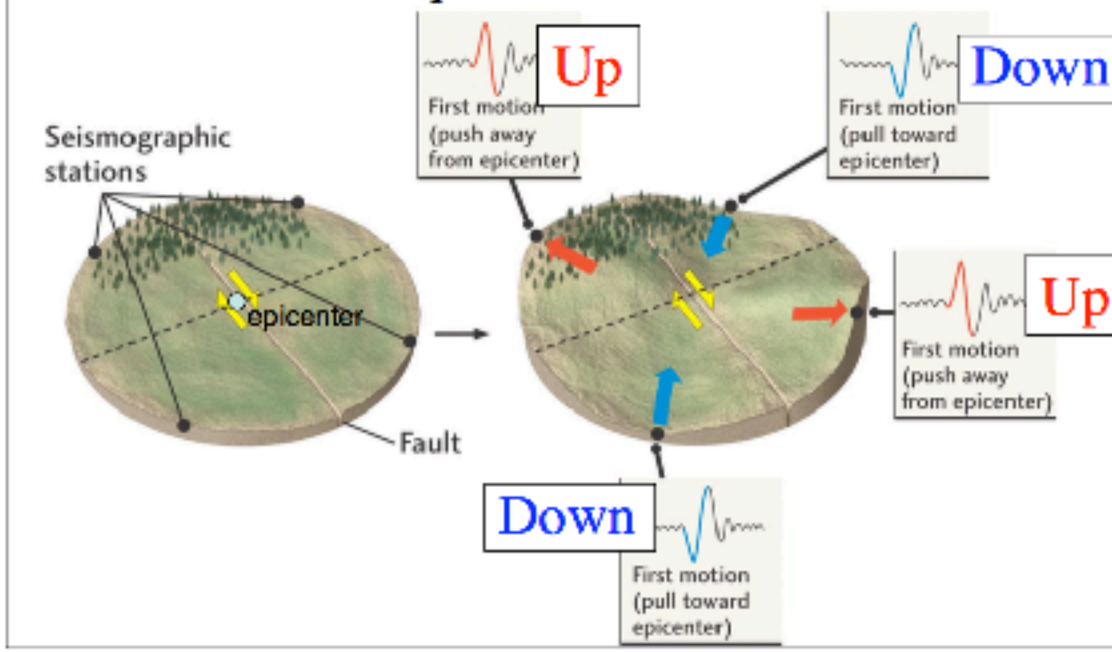
Figure 3.25

(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.

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



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

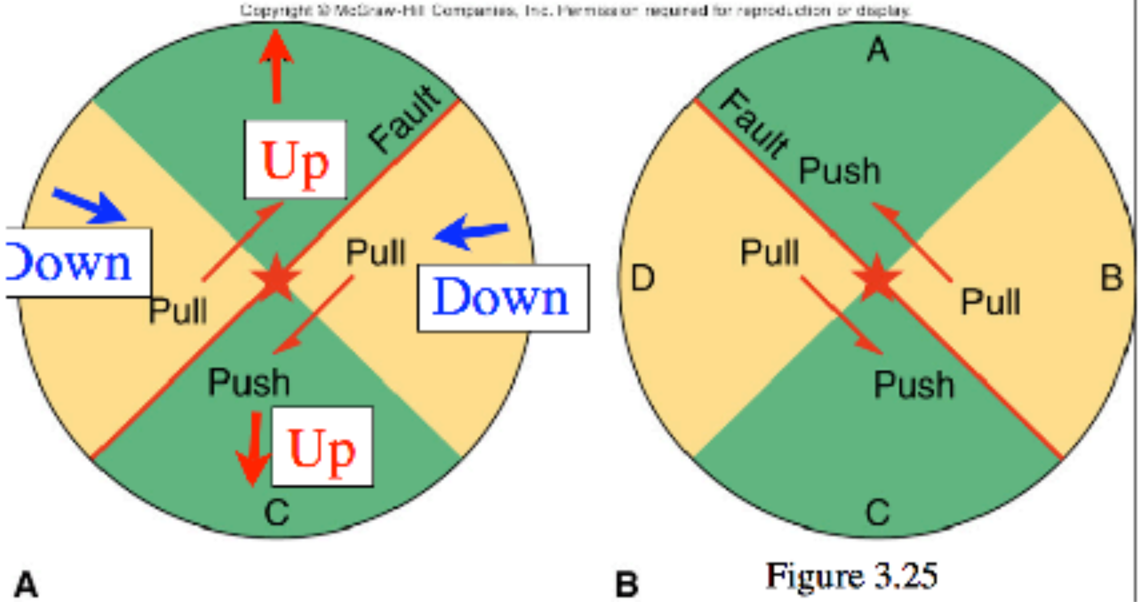
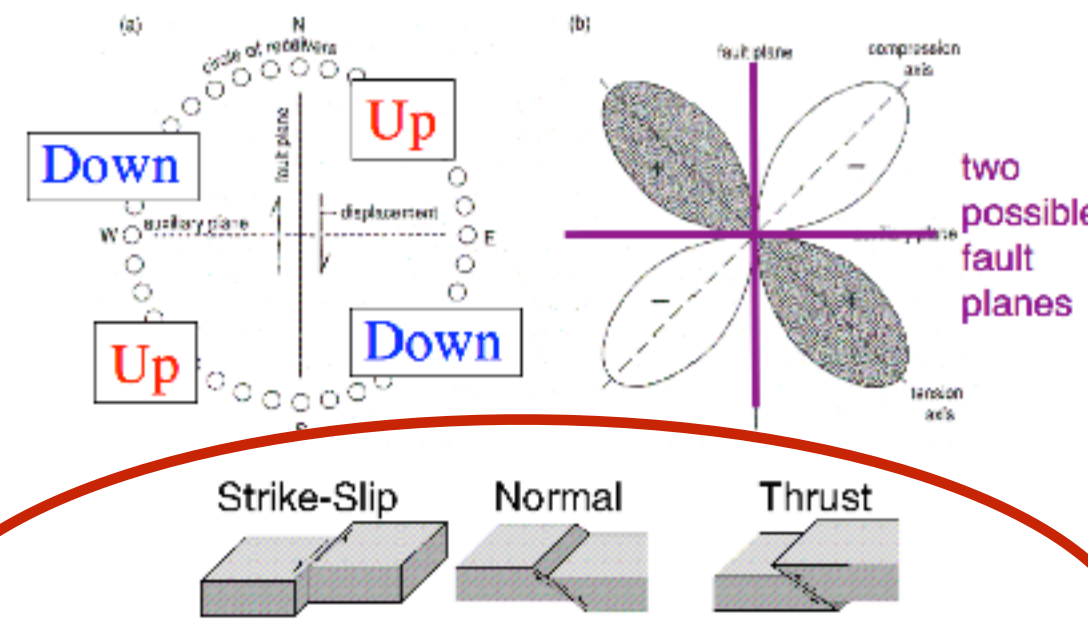
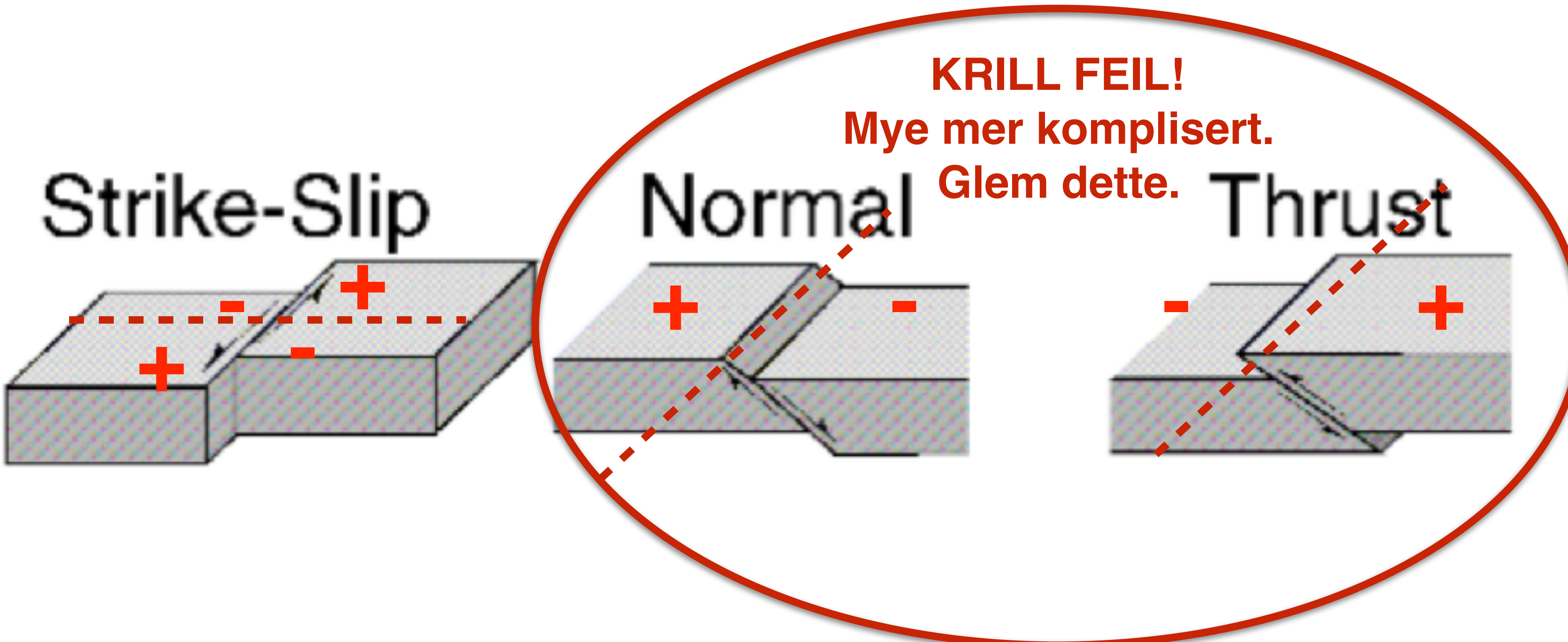


Figure 3.25



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



Kan bestemme om det er

sidelengs, normal, eller revers

(men det er alltid to mulige forkastningsplan, 90° fra hverandre)

