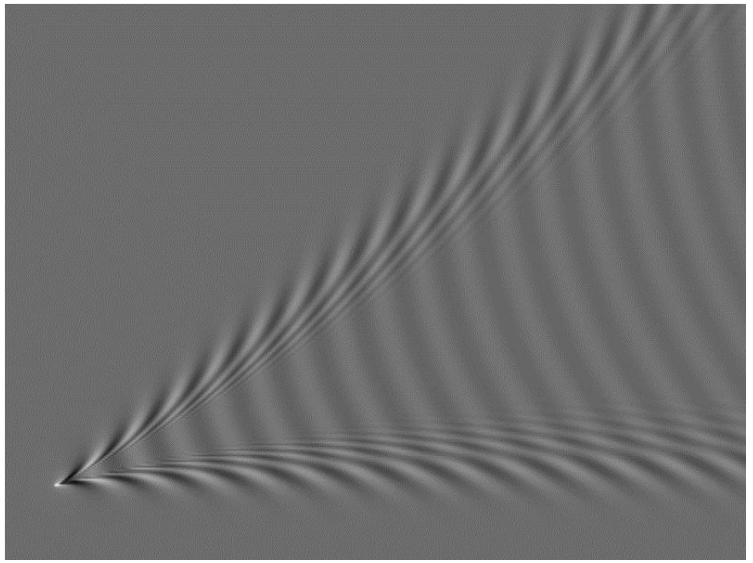
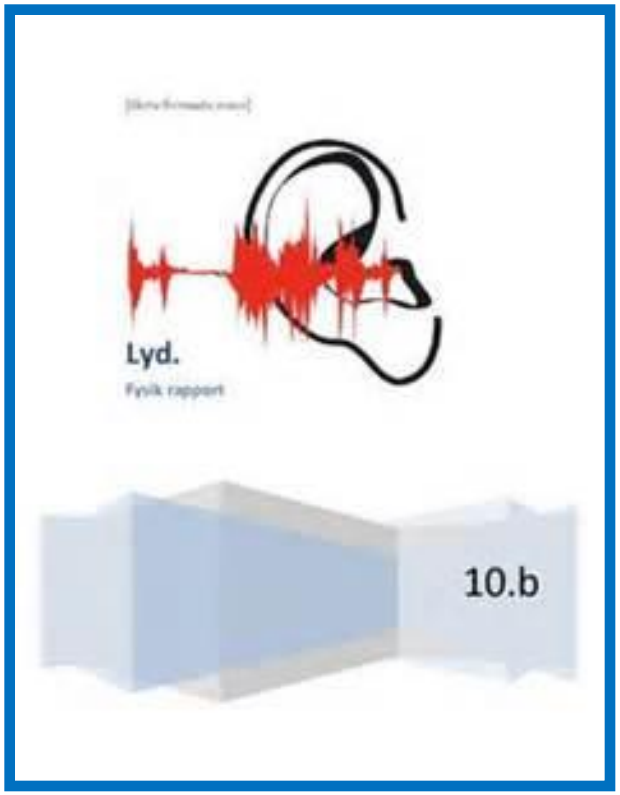
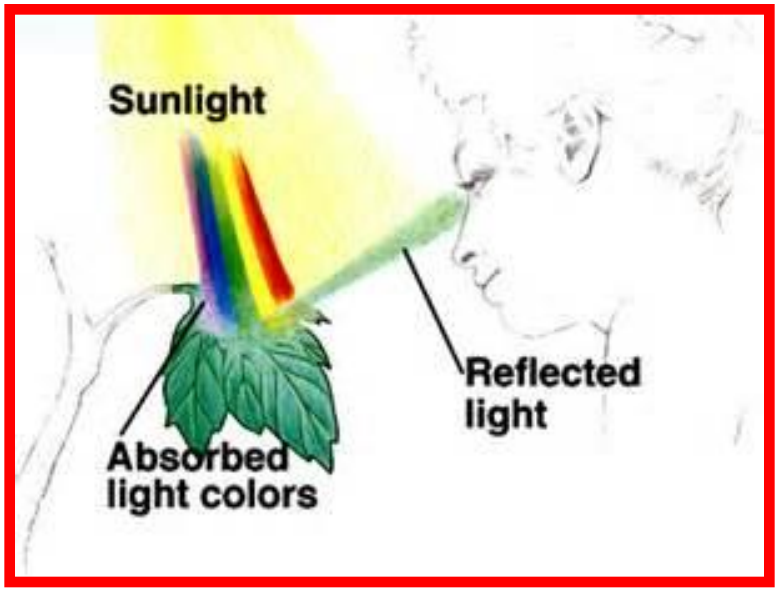
Bølger

Valérie Maupin, Geofag, UiO.

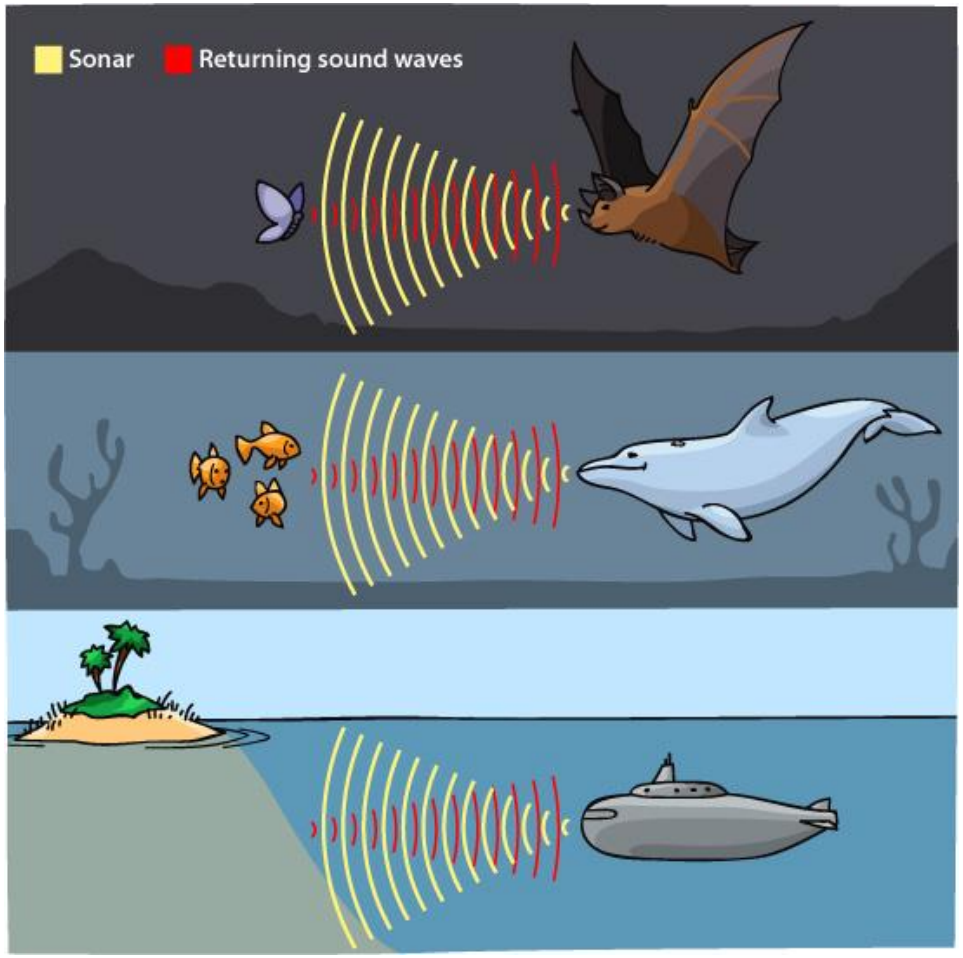


Eksempler på bølger: lyd og lys.





Ekkolokalisering: å bruke lyd for å se



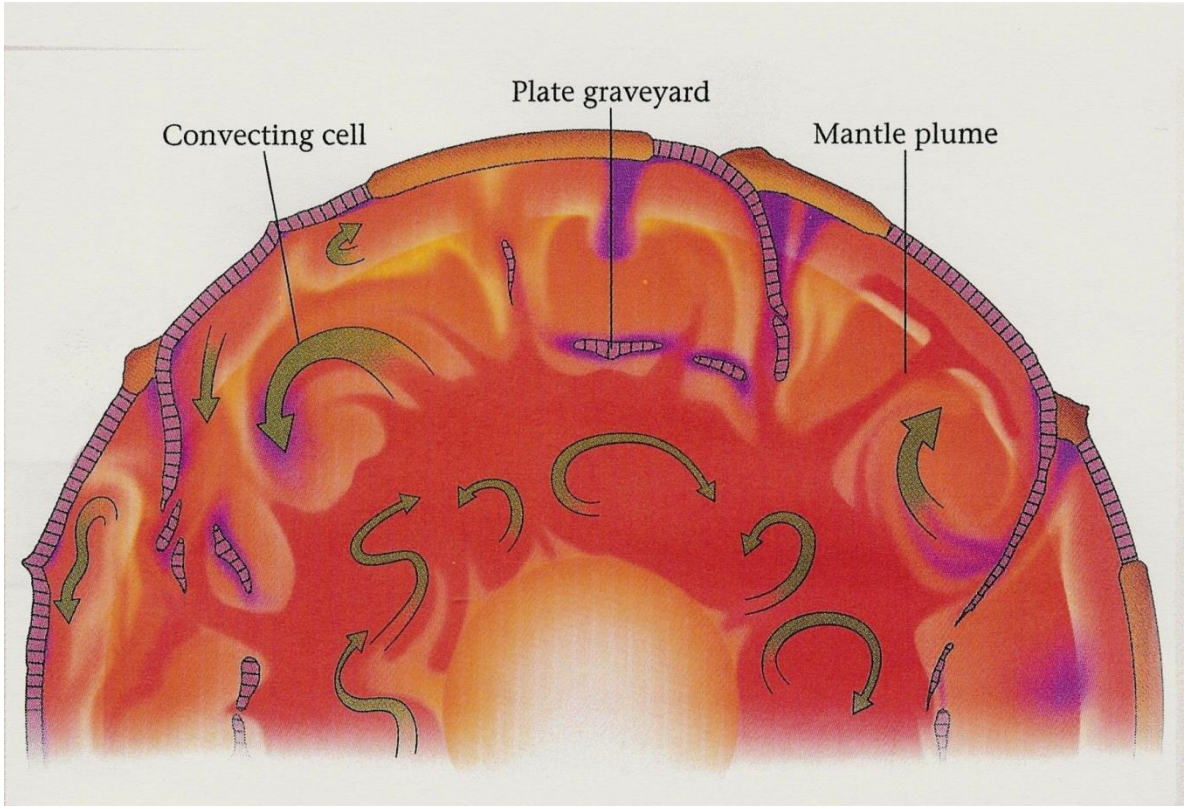
flaggermus

hval

ubåt

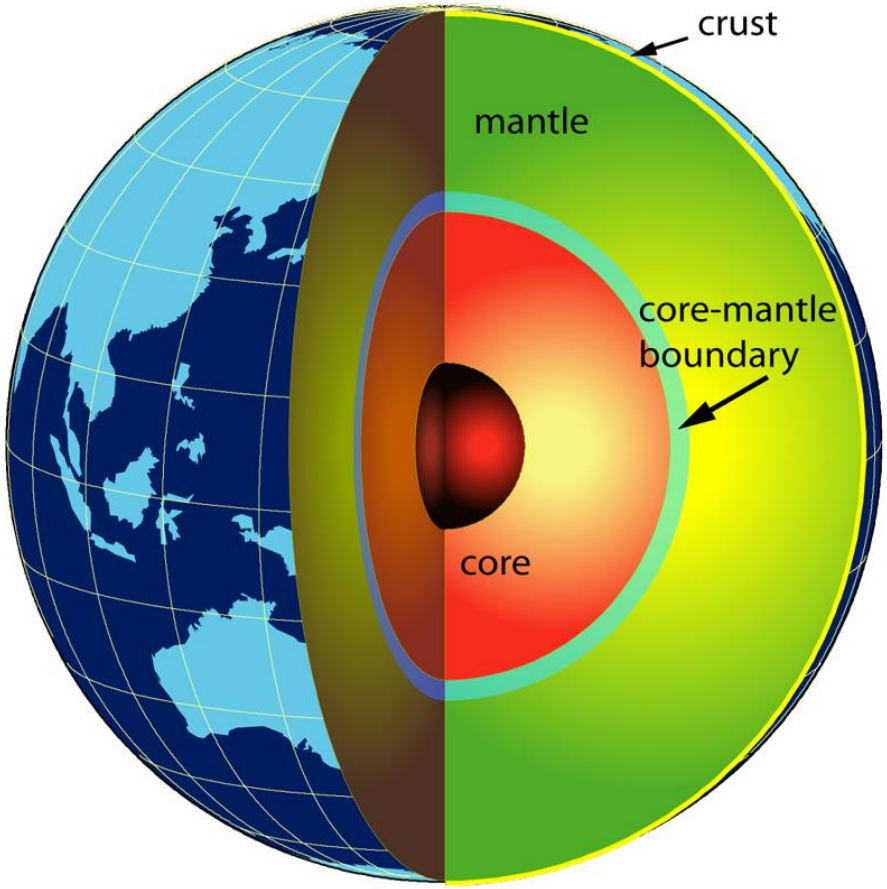
www.askabiologist.asu.edu

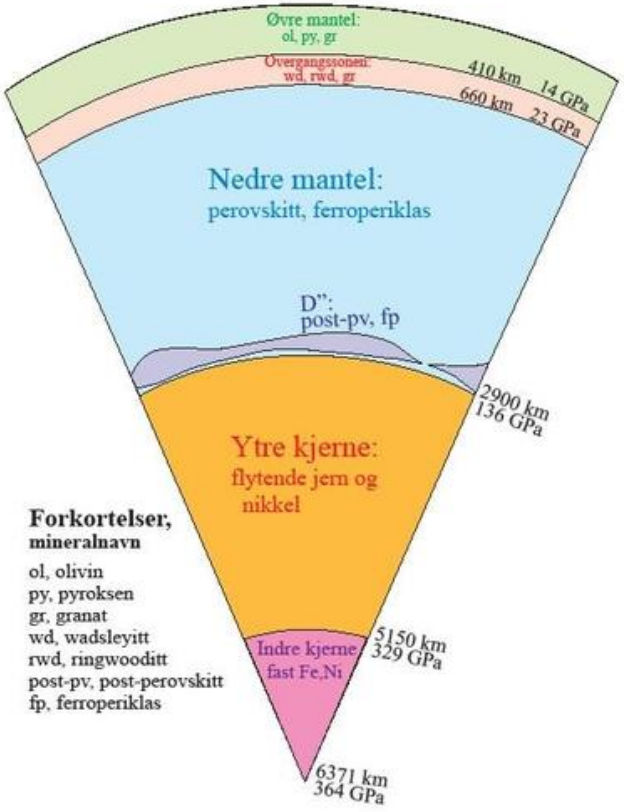
Seismologi: å ”se” inni Jorda med lyd.

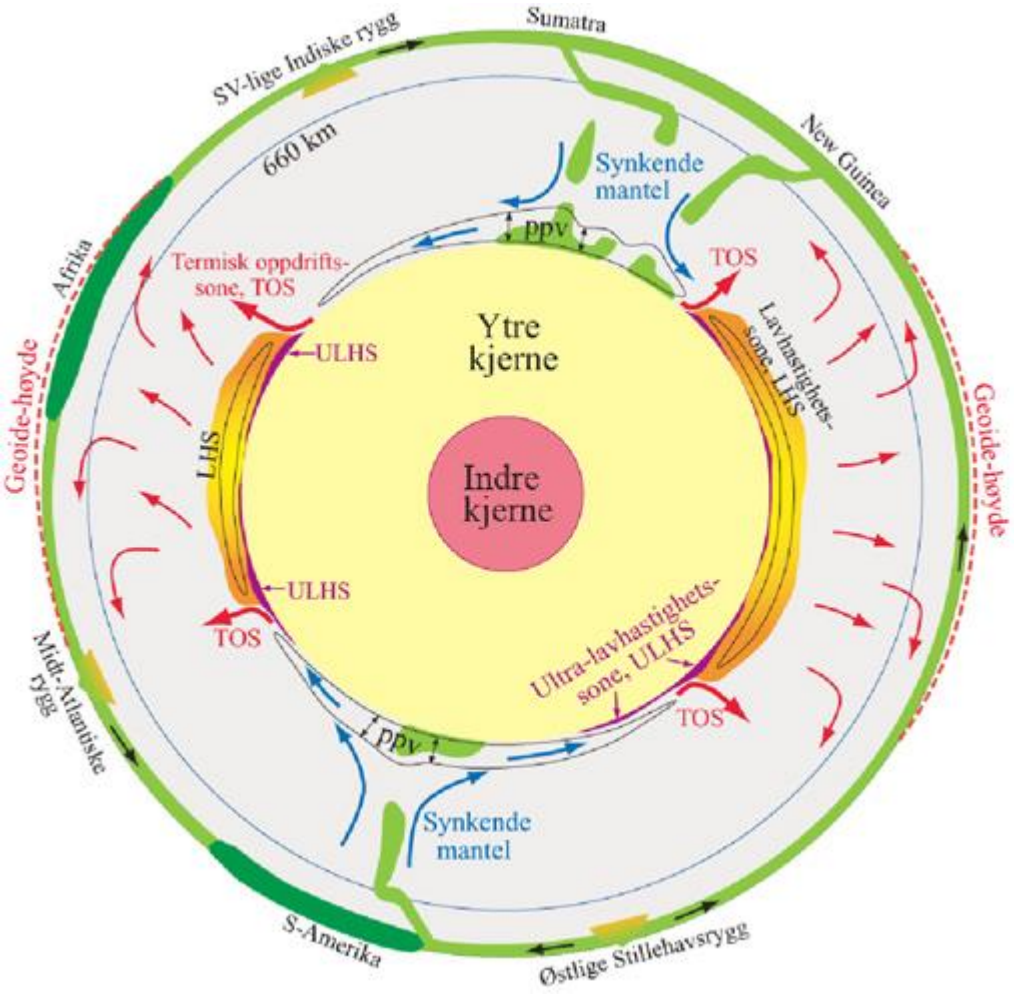


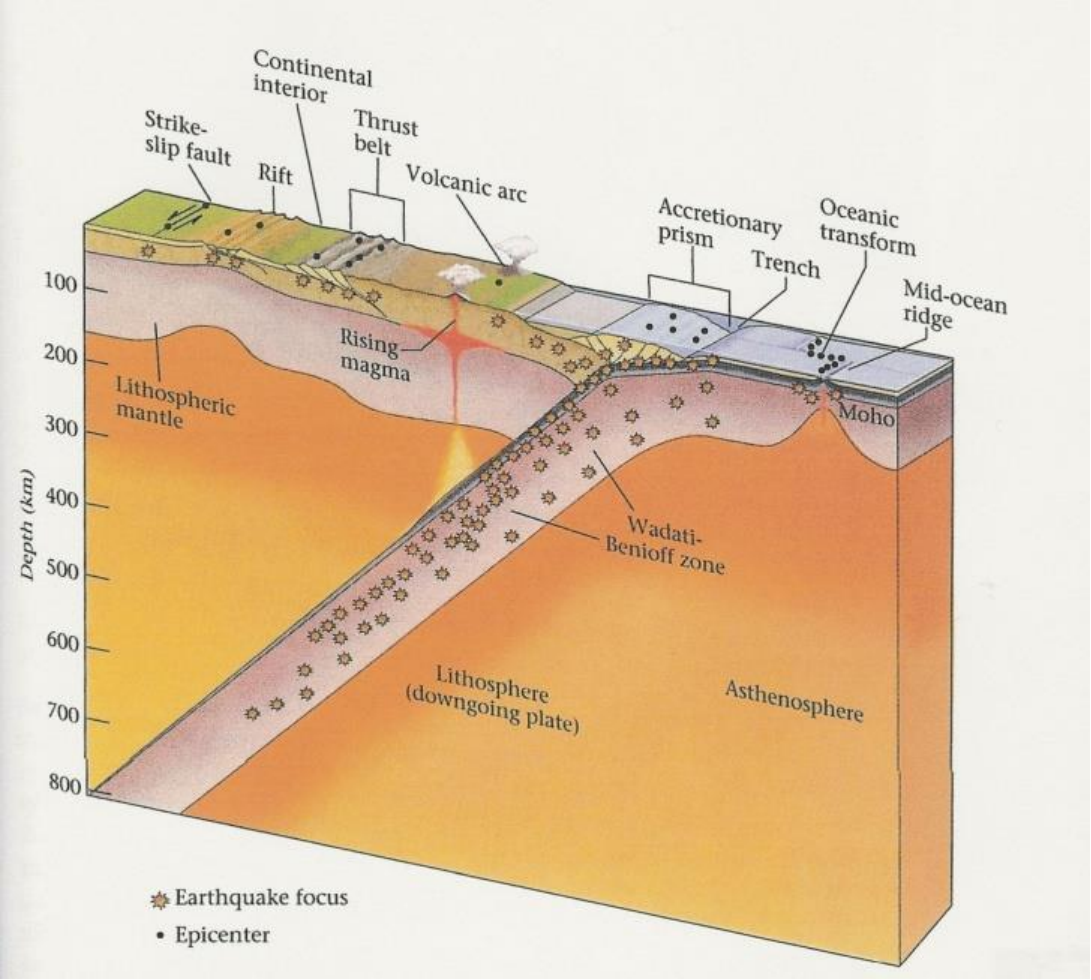
- Hva ”ser” jeg inni Jorda?
- Hva har jeg **egentlig** sett?
- Hvordan har jeg dannet meg dette bildet av Jorda fra det jeg har sett?

Jordens struktur

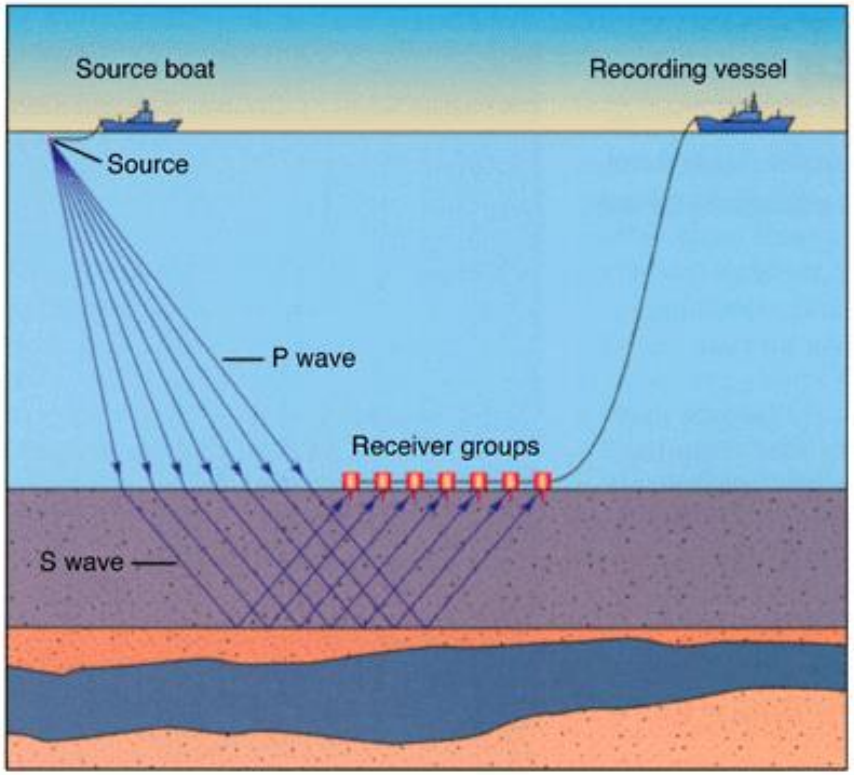





Sumatra
SV-lige Indiske rygg
New Guinea
660 km
Synkende mantel
ppv
TOS
Termisk oppdrifts-sone, TOS
Afrika
Ytre kjerne
Lavhastighets-sone, LHS
Geoide-høyde
ULHS
LHS
Indre kjerne
ULHS
TOS
Ultra-lavhastighets-sone, ULHS
TOS
Midt-Atlantiske rygg
ppv
Synkende mantel
S-Amerika
Østlige Stillehavsrygg


Continental interior
Strike-slip fault
Rift
Thrust belt
Volcanic arc
Accretionary prism
Trench
Oceanic transform
Mid-ocean ridge
Rising magma
Lithospheric mantle
Moho
Wadati-Benioff zone
Lithosphere (downgoing plate)
Asthenosphere
Depth (km)
100
200
300
400
500
600
700
800
Earthquake focus
Epicenter

Kartlegging av sedimenter



- Hva ”ser” jeg inni Jorda?
- Hva har jeg **egentlig** sett?
- Hvordan har jeg dannet meg dette bildet av Jorda fra det jeg har sett?