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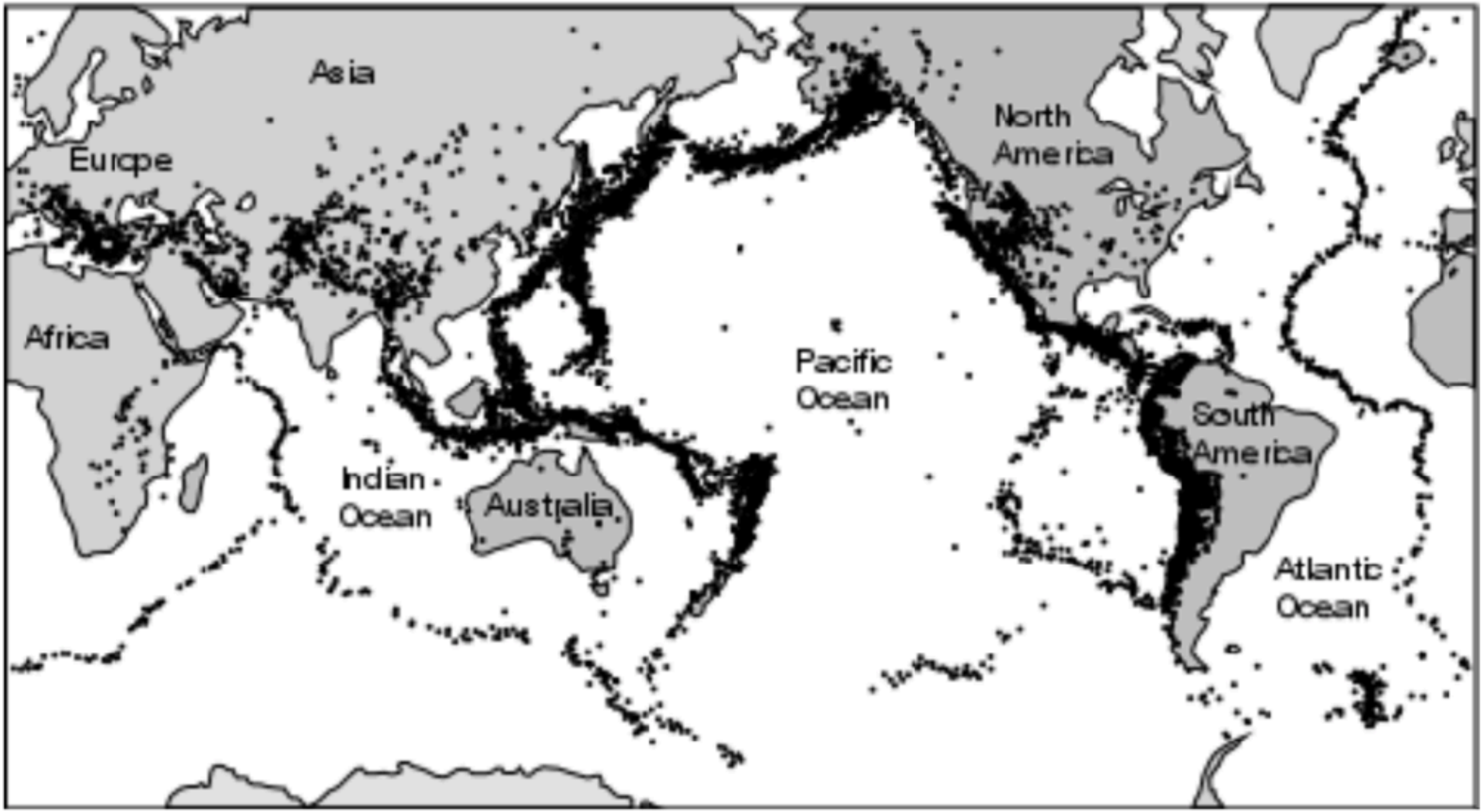
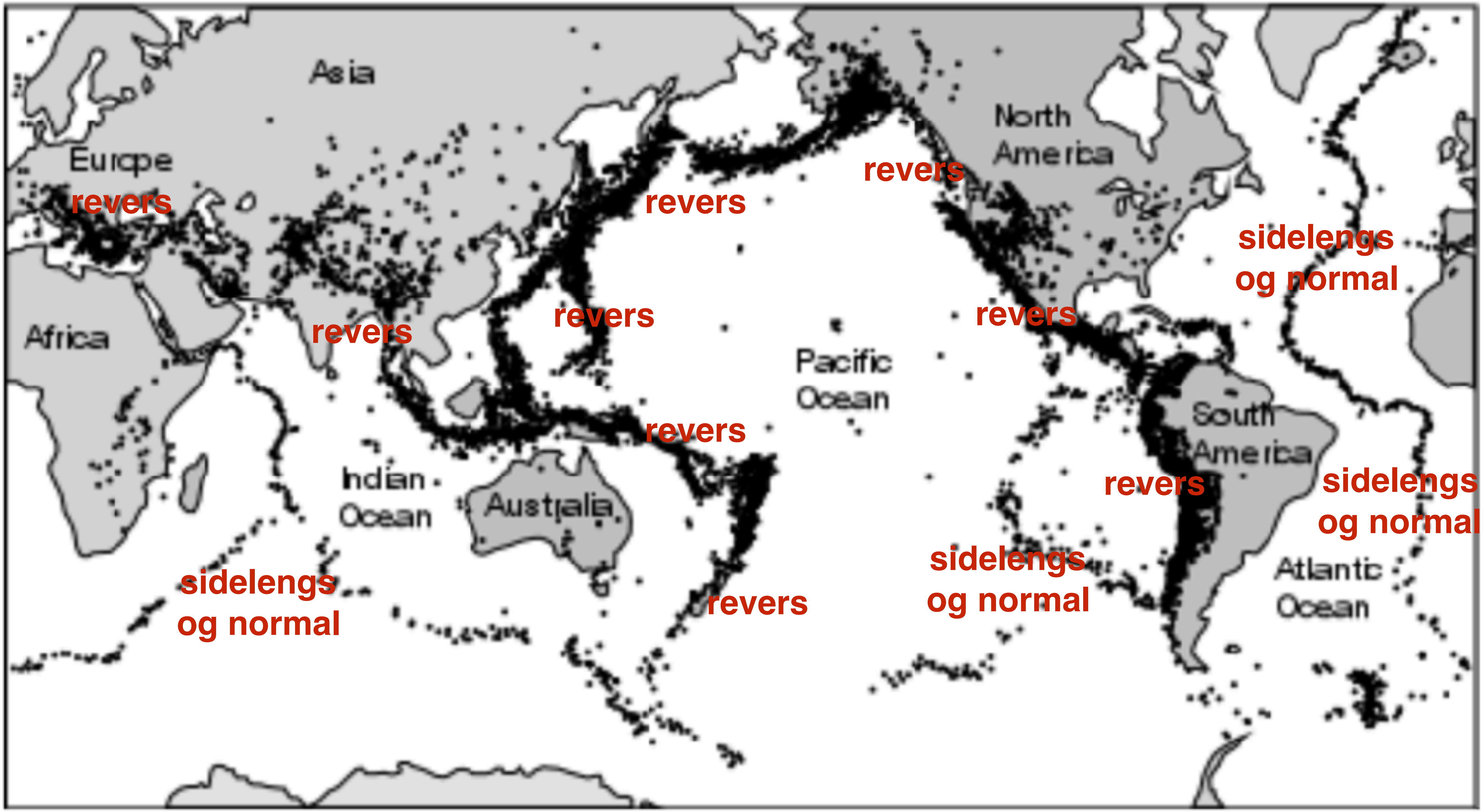
World Seismicity 1961 - 1967



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**.

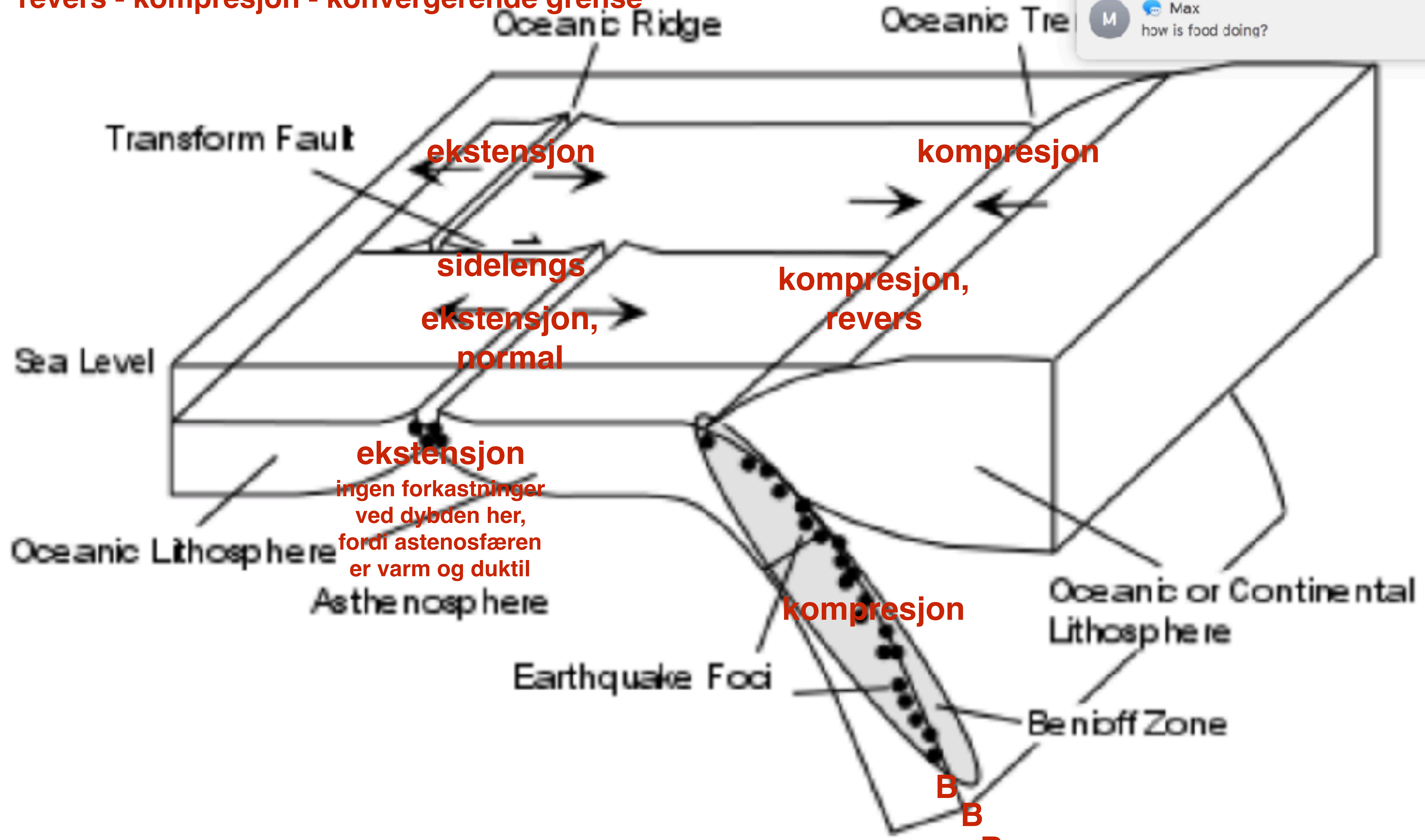
World Seismicity 1961 - 1967



sidelengs - transform grense

normal - ekstensjon - divergerende grense

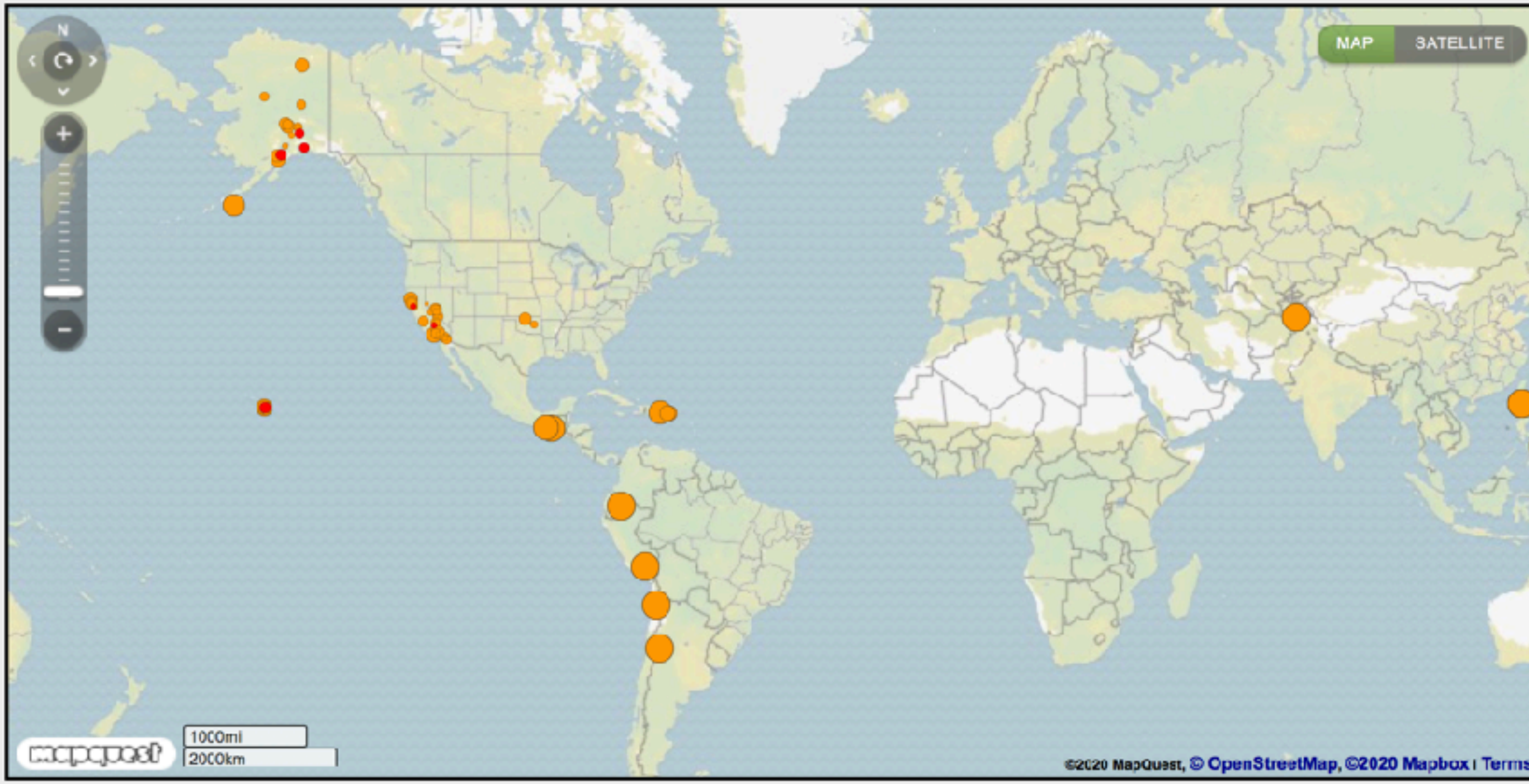
revers - kompresjon - konvergerende grense



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

quakes.globalincidentmap.com



GlobalIncidentMap.com | Amber-Alert Map | HAZMAT Situations Map | Forest Fires Map | Disease Outbreaks Map

Gang Activity Map | Border Security Issues | Presidential Threat Map | Terrorism Event Predictions | New - Quakes Map

Drug Interdictions Map | Non-Terror Aviation Incidents | NEW - Food/Medicine Incidents | NEW - Human Trafficking

DATE/TIME		REGION	MAGNITUDE		DEPTH (in km)	SOURCE	DETAIL
Tuesday October 13 2020, 08:36:33 UTC	14 minutes ago	15 km NW of Ninilchik, Alaska	●	1.7	74.3	USGS Feed	Detail
Tuesday October 13 2020, 08:34:40 UTC	16 minutes ago	4 km ESE of Pāhala, Hawaii	●	1.9	33.7	USGS Feed	Detail
Tuesday October 13 2020, 08:25:01 UTC	26 minutes ago	8 km E of Pāhala, Hawaii	●	1.9	30.1	USGS Feed	Detail
Tuesday October 13 2020, 08:24:53 UTC	26 minutes ago	17 km SW of Tatitlek, Alaska	●	1.4	20.5	USGS Feed	Detail

Standard skala for jordskjelv styrke:

"Richter skala"