Seismometre og seismogrammer

Geoscope stasjon ATD (Djibouti)

Seismometre:
måler kontinuerlig hvordan bakken rister

Norwegian National Seismological Network stasjon OSL (Oslo)

Seismometre og seismogrammer

Geoscope stasjon ATD (Djibouti)

Seismometre:
måler kontinuerlig hvordan bakken rister

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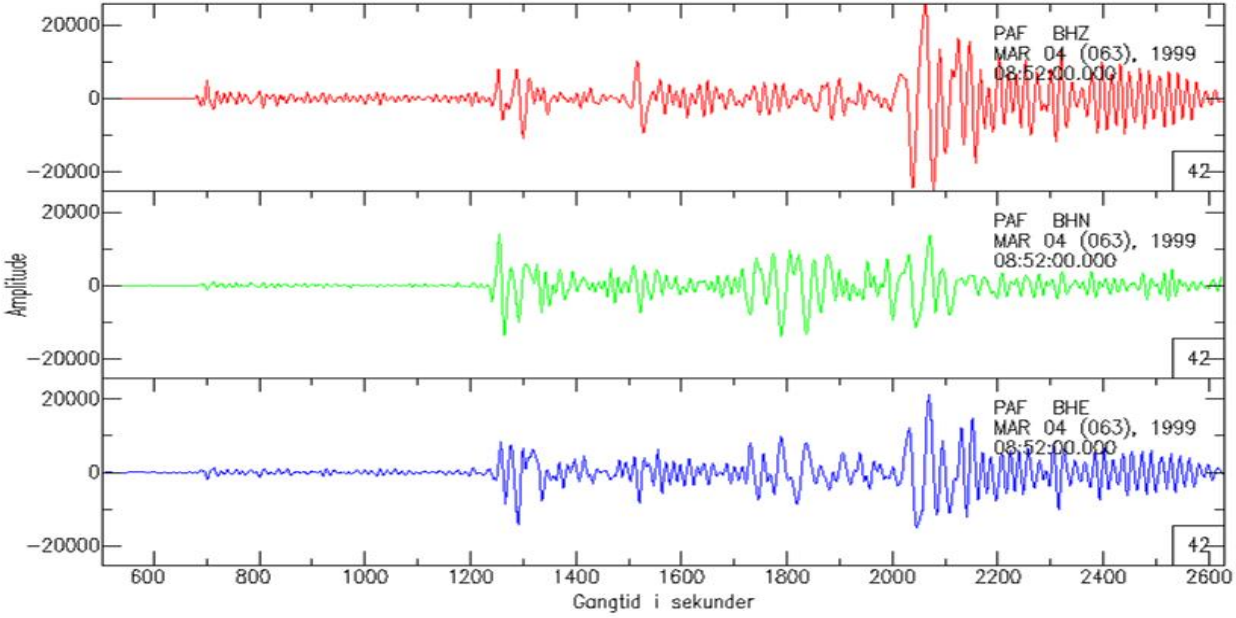
Seismometre og seismogrammer

Geoscope station ATD
(Djibouti)

Seismometre:
måler kontinuerlig hvordan bakken rister

Seismogrammer etter jordskjelv

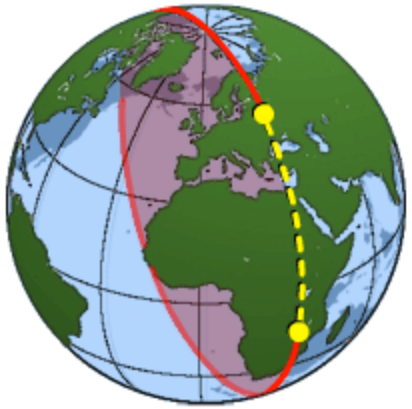


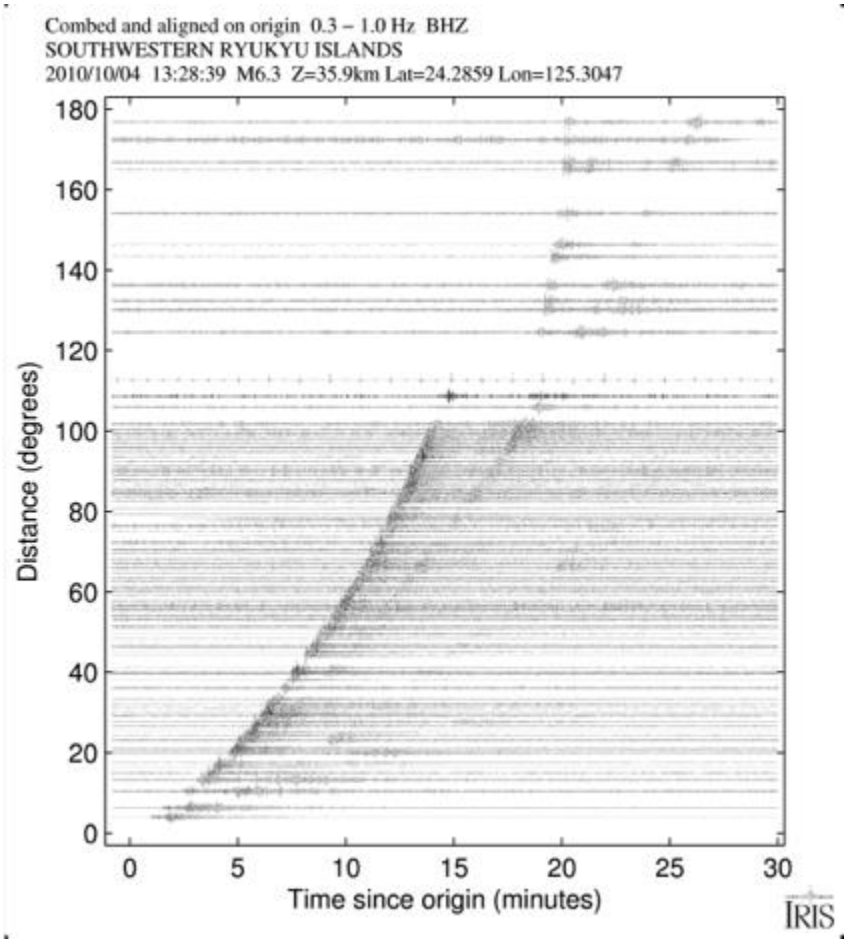
vertikal

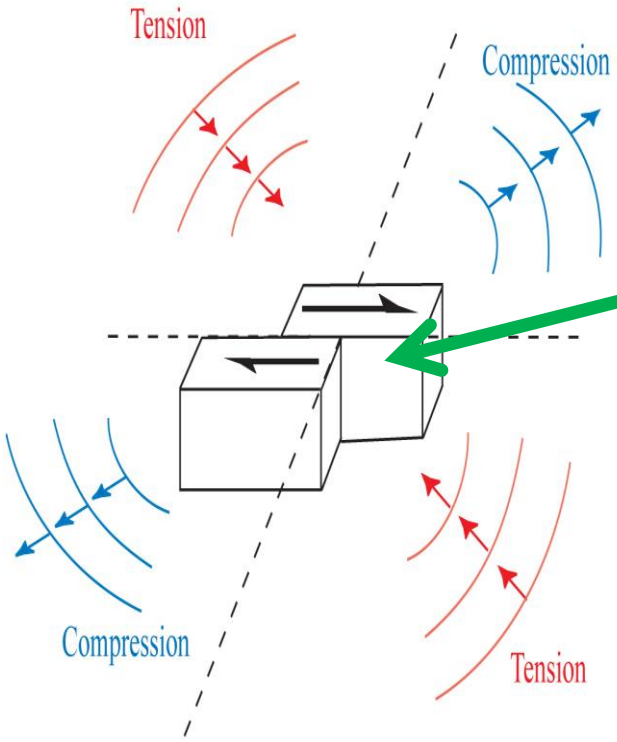
N - S

Ø - V

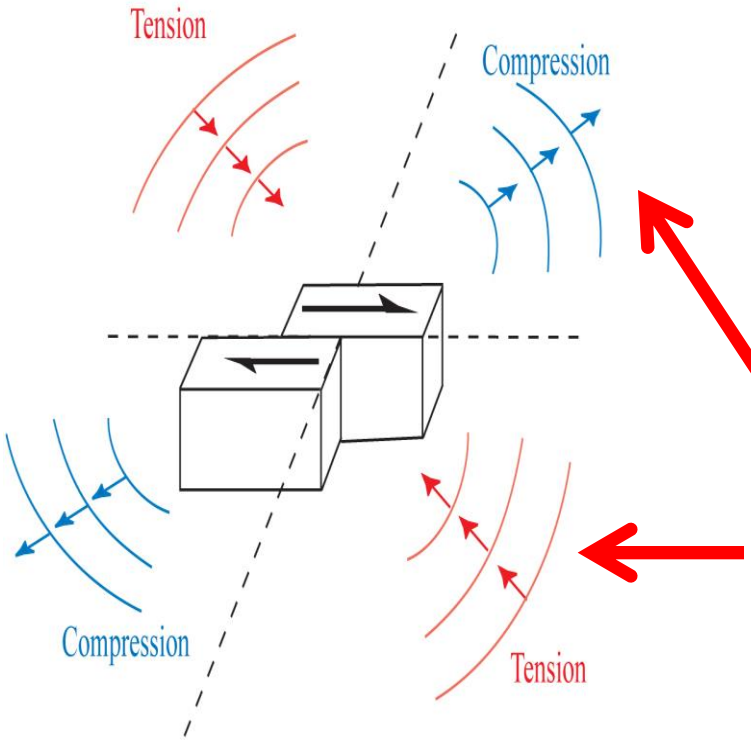
Flere seismogrammer satt sammen







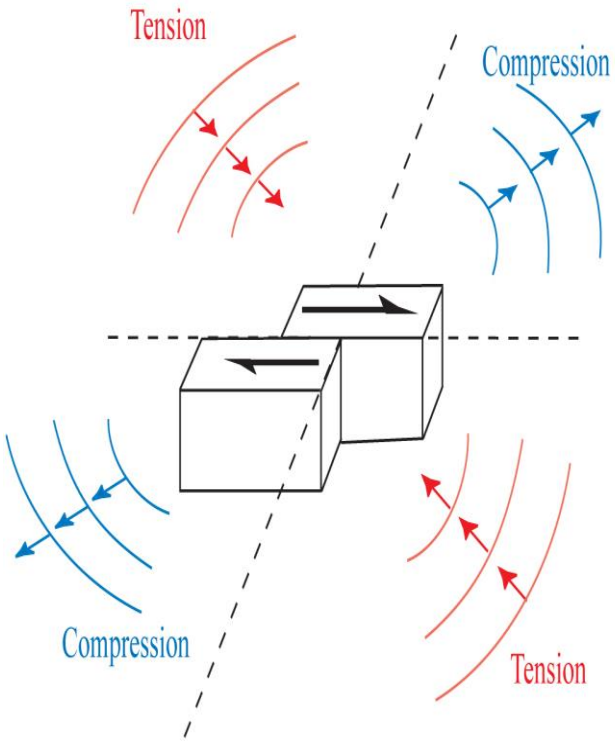
Et jordskjelv er en plutselig bevegelse langs en forkastning.



Et jordskjelv er en plutselig bevegelse langs en forkastning.

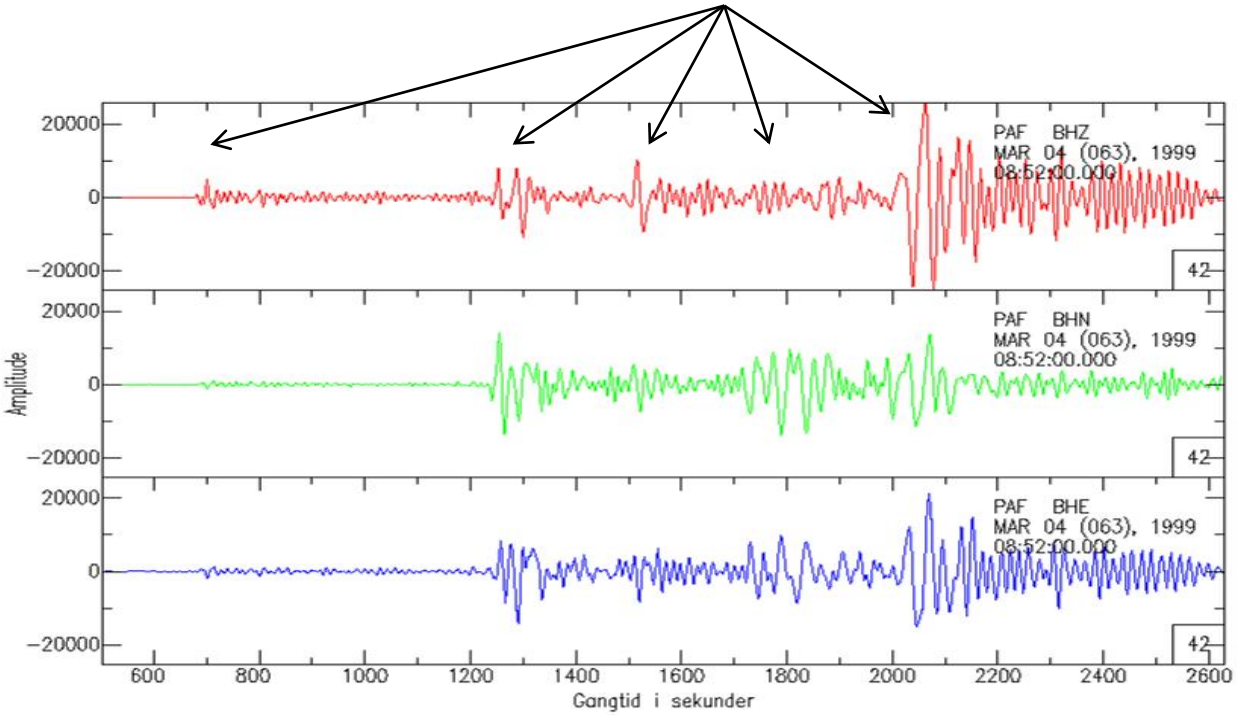
Jordskjelv forårsaker vibrasjoner som forplanter seg gjennom Jorda

Jordskjelv forårsaker vibrasjoner som forplanter seg gjennom Jorda, akkurat som en stein kastet i vann lager bølger



Seismogrammer etter jordskjelv:

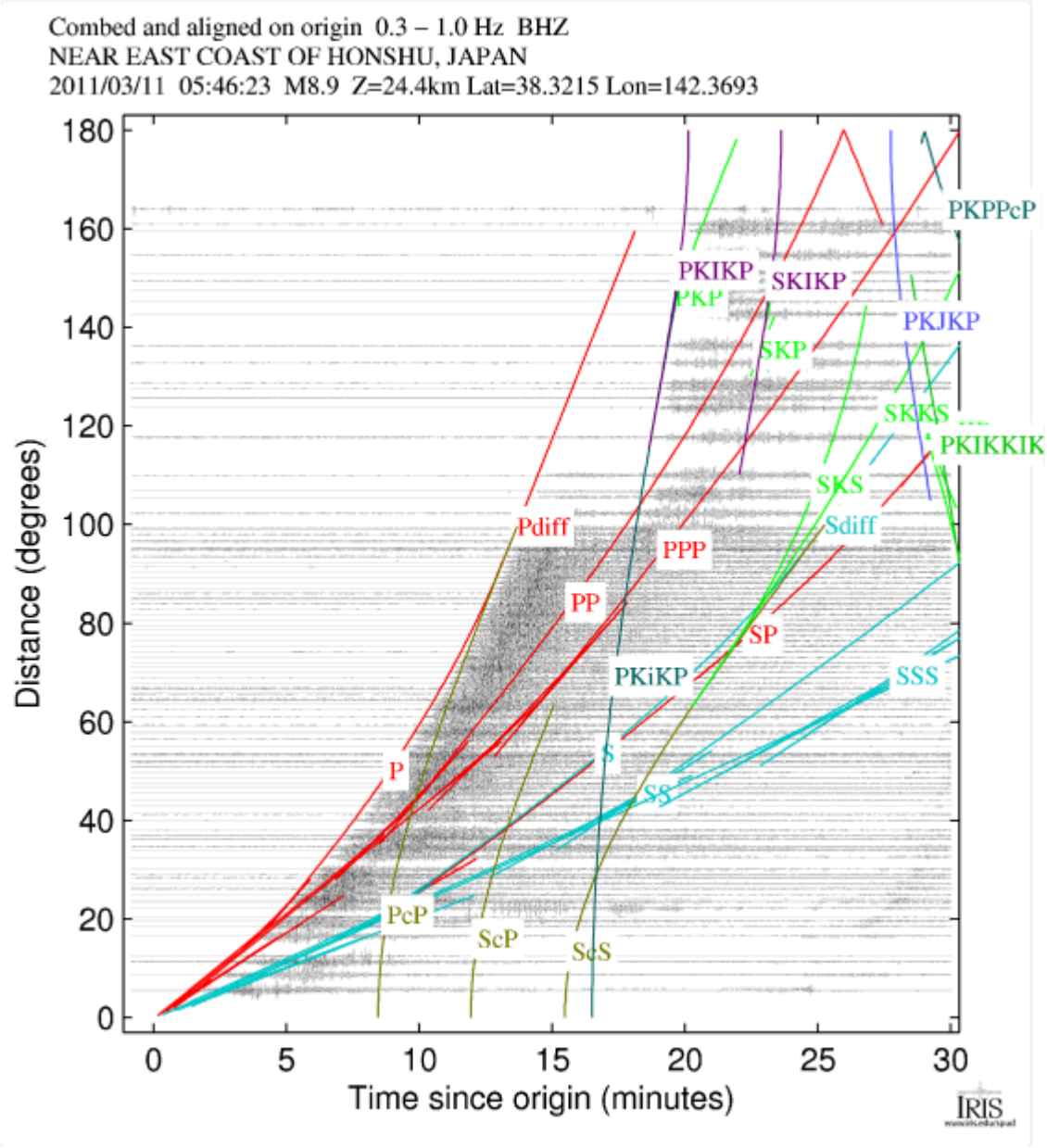
det kommer **mange** bølger



vertikal

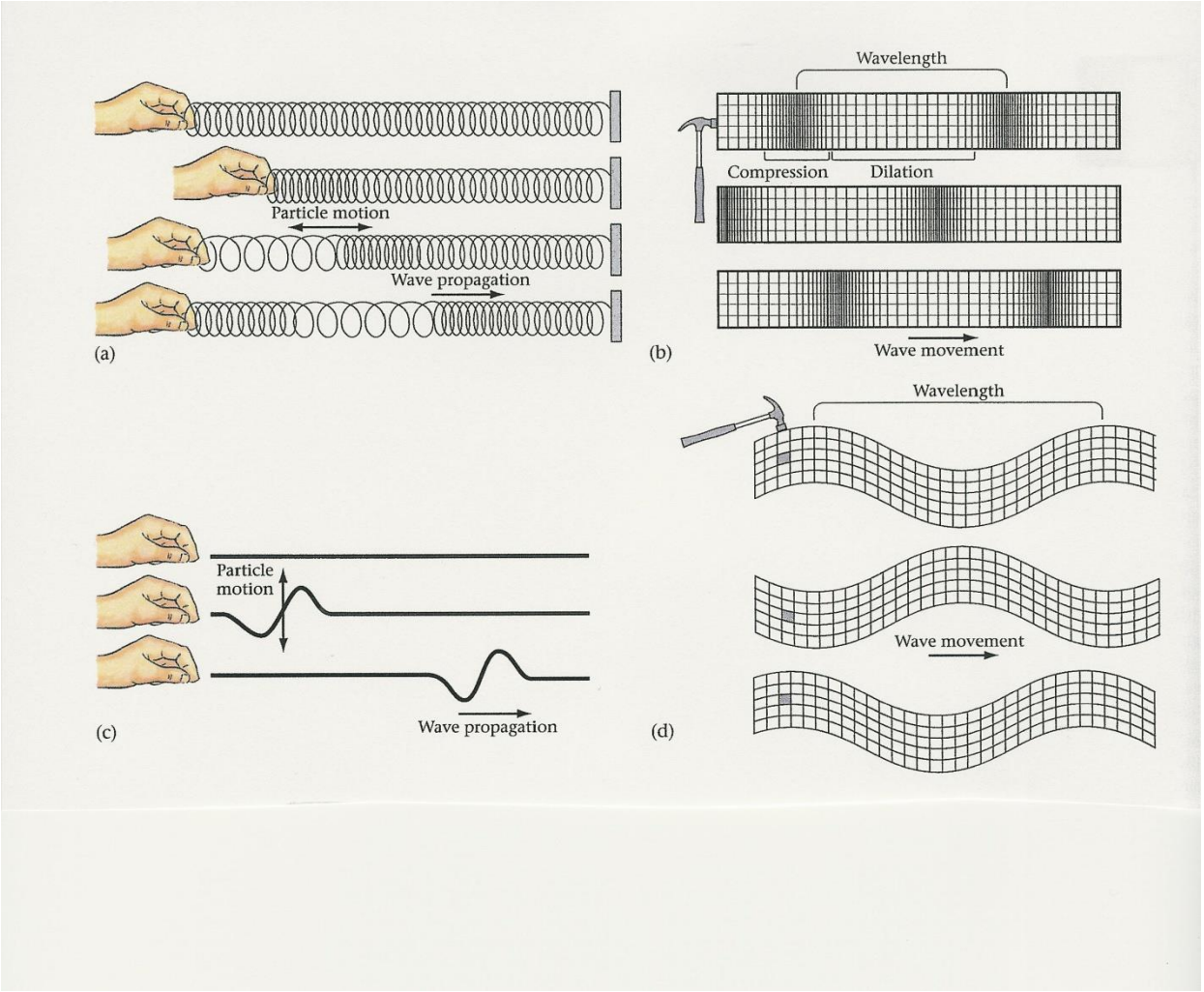
N - S

Ø - V


Combed and aligned on origin 0.3 – 1.0 Hz BHZ
NEAR EAST COAST OF HONSHU, JAPAN
2011/03/11 05:46:23 M8.9 Z=24.4km Lat=38.3215 Lon=142.3693
Distance (degrees)
Time since origin (minutes)
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160
180
PKPPcP
PKIKP
SKIKP
PKP
PKJKP
SKP
SKKS
PKIKKIK
SKS
Sdiff
Pdiff
PPP
PP
SP
PKiKP
SSS
S
SS
P
PcP
ScP
ScS
IRIS

Trykk-bølger (P)

Skjær-bølger (S)