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

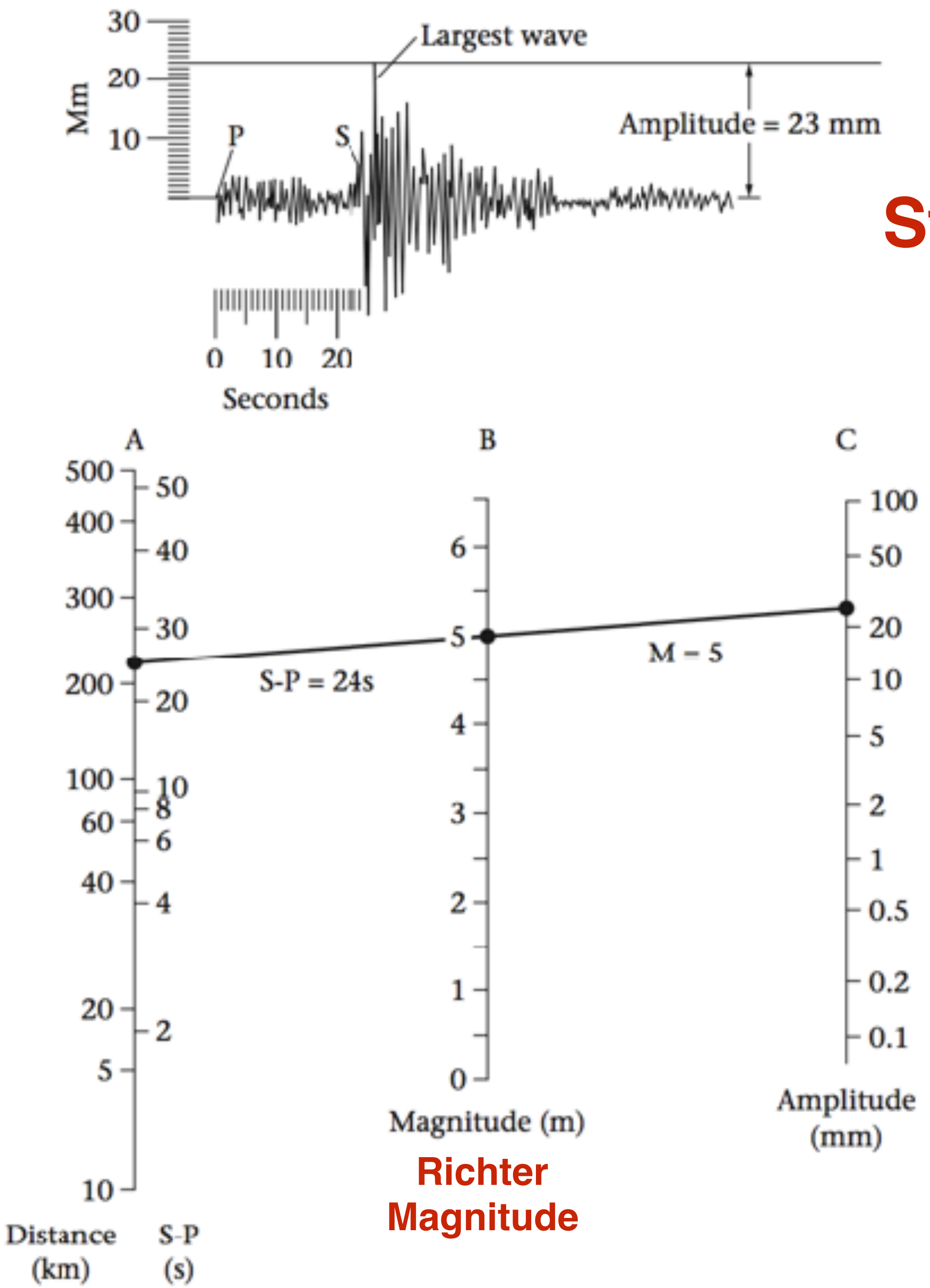
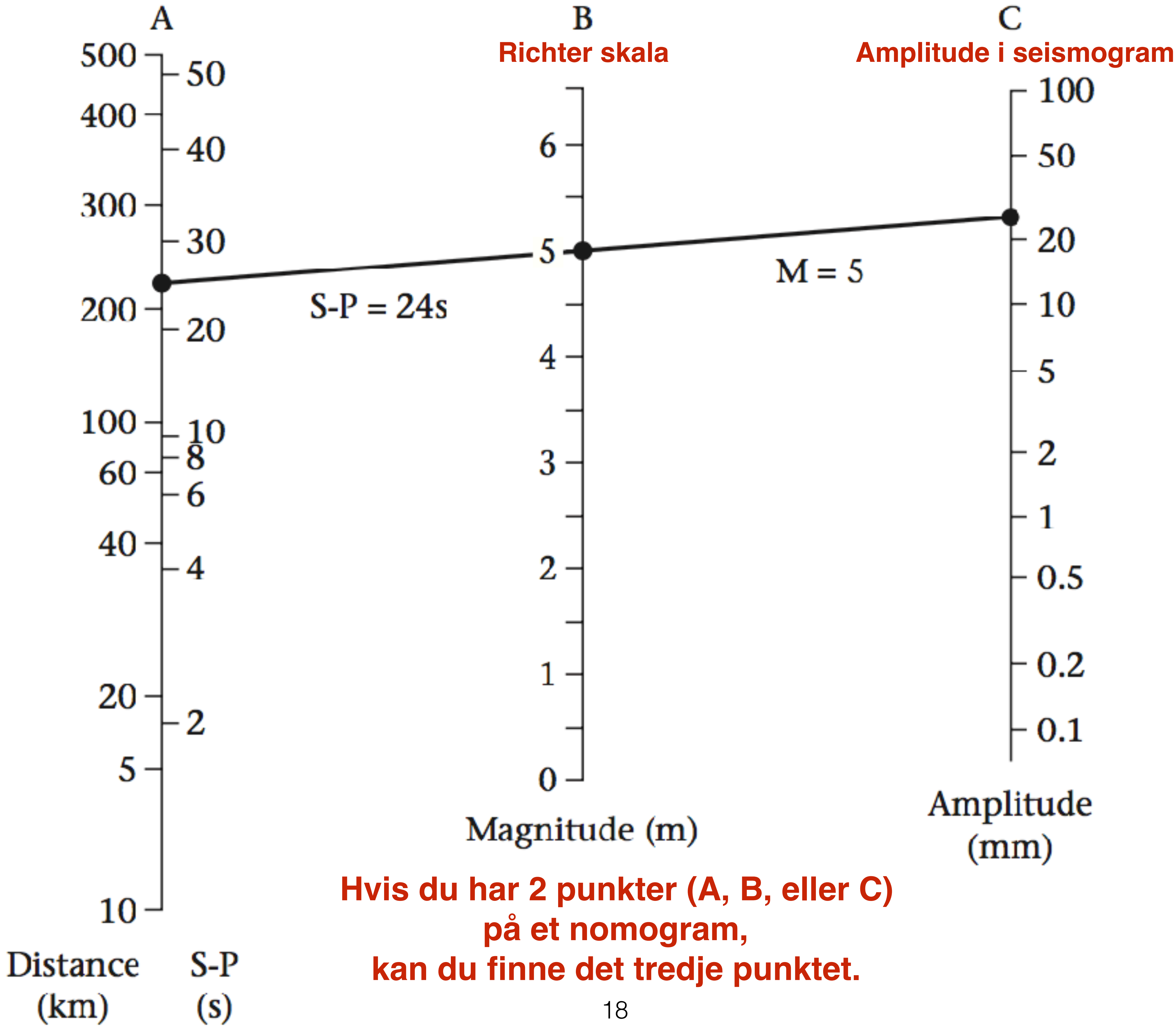
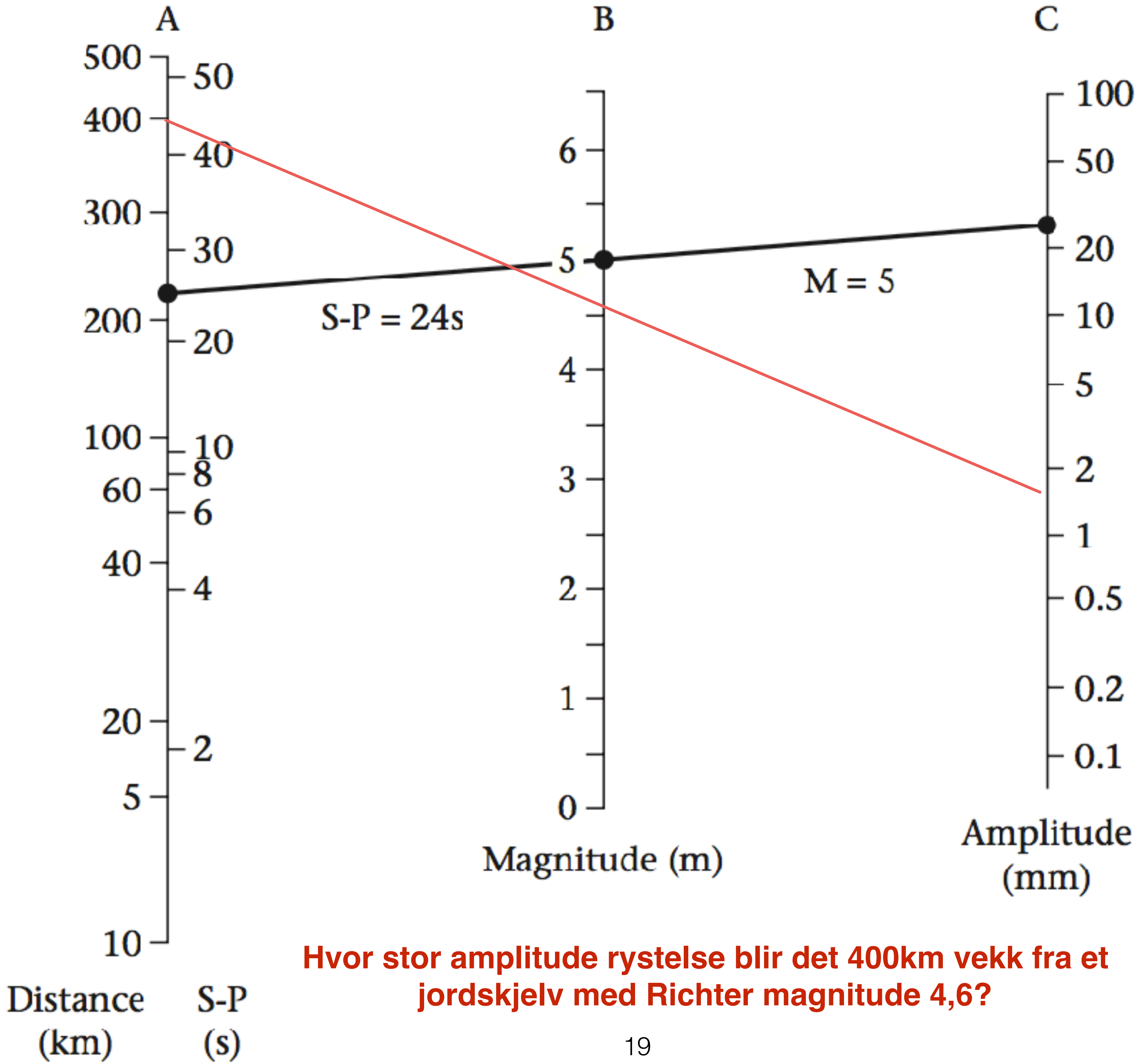


FIGURE 10.18 To calculate the Richter magnitude from a seismogram, first measure the S-minus-P time to determine the distance to the epicenter; then measure the height, or amplitude (in mm), of the largest wave recorded by the seismograph. Draw a line from the point on column A representing the S-minus-P 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.

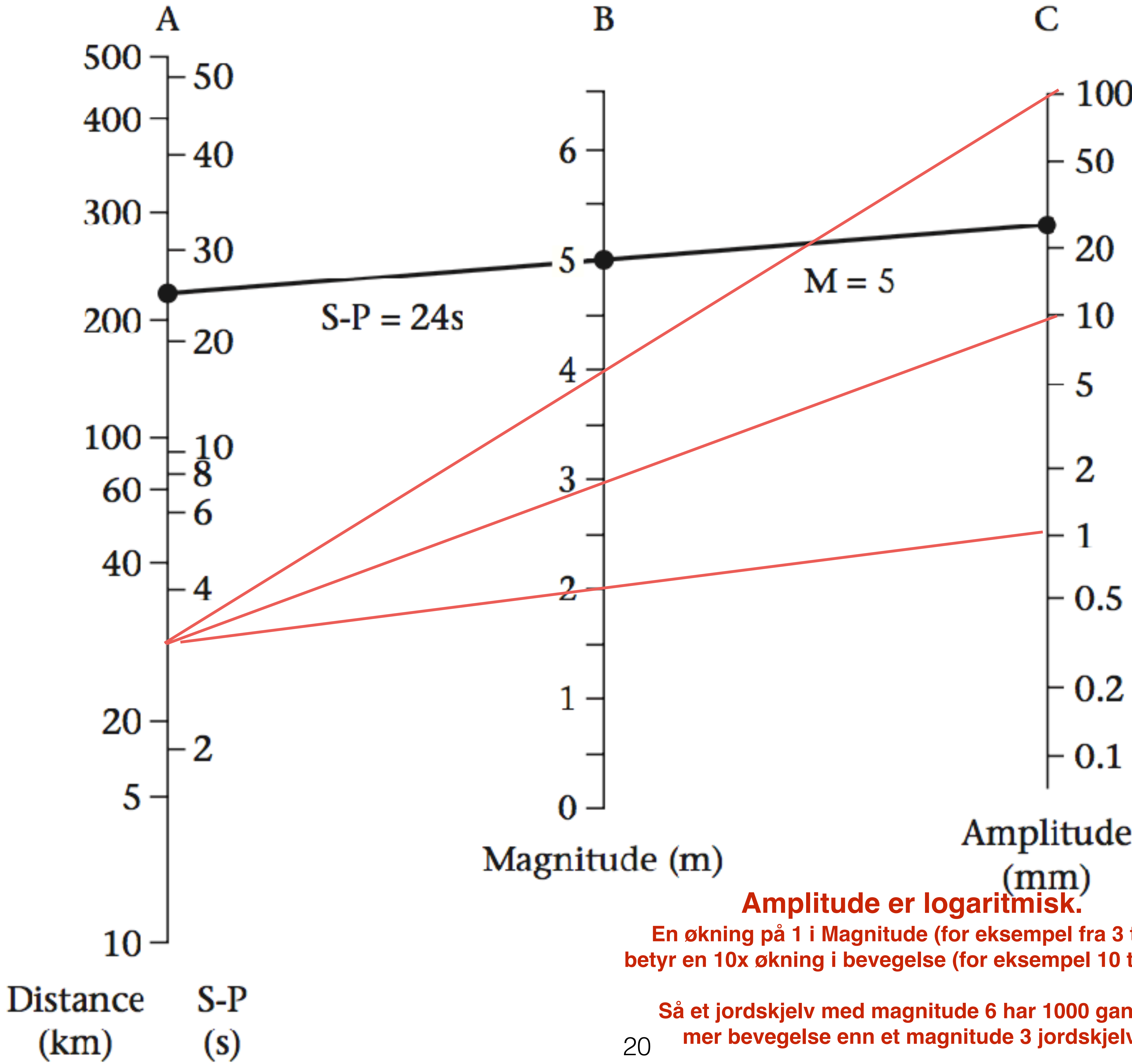
et slik treskala-diagram kalles et nomogram



Hvis du har 2 punkter (A, B, eller C)
på et nomogram,
kan du finne det tredje punktet.