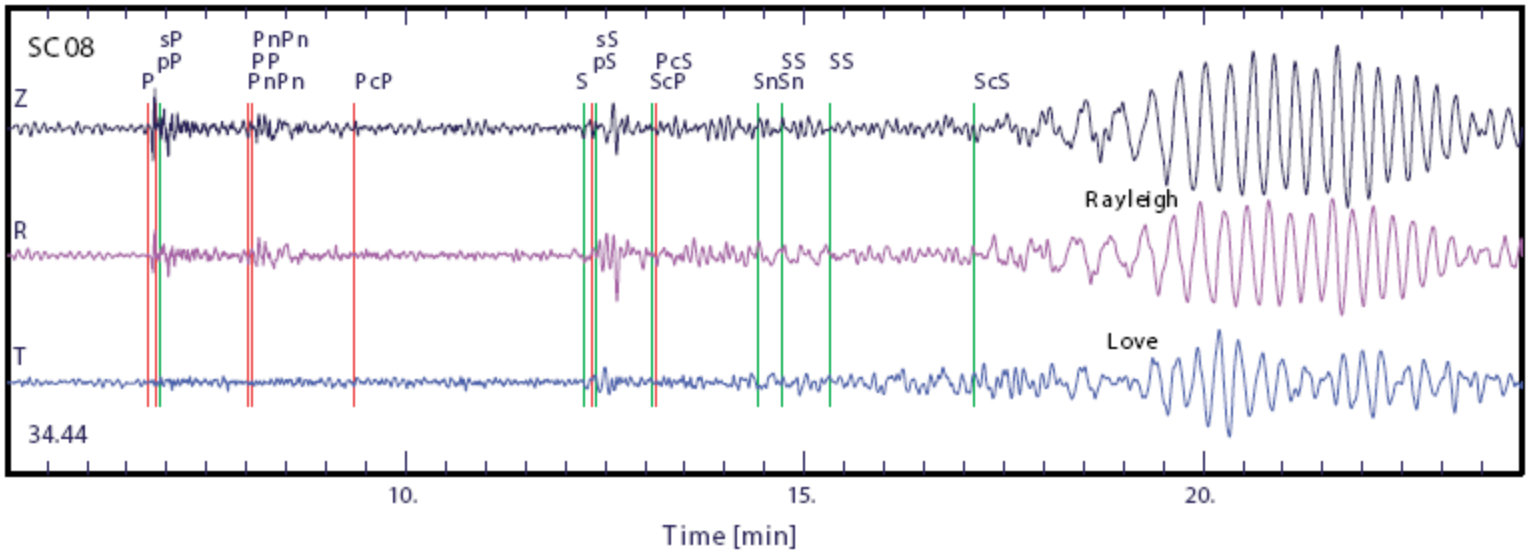
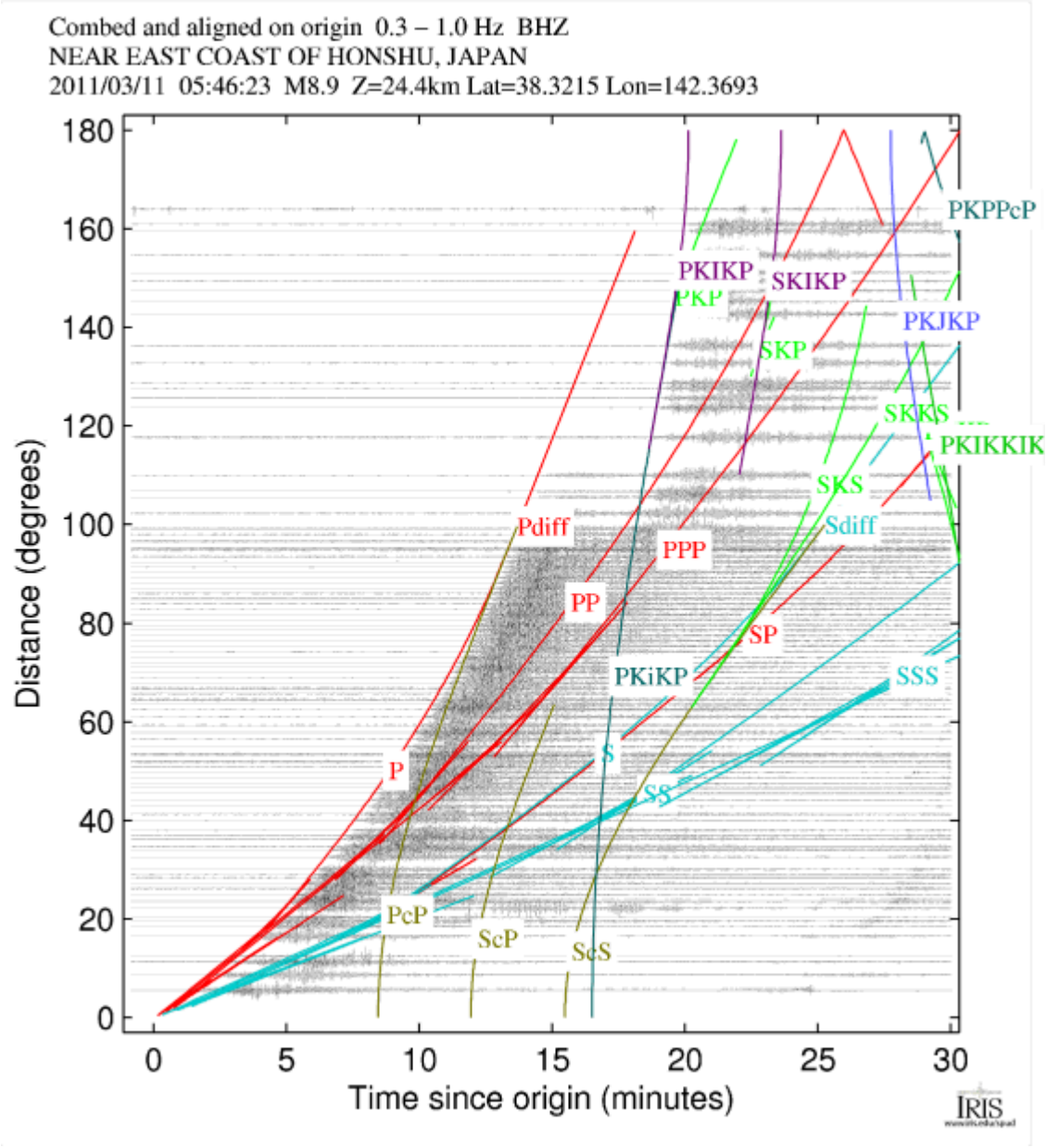
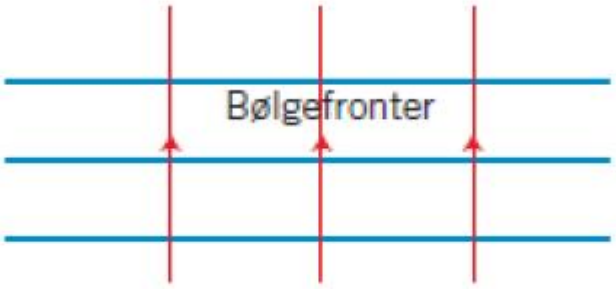


Figure 1: Example of a 3-component (Z, R, T), broadband seismic record, with particularly prominent surface wave signal; epicentral distance $\sim$ 34°. A few phases have been identified on the seismograms. I took this and some of the following images from http://wwwrses.anu.edu.au/seismology/SHon2002/

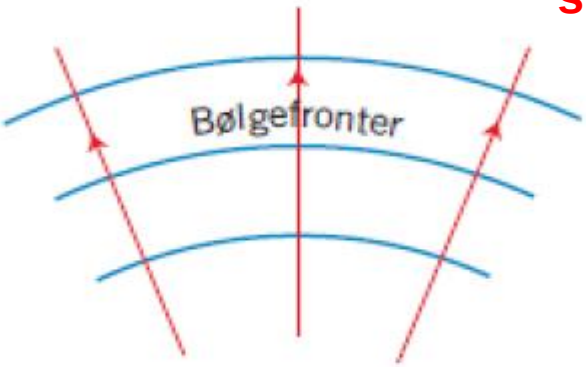

Combed and aligned on origin 0.3 – 1.0 Hz BHZ
NEAR EAST COAST OF HONSHU, JAPAN
2011/03/11 05:46:23 M8.9 Z=24.4km Lat=38.3215 Lon=142.3693
Distance (degrees)
Time since origin (minutes)
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160
180
PKPPcP
PKIKP
SKIKP
PKP
PKJKP
SKP
SKKS
PKIKKIK
SKS
Sdiff
Pdiff
PPP
PP
SP
PKiKP
SSS
S
SS
P
PcP
ScP
ScS
IRIS

- Hva ”ser” jeg inni Jorda?
- Hva har jeg **egentlig** sett?
- Hvordan har jeg dannet meg dette bildet av Jorda fra det jeg har sett?

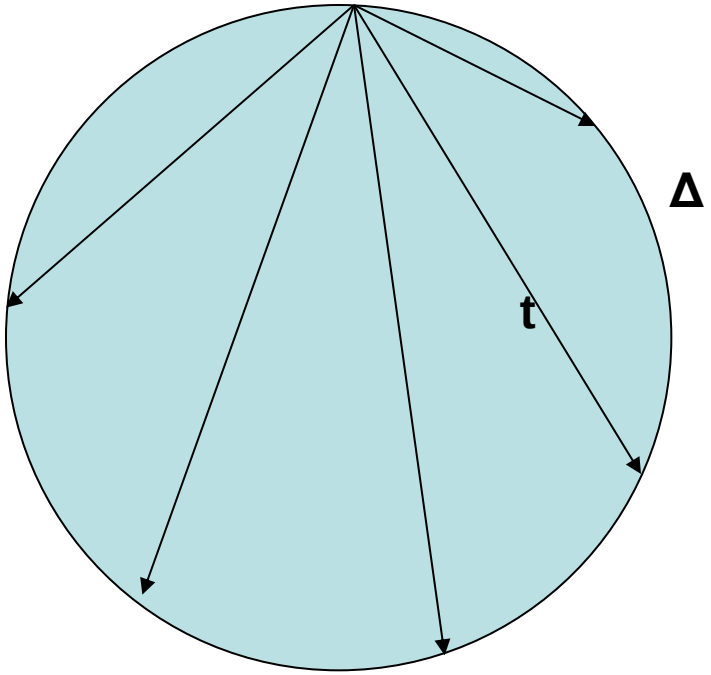
Begrep avklaring: bølgefronter/stråler



stråler



Bølgeforplantning hvis Jorda hadde vært en homogen kule:



t = 2 a/v sin(Δ/2)

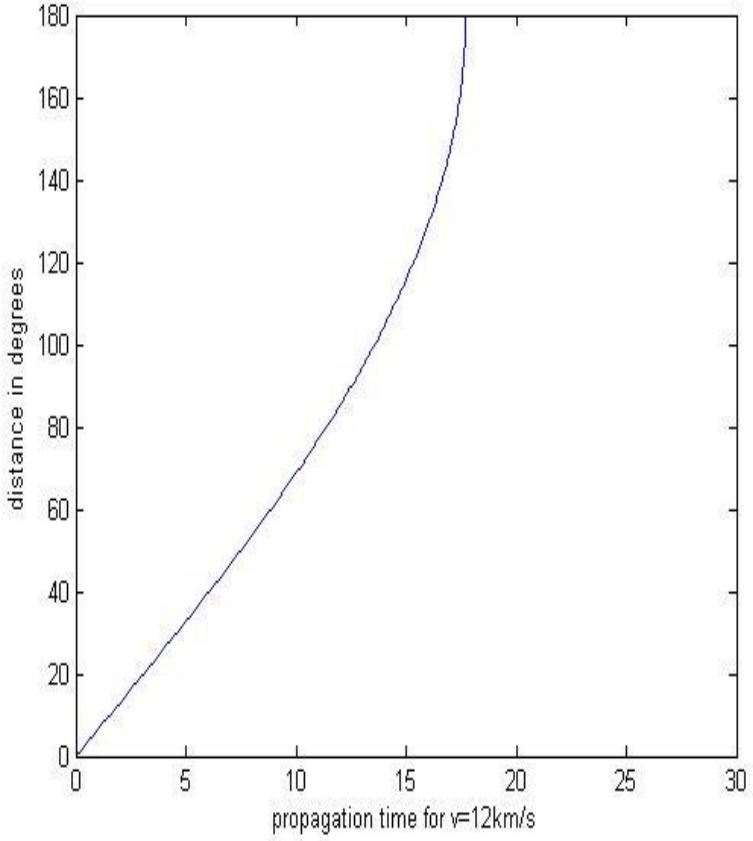
t: forplantningstid

a: radius (6371km)

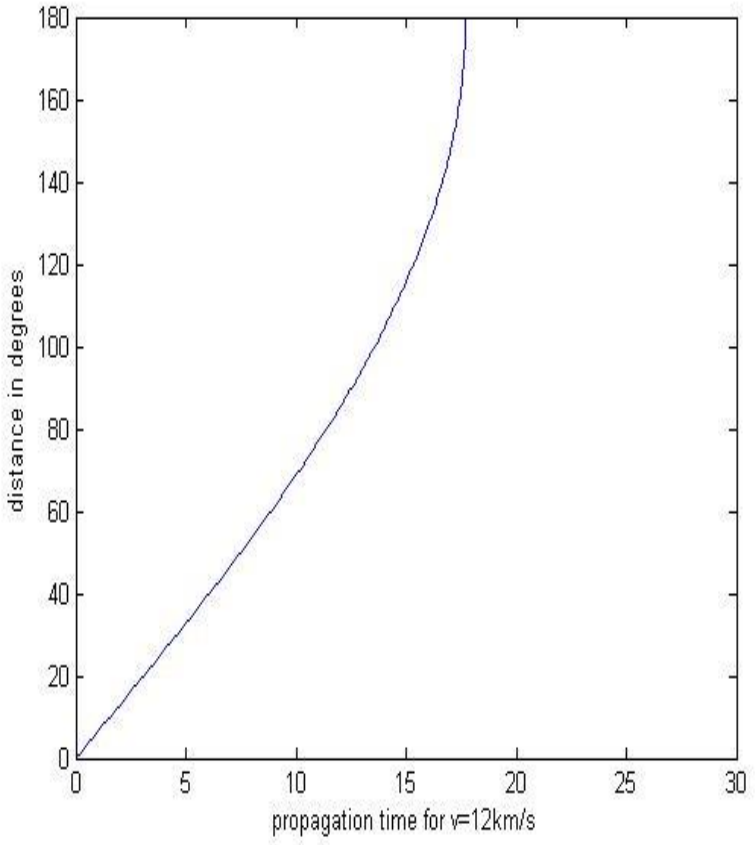
v: bølgehastighet

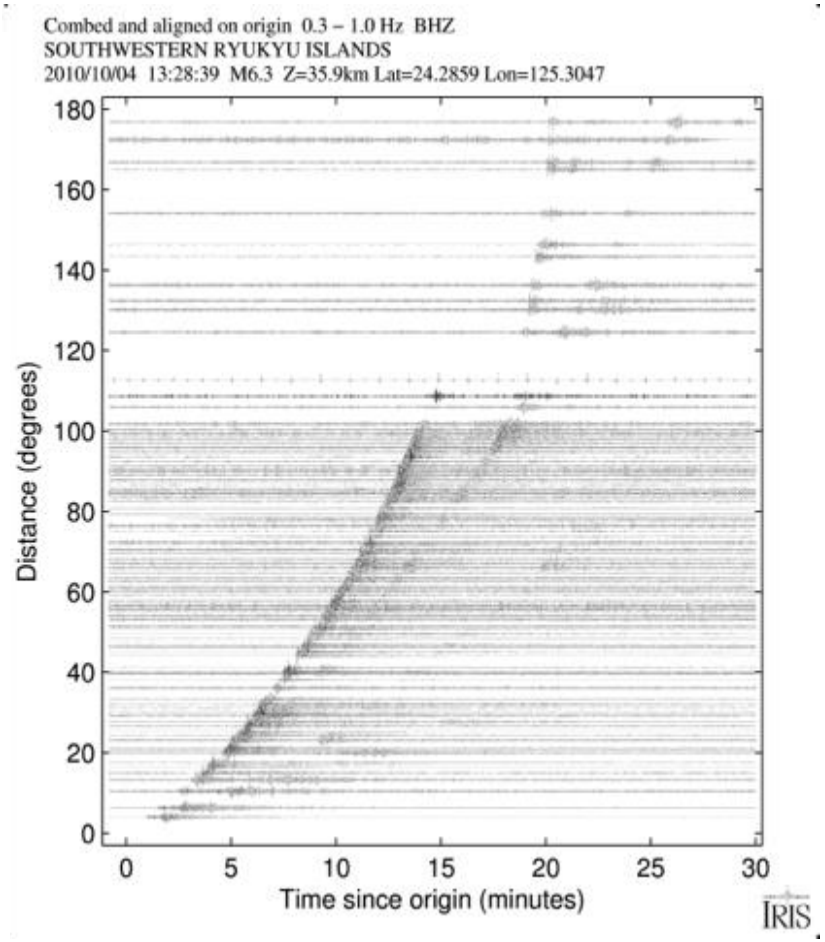
Δ: avstand i grader

Sammenligning Jorda og homogen kule

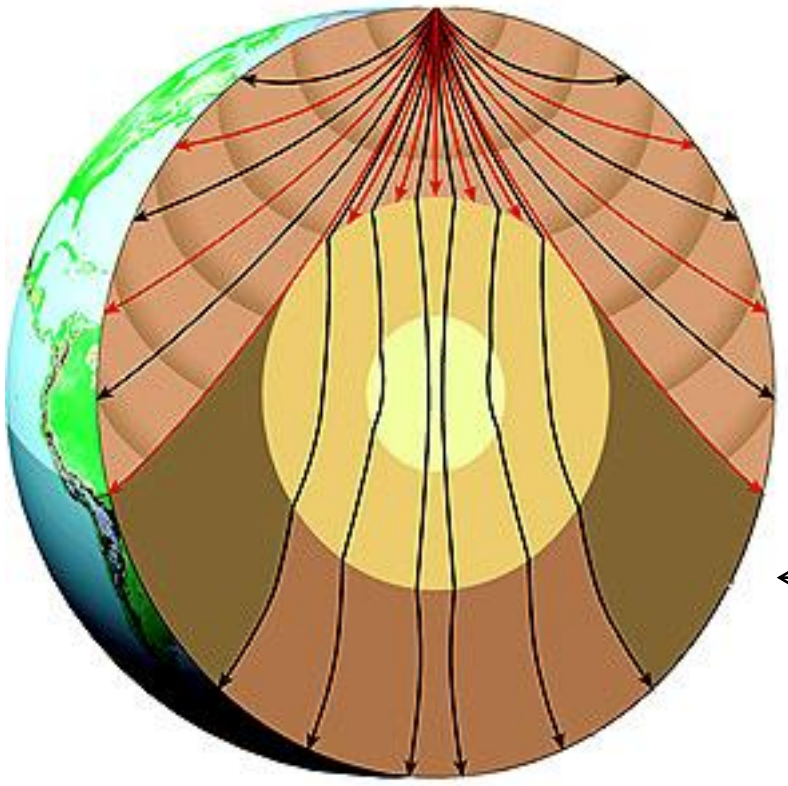


Sammenligning Jorda og homogen kule



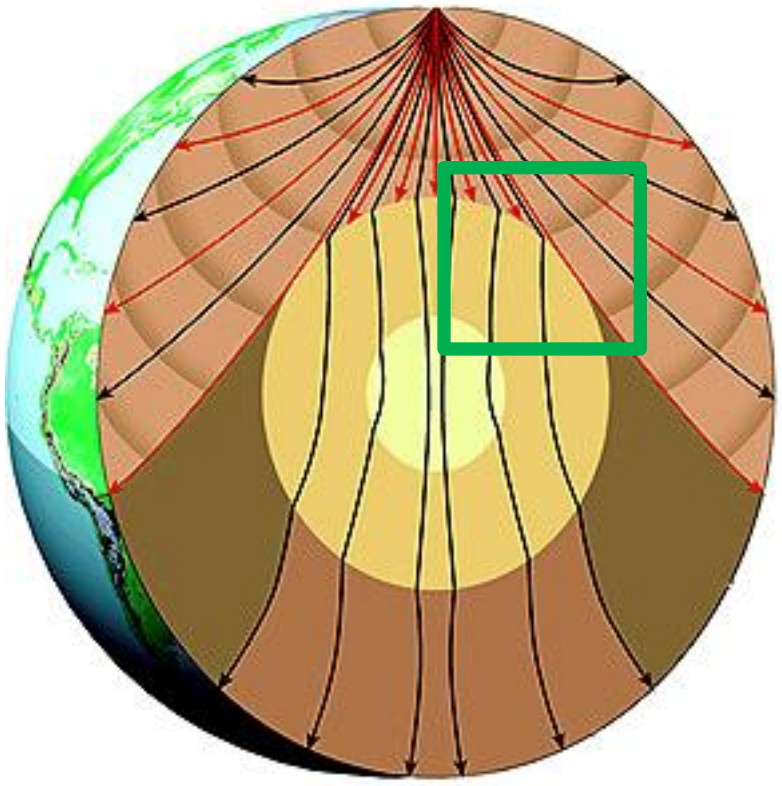


Bølgeforplantning som forklarer ankomstidene

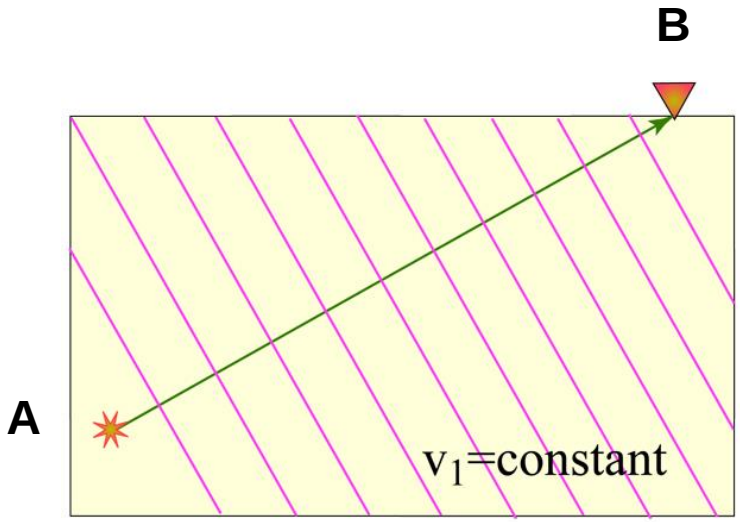


Skyggezone etter 100 grader avstand

Brytning



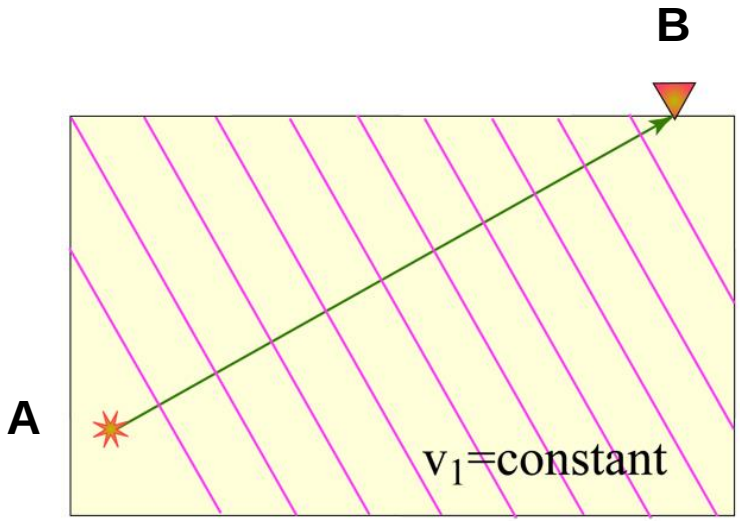
Brytning



Bølgen bruker minst mulig tid fra A til B.