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 bevegelse enn et magnitude 3 jordskjelv.

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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}	

En økning på 1 i Magnitude betyr en 10x økning i Amplitude.

Men ca. 31x økning i ENERGI, sier Nelson.

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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 Mer enn 2 per dag
4.0 - 4.9	6,200	Minor
3.0 - 3.9	49,000	
2.0 - 2.9	300,000	
0 - 1.9	700,000	

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

her er
“Mercalli skala.”
ikke Richter skala.

Kan brukes for historiske jordskjelv
før det eksisterte seismogramer.

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

Det finnes bedre skala enn Richters,
men Richters er i vanlig bruk..

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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

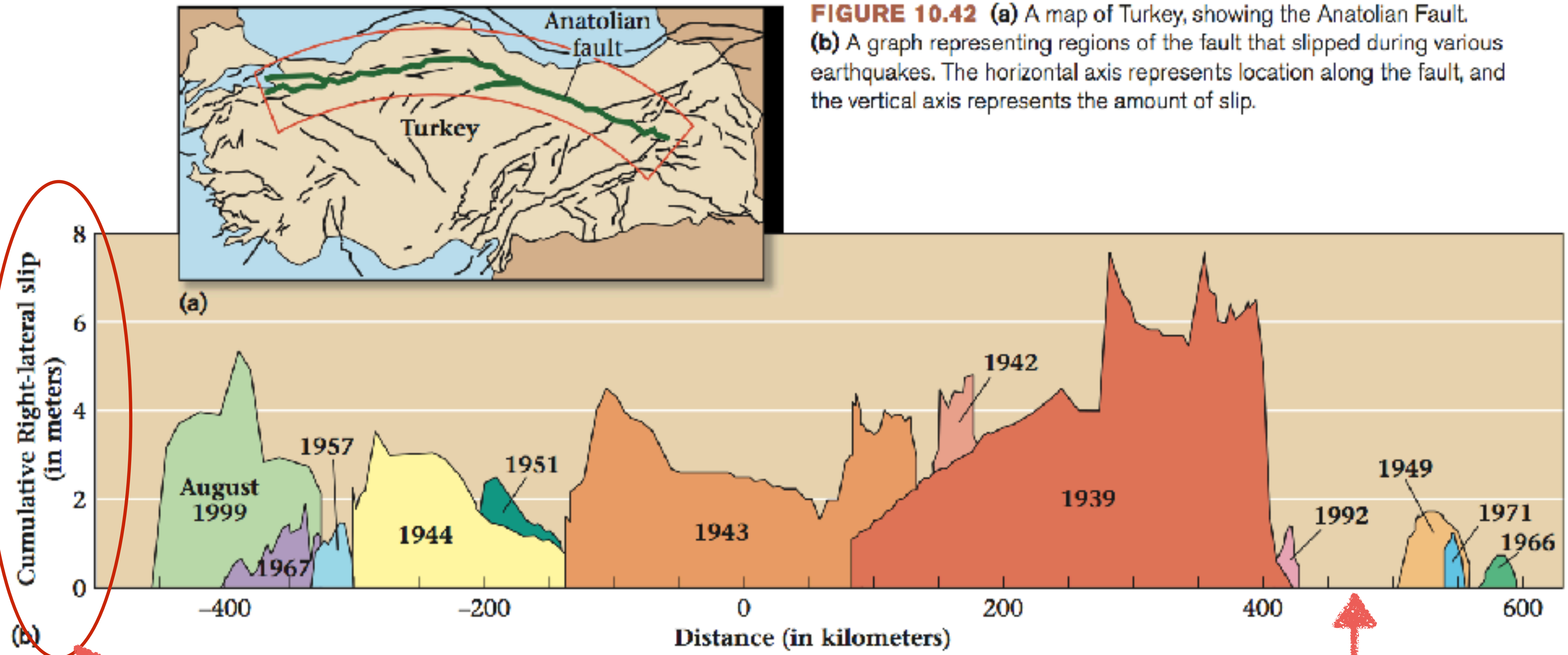


FIGURE 10.42 **(a)** A map of Turkey, showing the Anatolian Fault. **(b)** A graph representing regions of the fault that slipped during various earthquakes. The horizontal axis represents location along the fault, and the vertical axis represents the amount of slip.

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.)

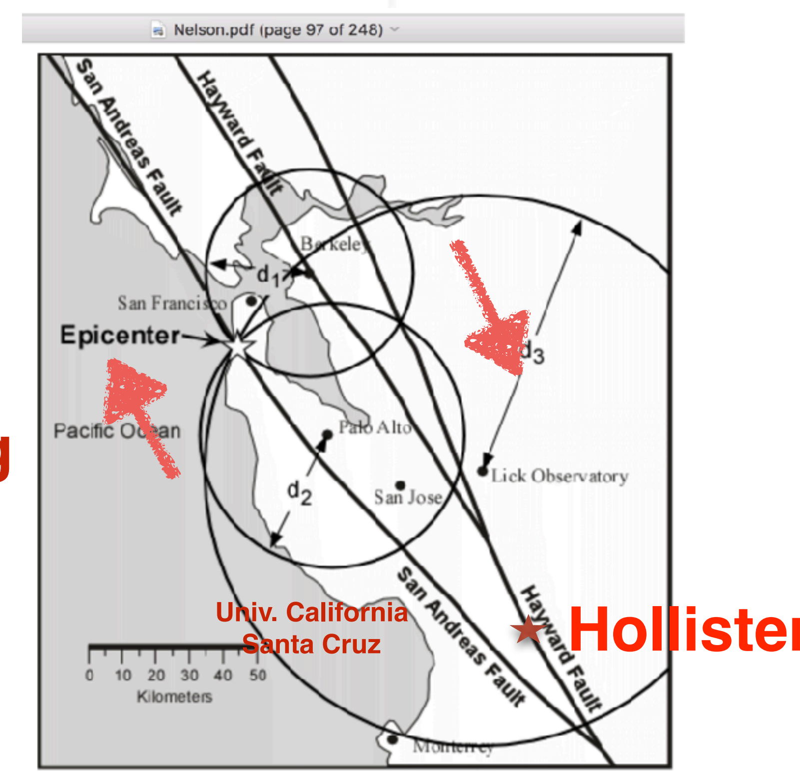
In the Bay area there are three major faults, from West to East the San Andreas, the Hayward, and the Calaveras; all are part of the San Andreas fault system. The USGS continuously monitors their activity. All of these are ``right-lateral strike-slip faults", which means that the motion is predominantly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

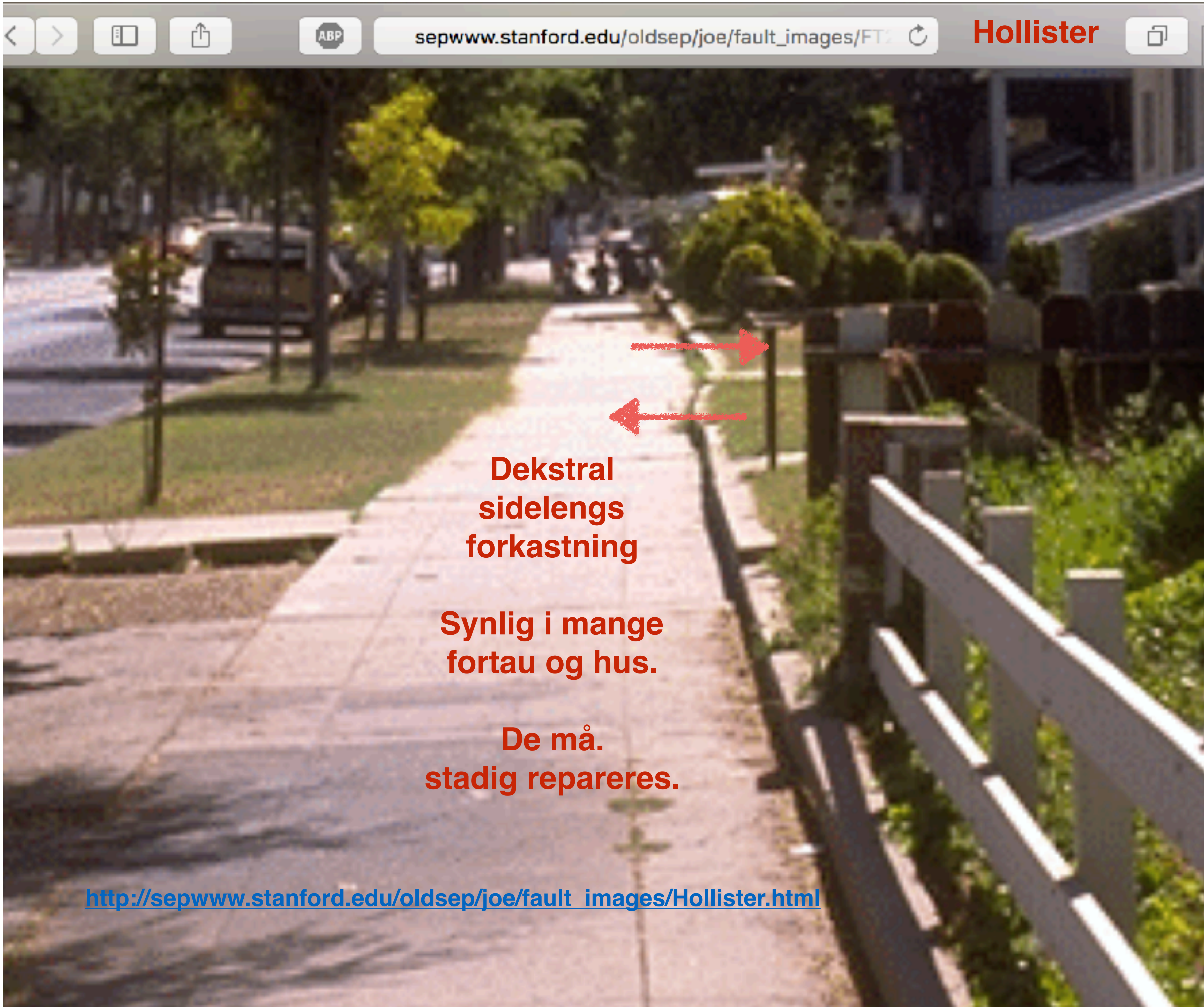
Here is a map showing the approximate active trace of the fault for the part of town covered in our tour.

dekstral sidelengs forkastning



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

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

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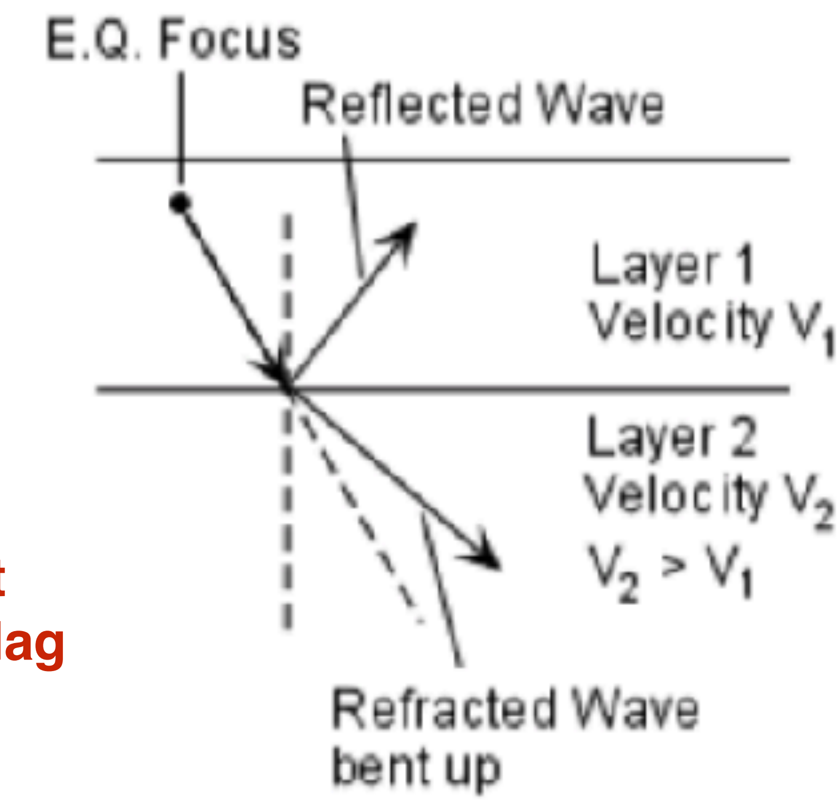
1. If the seismic wave velocity in the rock above an interface is less than the seismic wave velocity in the rock below the interface, the waves will be refracted or bent upward relative to their original path.