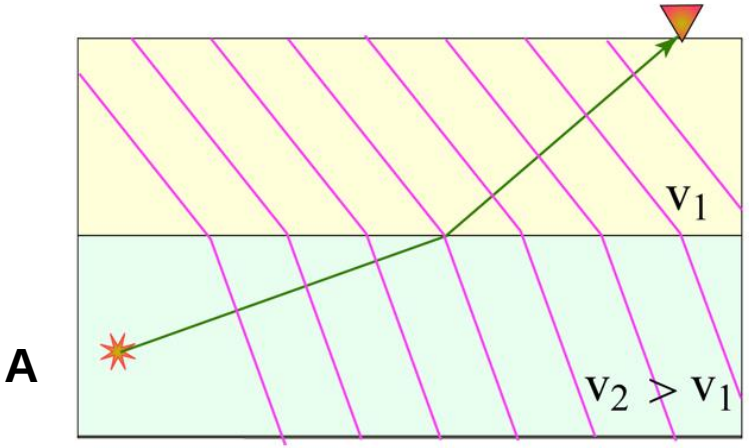
(Fermats prinsipp)

Brytning



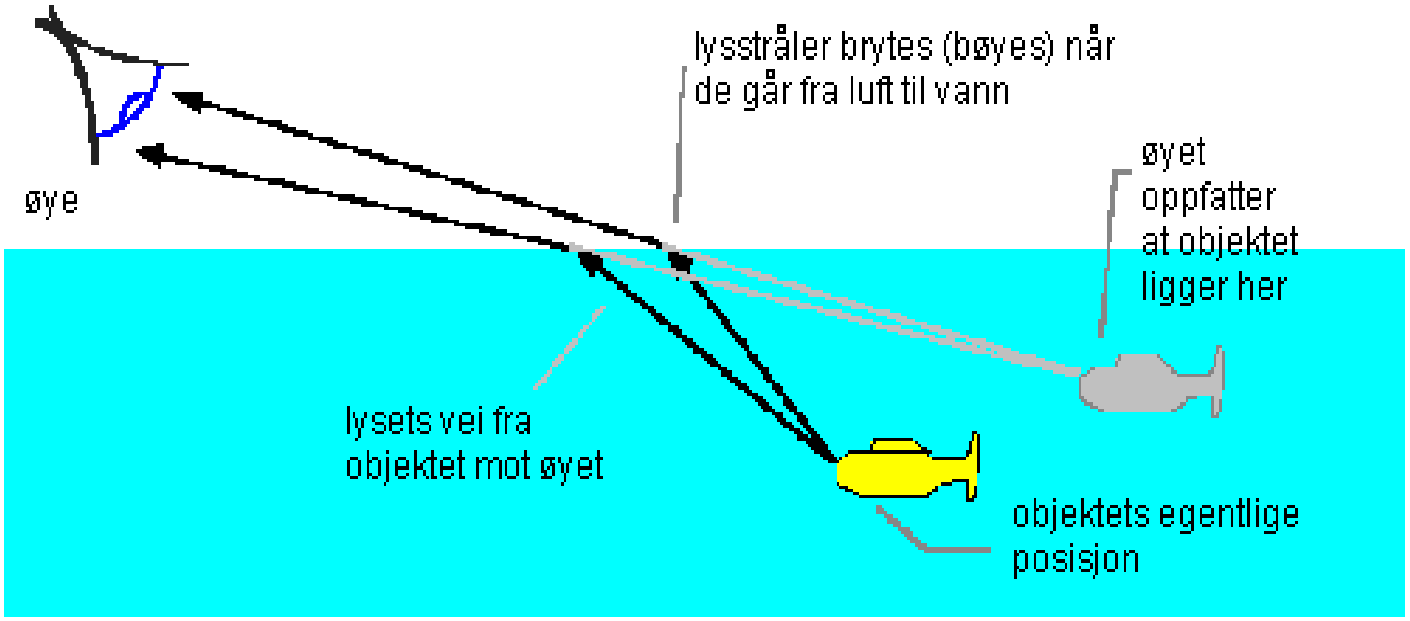
Bølgen bruker minst mulig tid fra A til B.

(Fermats prinsipp)

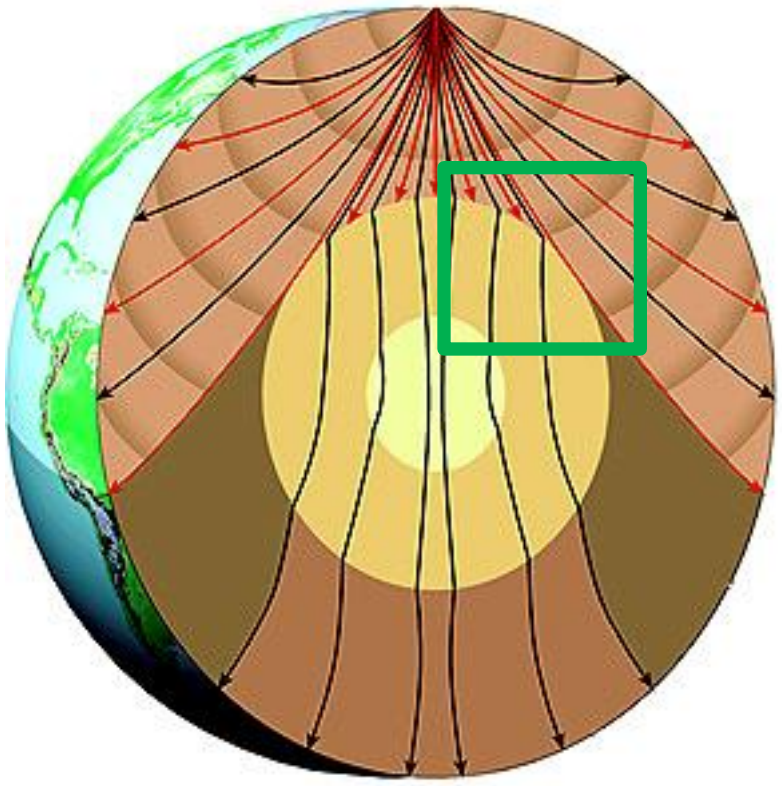


Bruker derfor en bane som går litt mer i området med størst hastighet.

brytning ved en vannoverflate

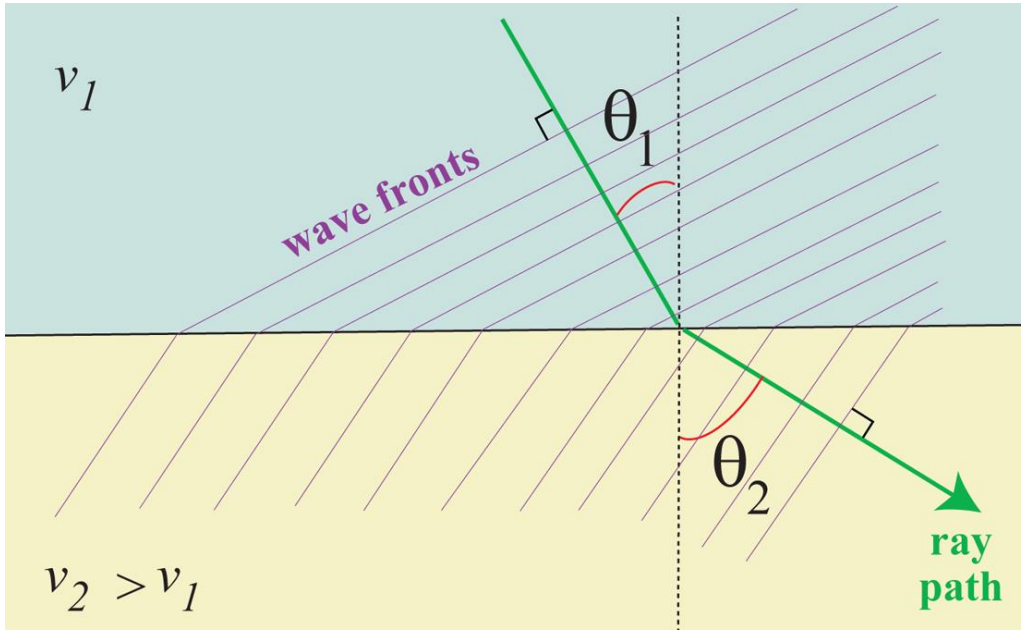


metskole.gfi.uib.no



Brytning mellom mantelen og kjernen

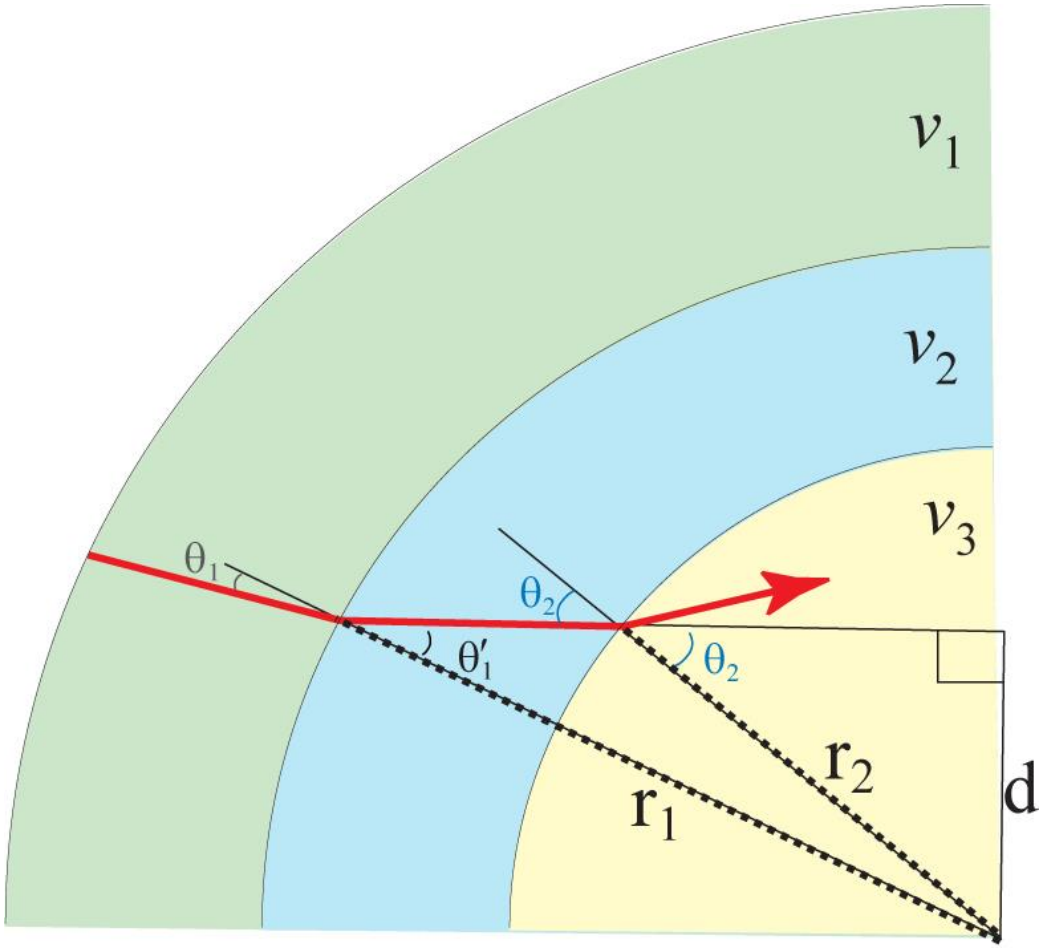
Brytning inni mantelen



I mantelen øker hastigheten med dyp

fordi materialet blir tettere og tettere.