Vanlig i grensen mellom skorpe og mantel

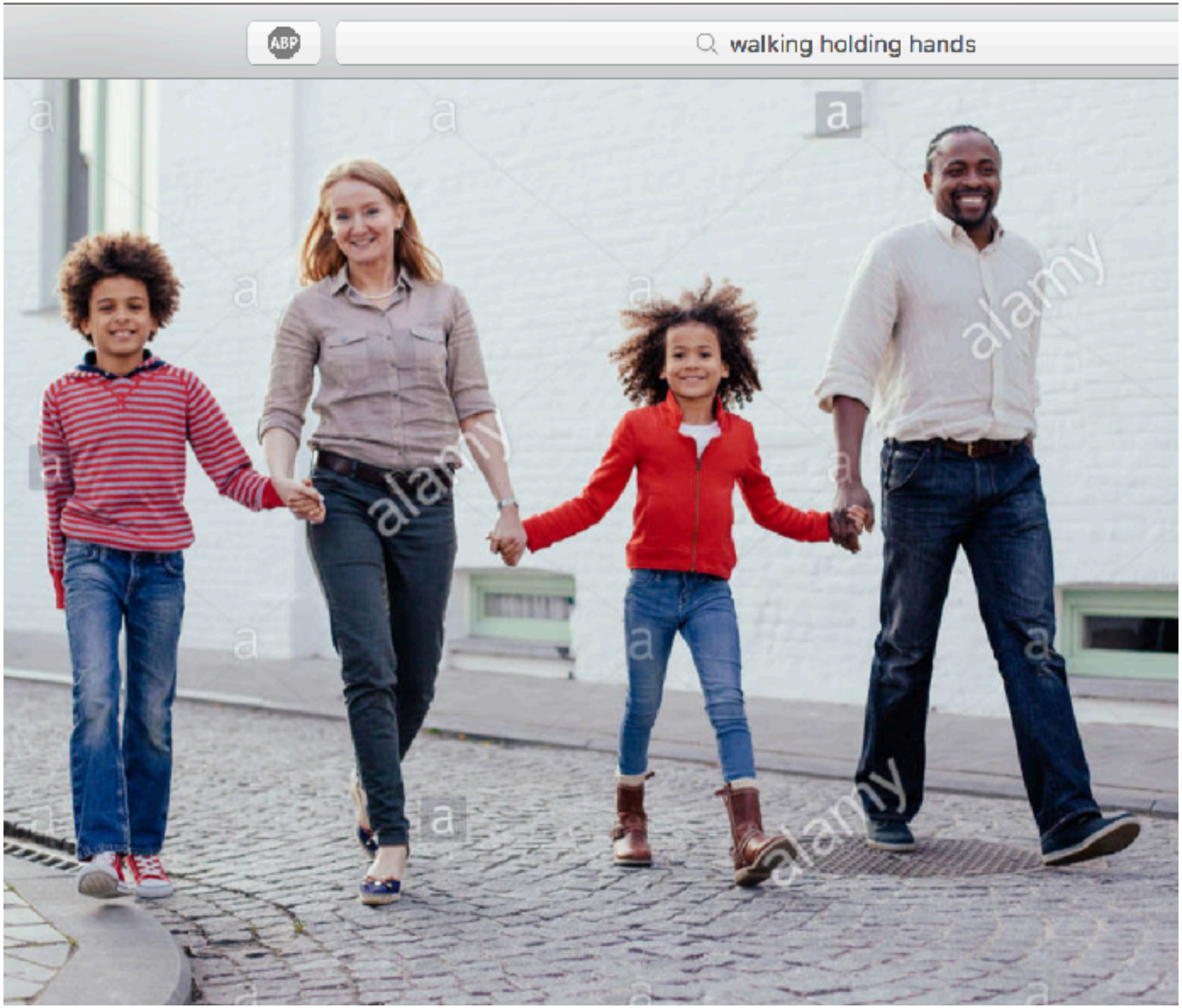
Raskere seismisk hastighet i et dypere lag

Hvis noe (lysbølger, seismiske bølger, bildekk)
går saktere på en side av en hastighetsgrense, bryter noe i den retning.

2 hjul på asfalt høy hastighet

2 hjul i sand har lav hastighet

Hvis en side går litt saktere,
vil de andre svinge (bryte) i hans retning.
Slik er det også med havbølger på kysten, og seismiske bølger.



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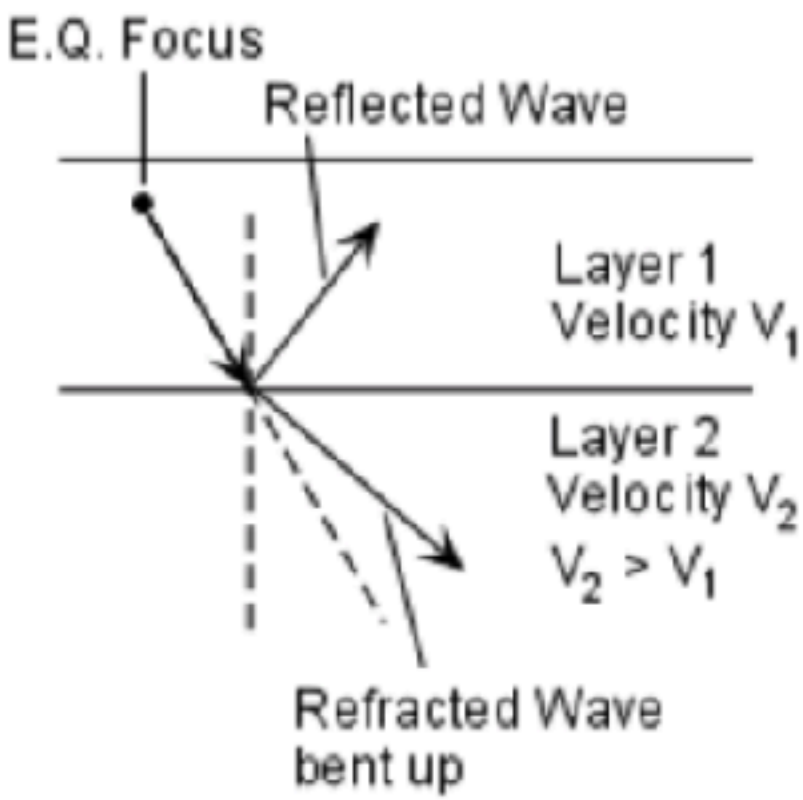
1. If the seismic wave velocity in the rock above an interface is less than the seismic wave velocity in the rock below the interface, the waves will be refracted or bent upward relative to their original path.



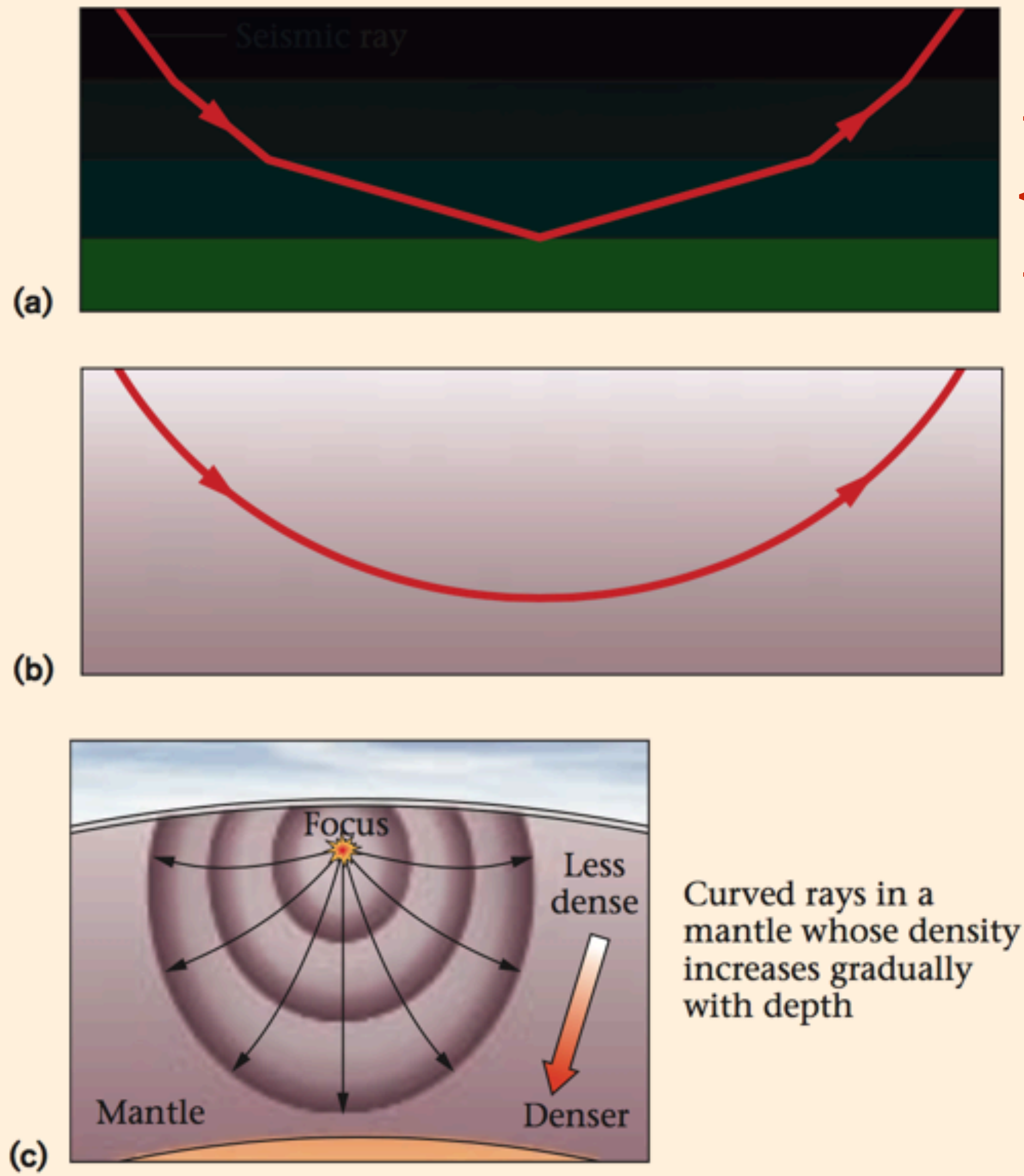
Seismisk hastighet øker gradvis nedover, innenfor mantelen

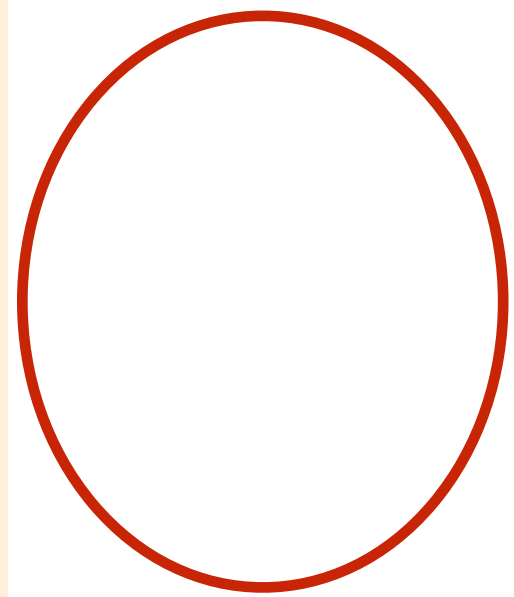
4 lag med
<— økende
<— seismisk
<— hastighet
<— nedover

Her er det 3 grenser. Brytning oppover ved hver grense.

gradvis økende seismisk hastighet nedover

Her er det ingen grenser. Gradvis brytning.





bølgefronter er derfor ovale, ikke sirkulære

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

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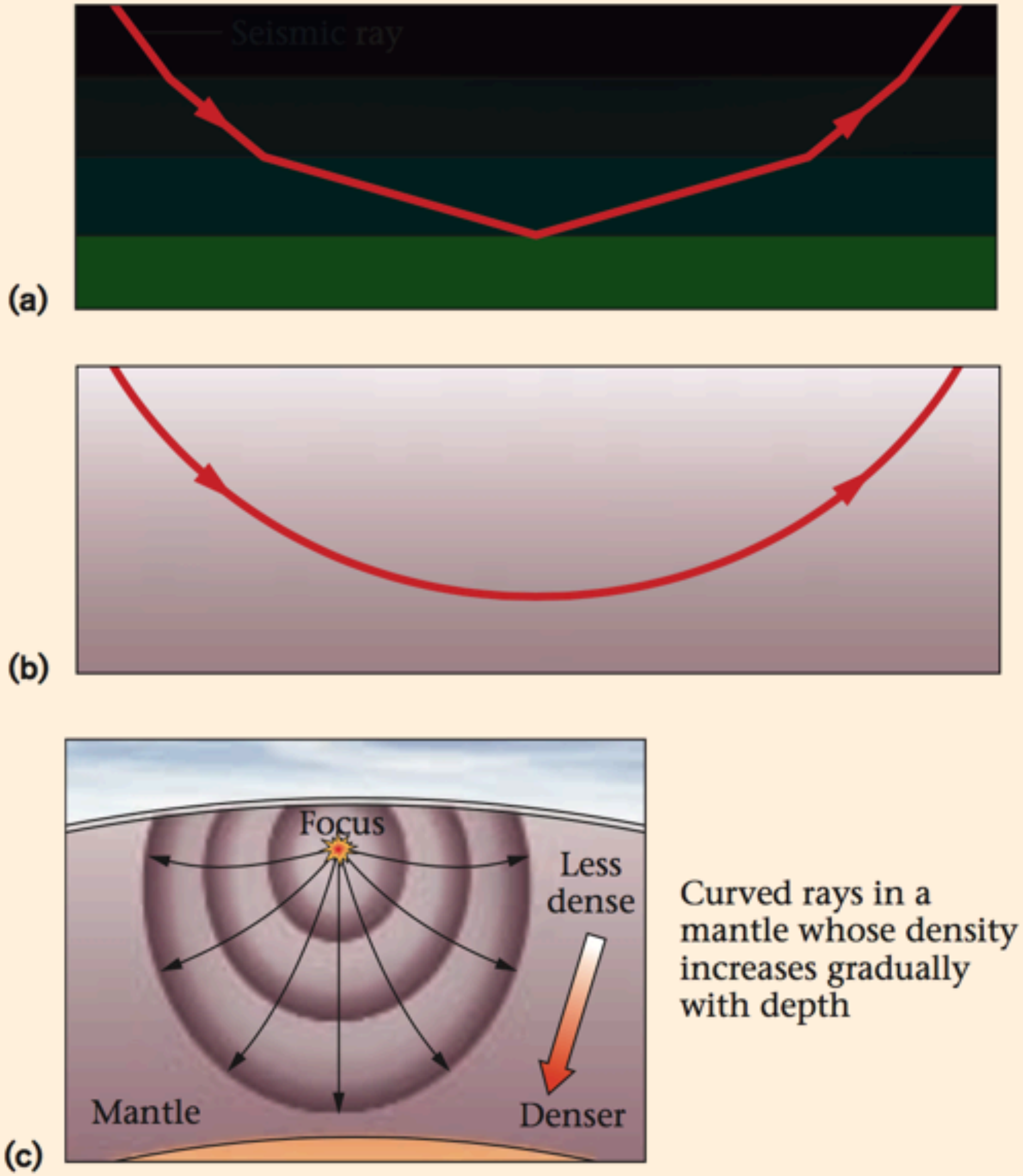

FIGURE D.8 **(a)** In a stack of layers in which seismic waves travel at different velocities (fastest in the lowest layer), a seismic ray gradually bends around and heads back to the surface. The curve consists of several distinct segments. **(b)** If the mantle's density increased gradually with depth,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

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

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, men pga. økning i *μ* (stivhet) har mer betydning enn økning i ρ.

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

K+1,33μ

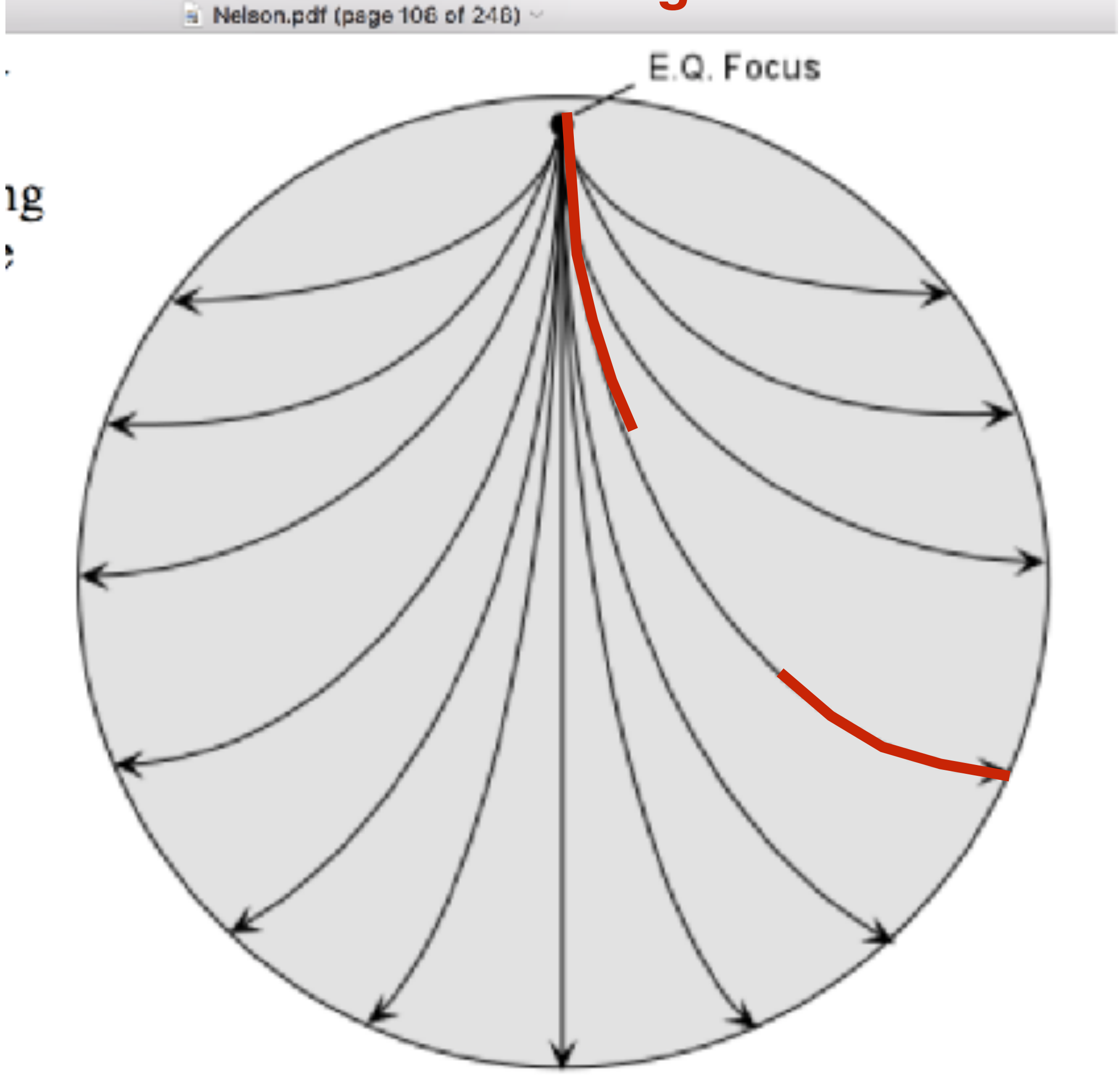
Where, V_p is the velocity of the P-wave, K is the incompressibility of the material, μ is the rigidity of the material, and ρ is the density of the material.

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

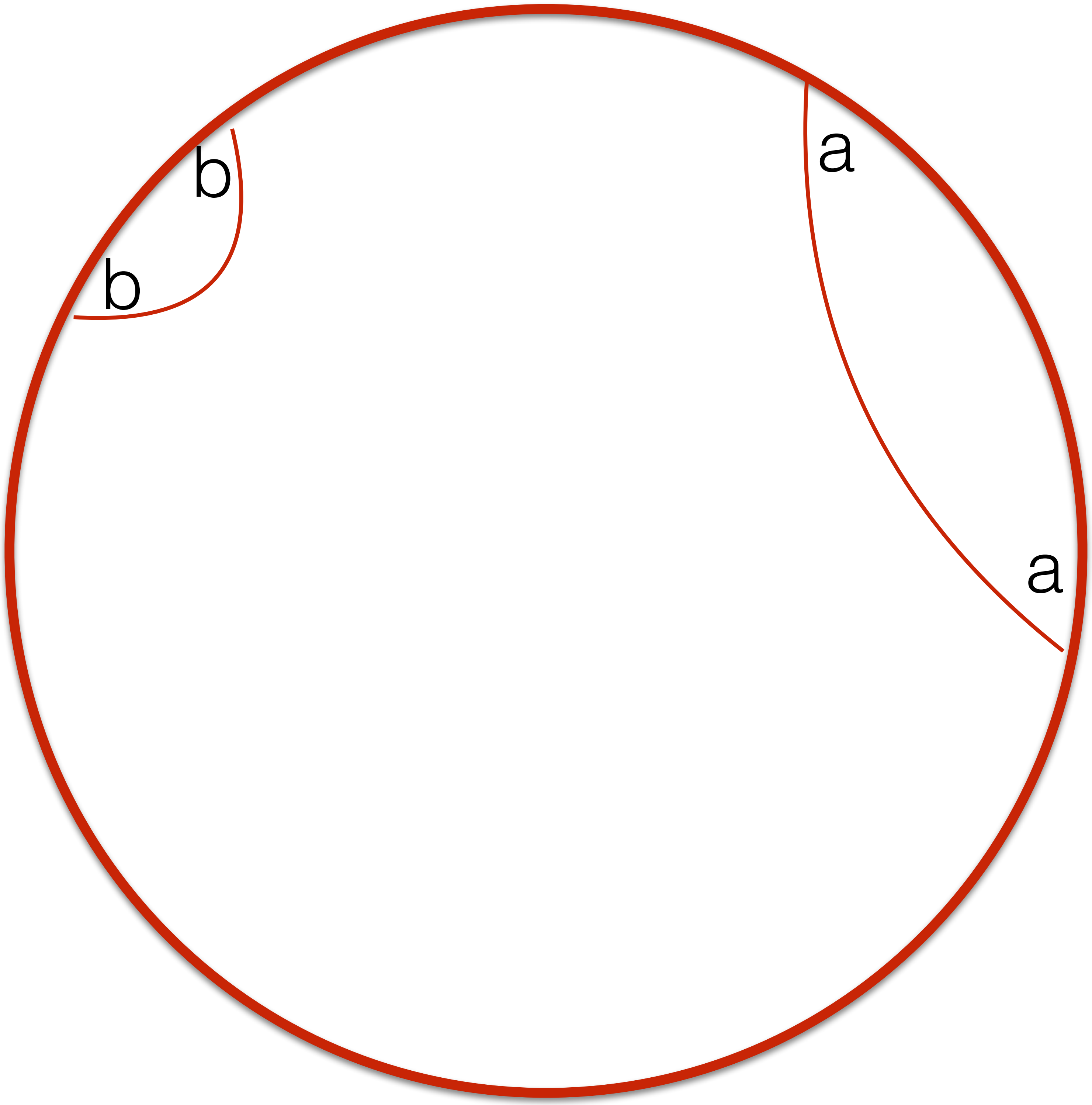
Seismiske bølger bryter mot den SAKTE siden av de usynlige grensene.

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

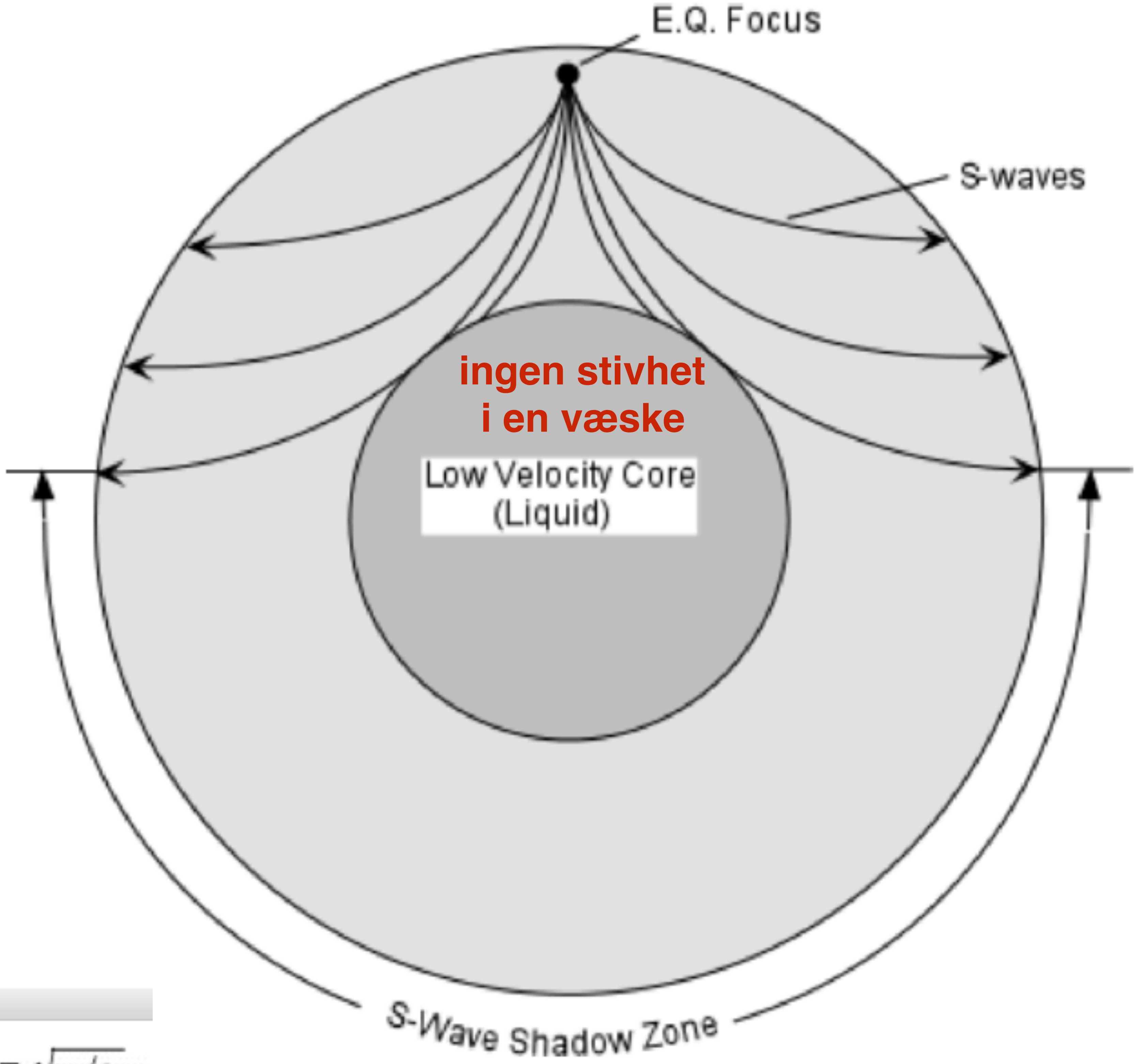
Nelsons stråler er ikke tegnet helt riktig. Vinkel inn skal være samme som vinkel ut, Alle stråler bør være SYMMETRISKE buer.

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

må være samme vinkel



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



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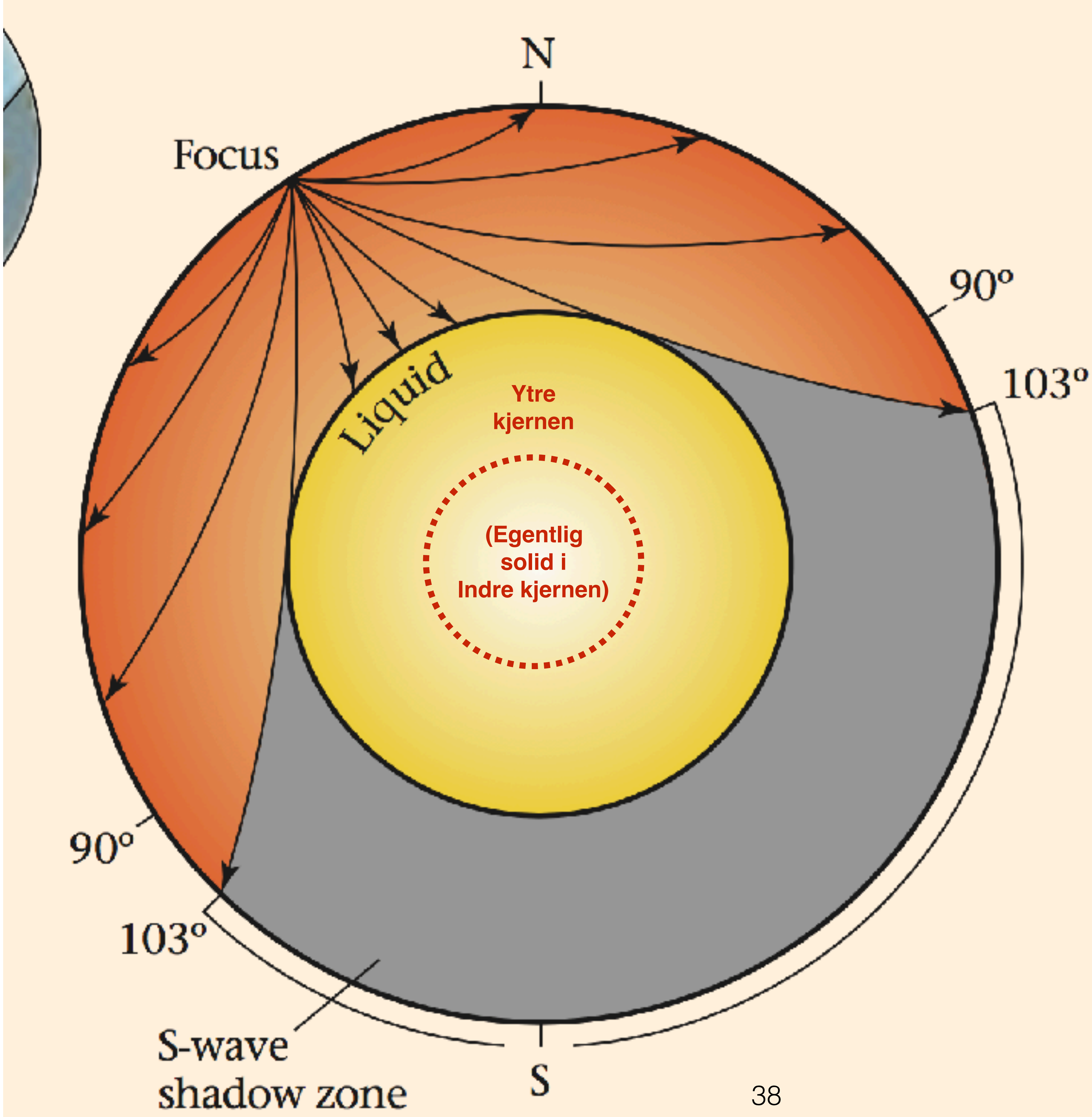
$$V_p = \sqrt{[(K+4/3\mu)/\rho]}$$

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
(Egentlig
solid i
Indre kjernen)
90°
103°
S-wave
shadow zone
S

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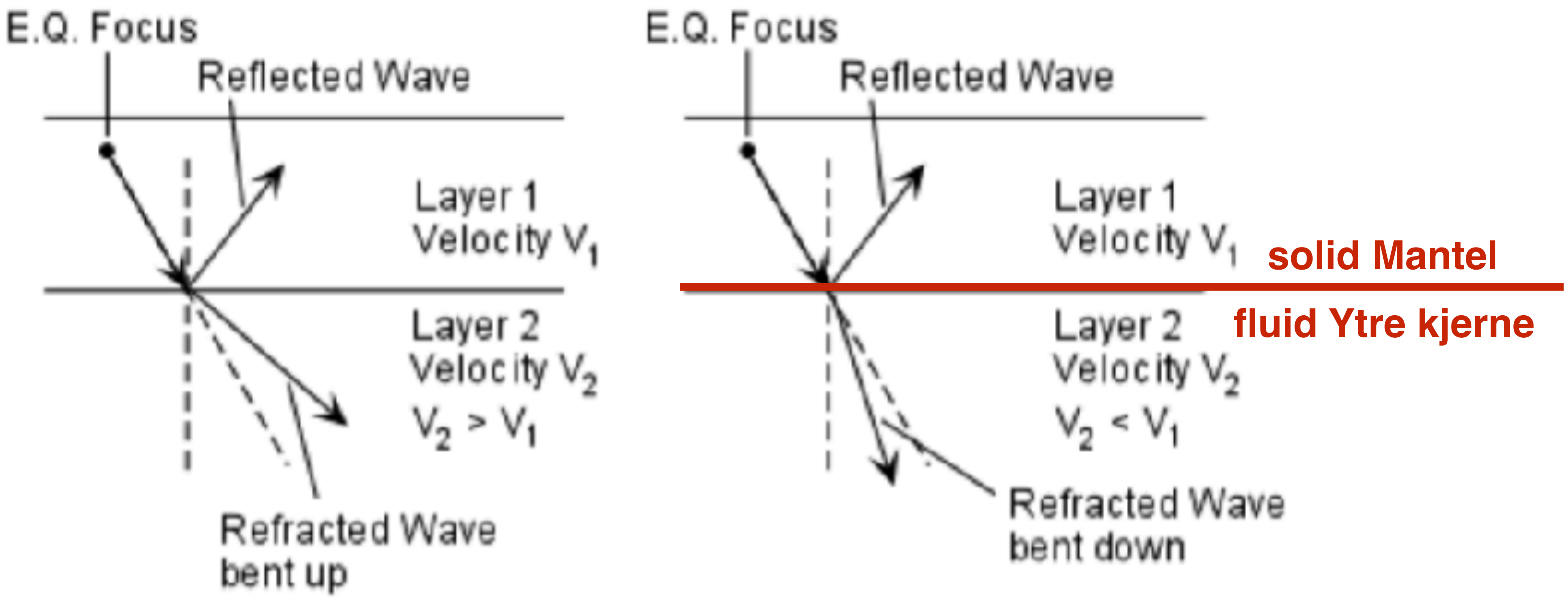
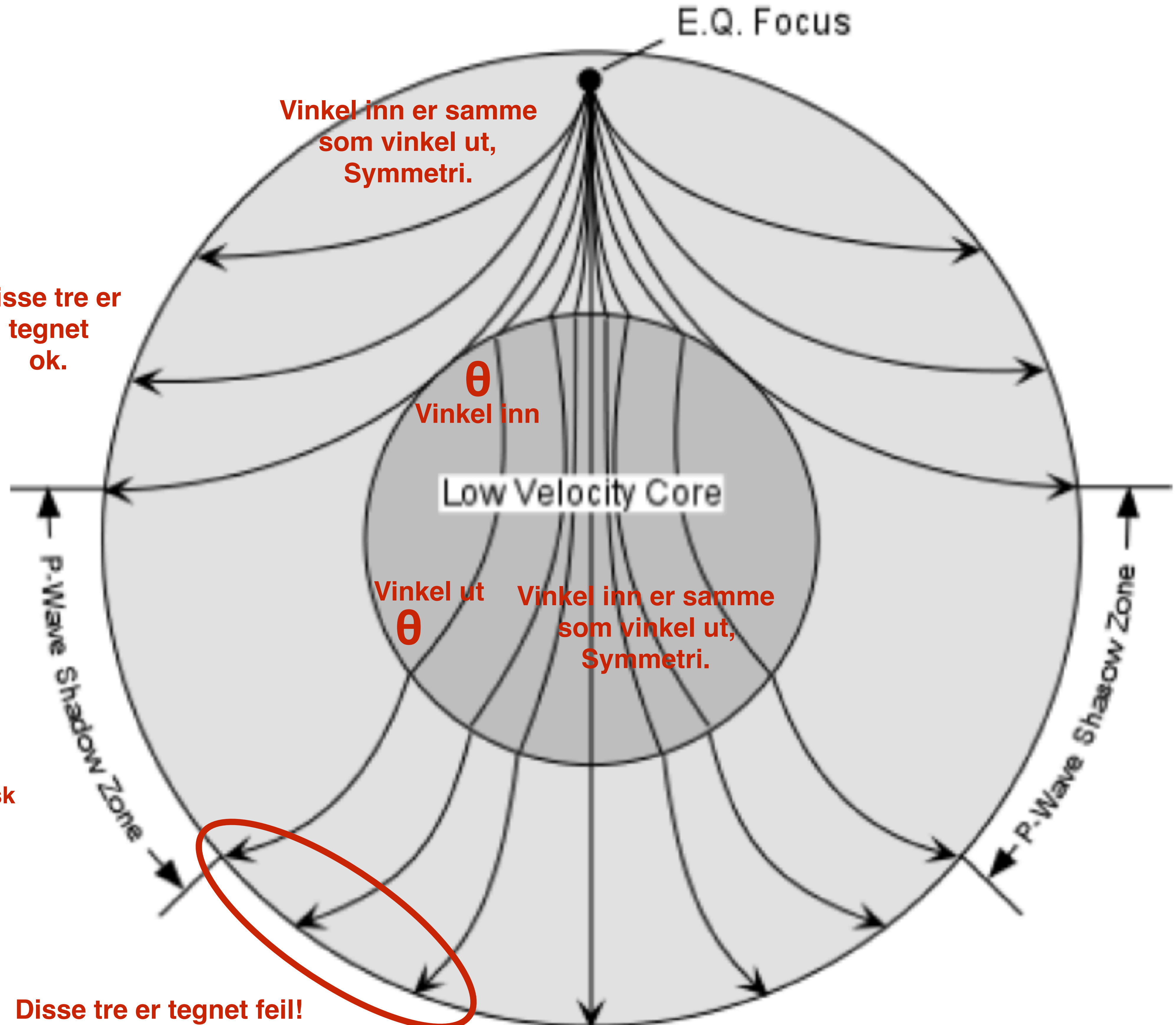
1. If the seismic wave velocity in the rock above an interface is less than the seismic wave velocity in the rock below the interface, the waves will be refracted or bent upward relative to their original path.



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.

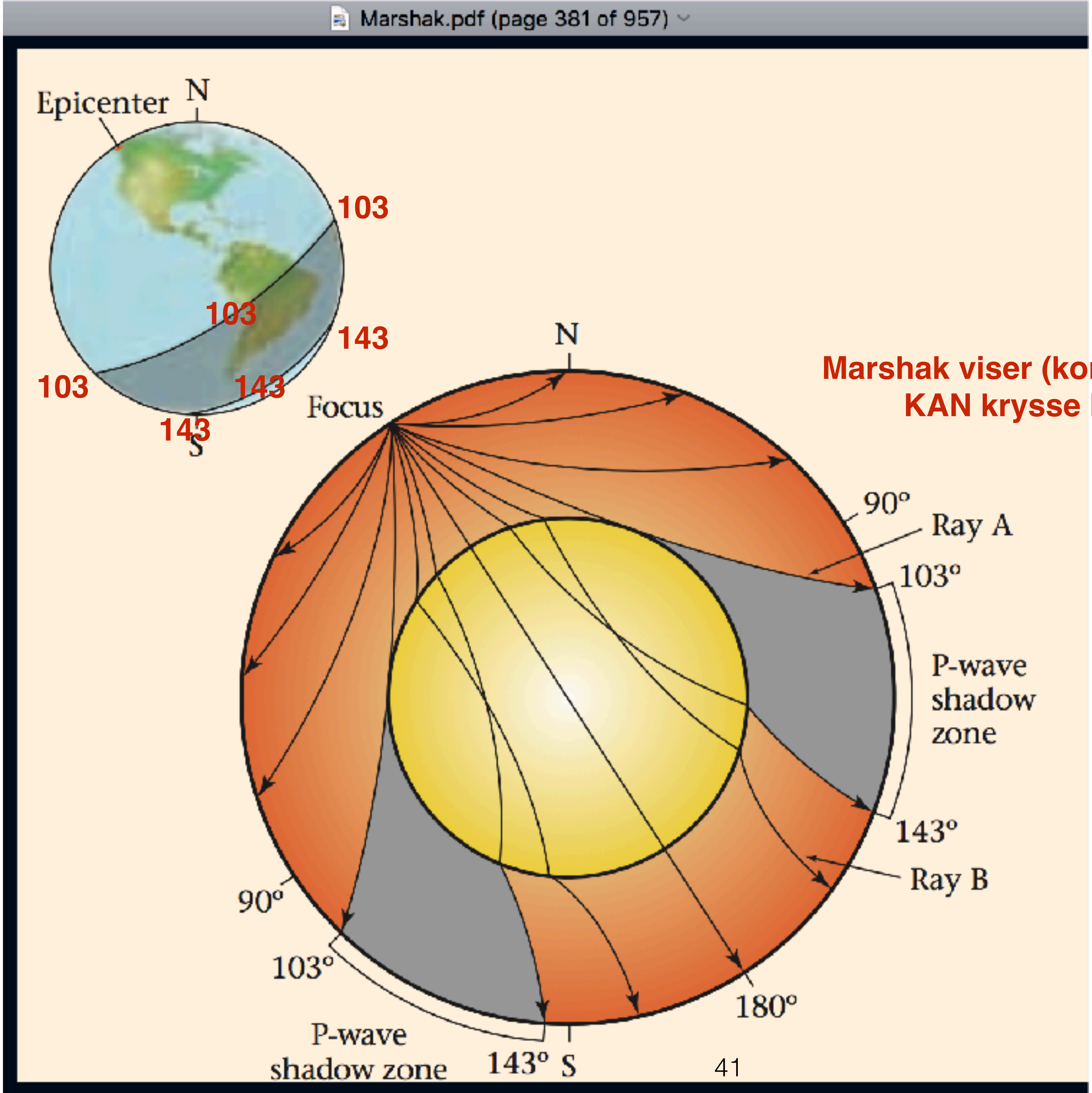


Disse tre er tegnet ok.

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

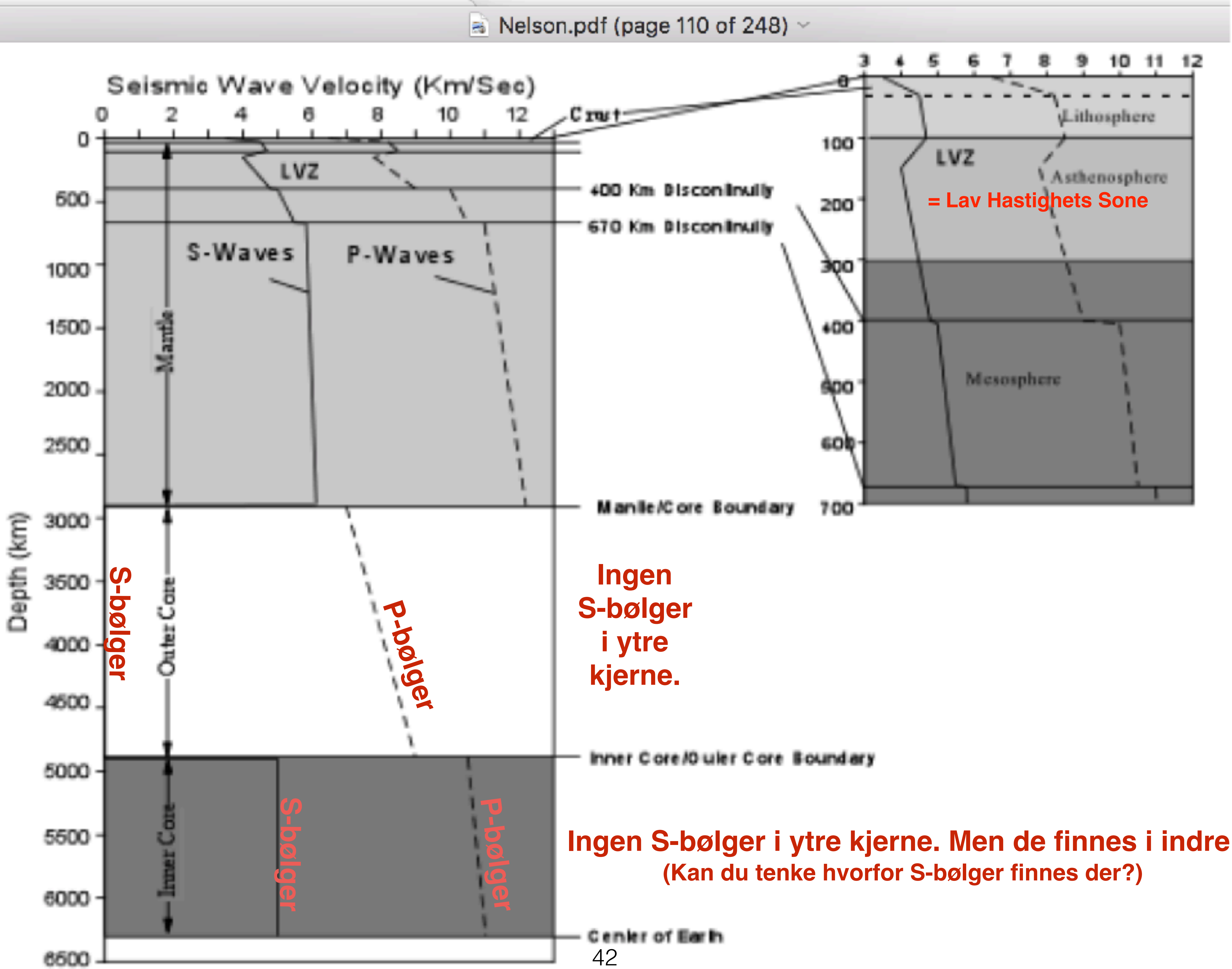
Disse tre er tegnet feil! En stråle kan ikke bøye først til høyre og så til venstre mantelen.

Den er tegnet ok.



Marshak viser (korrekt) at strålene KAN krysse hverandre!

103°-143°



Ingen S-bølger i ytre kjerne.

Ingen S-bølger i ytre kjerne. Men de finnes i indre!
(Kan du tenke hvorfor S-bølger finnes der?)

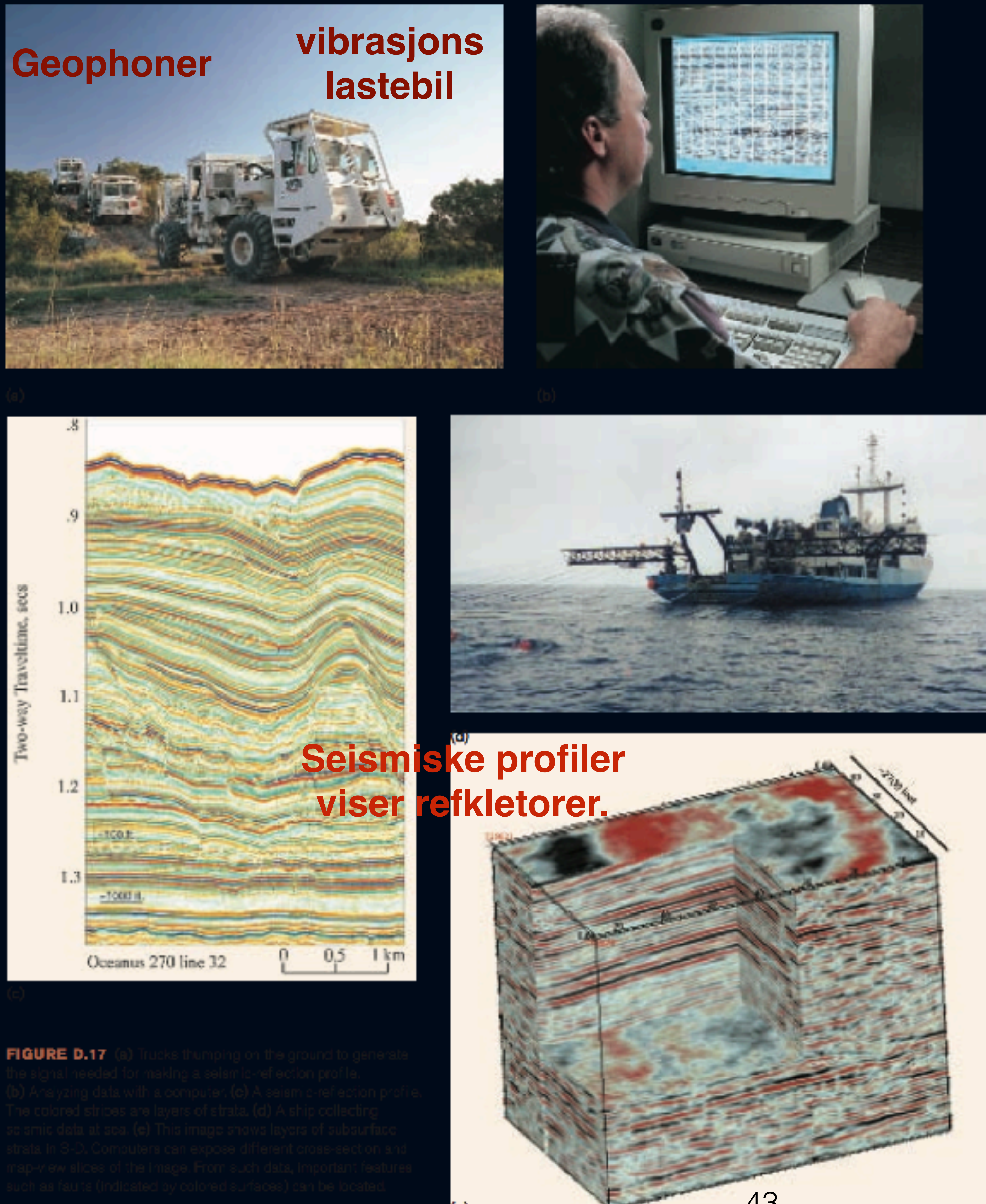


FIGURE D.17 (a) Trucks thumping on the ground to generate the signal needed for making a seismic-reflection profile. (b) Analyzing data with a computer. (c) A seismic-reflection profile. The colored stripes are layers of strata. (d) A ship collecting seismic data at sea. (e) This image shows layers of 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.

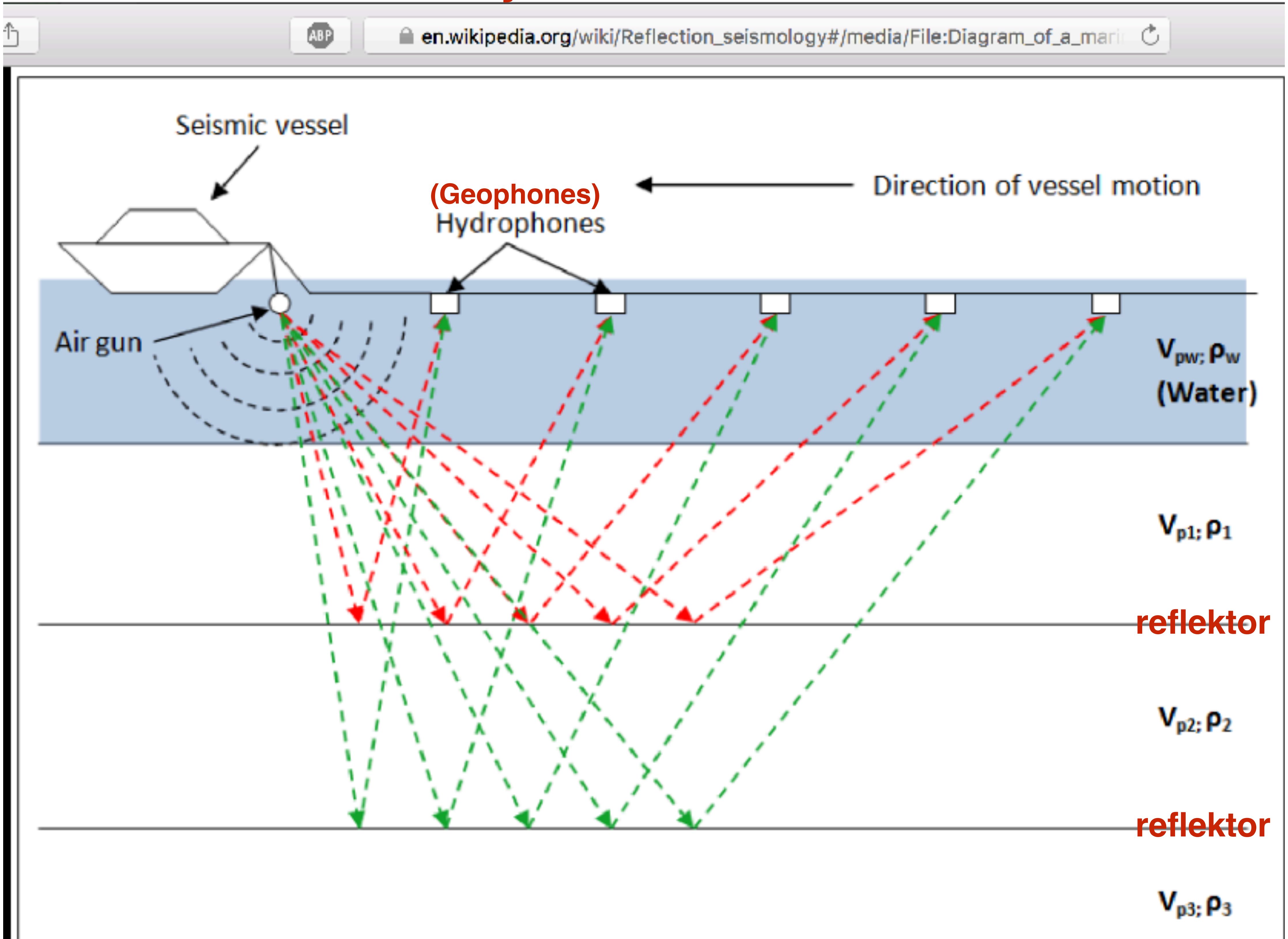


Diagram of a marine towed streamer seismic survey with the raypaths that result from a single shot by an airgun into a streamer containing 5 hydrophones.

--- = 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.