Krumme bølgevei ned i Jordens mantel



Strålebaner og gangtider for P-bølger

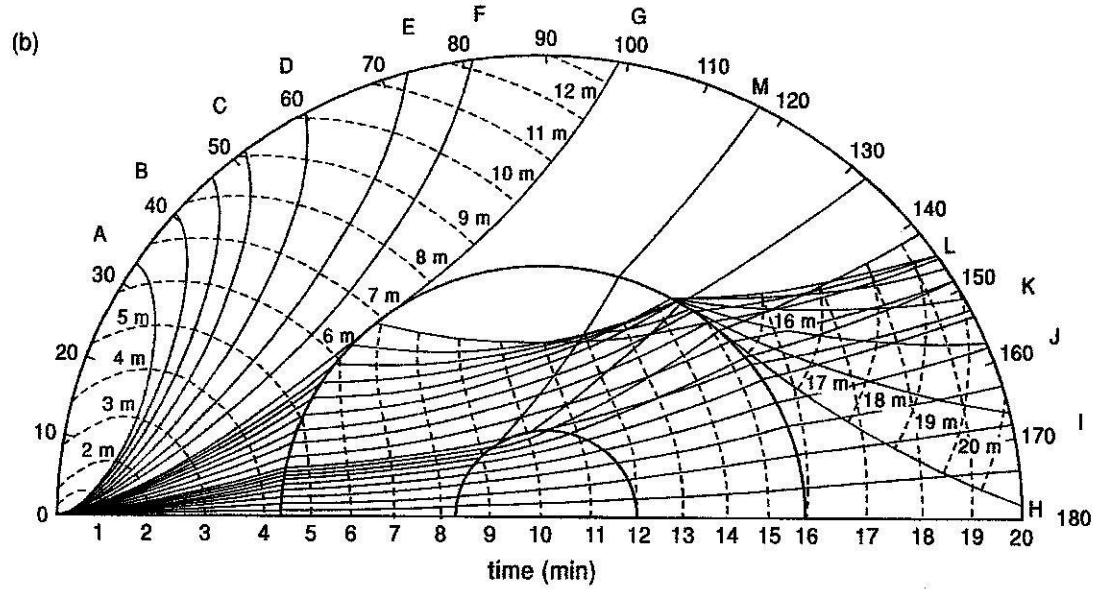
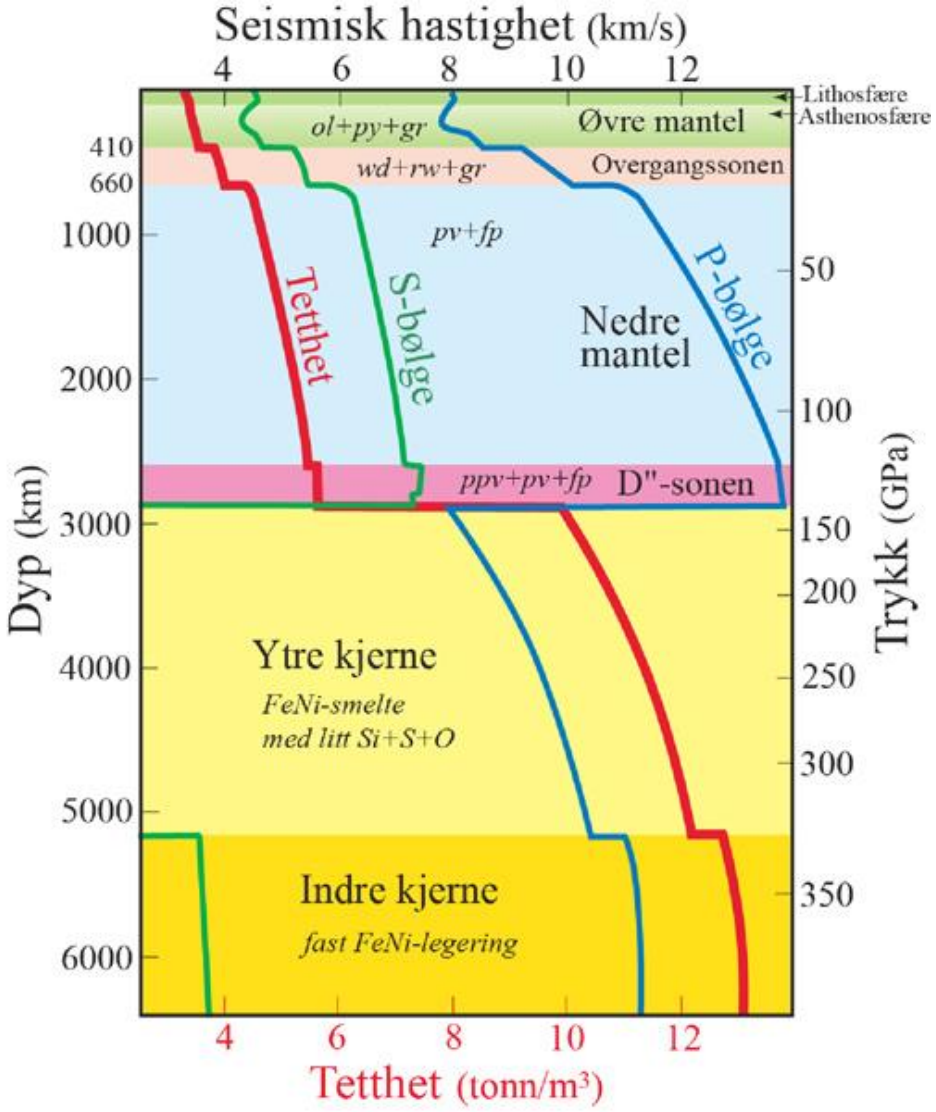


Figure 4.20 Ray paths in the Earth.

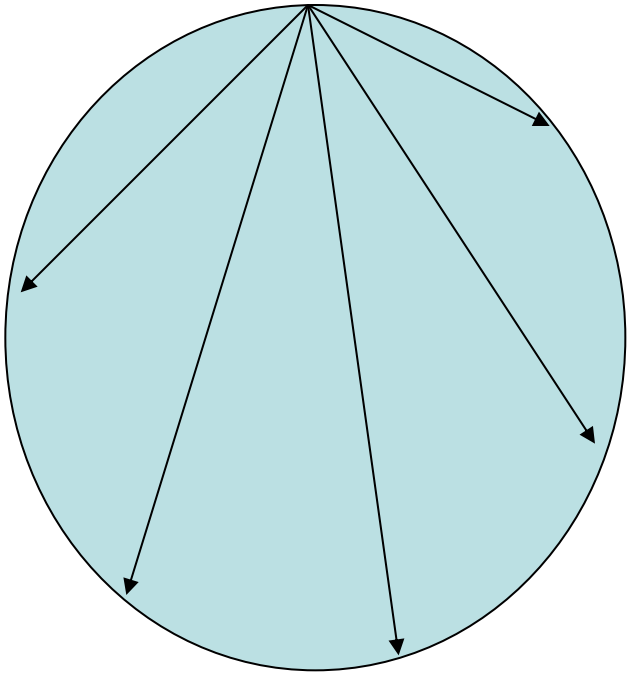

Seismisk hastighet (km/s)
4
6
8
10
12
Lithosfære
Asthenosfære
ol+py+gr
Øvre mantel
wd+rw+gr
Overgangssonen
pv+fp
Tetthet
S-bølge
P-bølge
Nedre mantel
ppv+pv+fp
D"-sonen
Ytre kjerne
FeNi-smelte
med litt Si+S+O
Indre kjerne
fast FeNi-legering
Dyp (km)
410
660
1000
2000
3000
4000
5000
6000
Trykk (GPa)
50
100
150
200
250
300
350
4
6
8
10
12
Tetthet (tonn/m³)

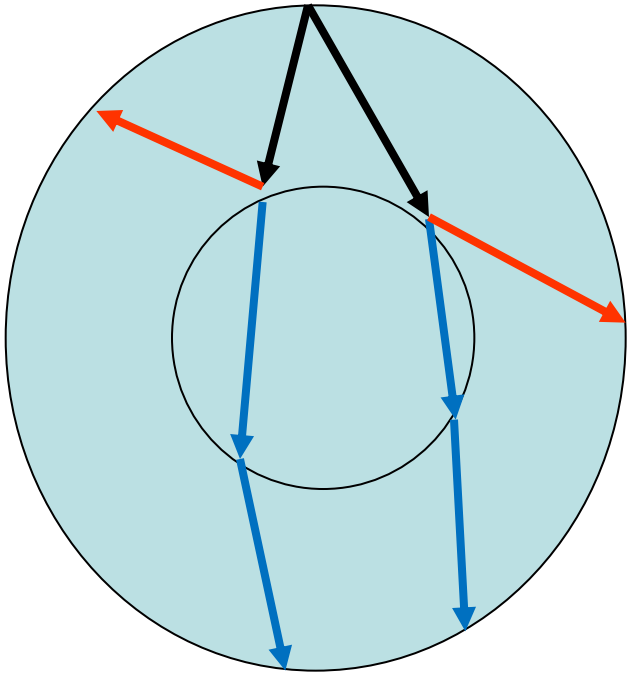
Refleksjon

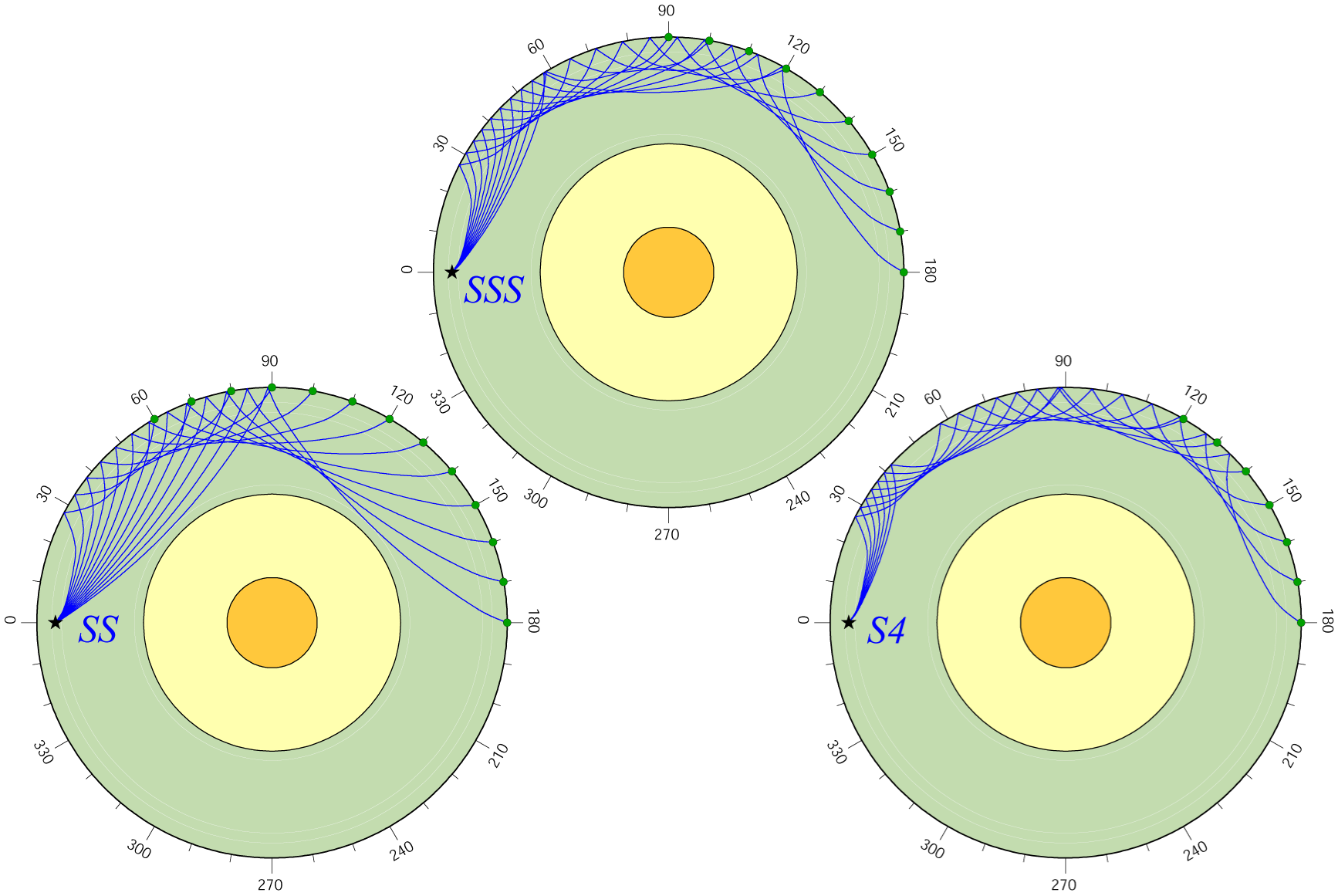
eksempel: refleksjon av lyset på vannoverflate

Fra Gjermund Svinsås

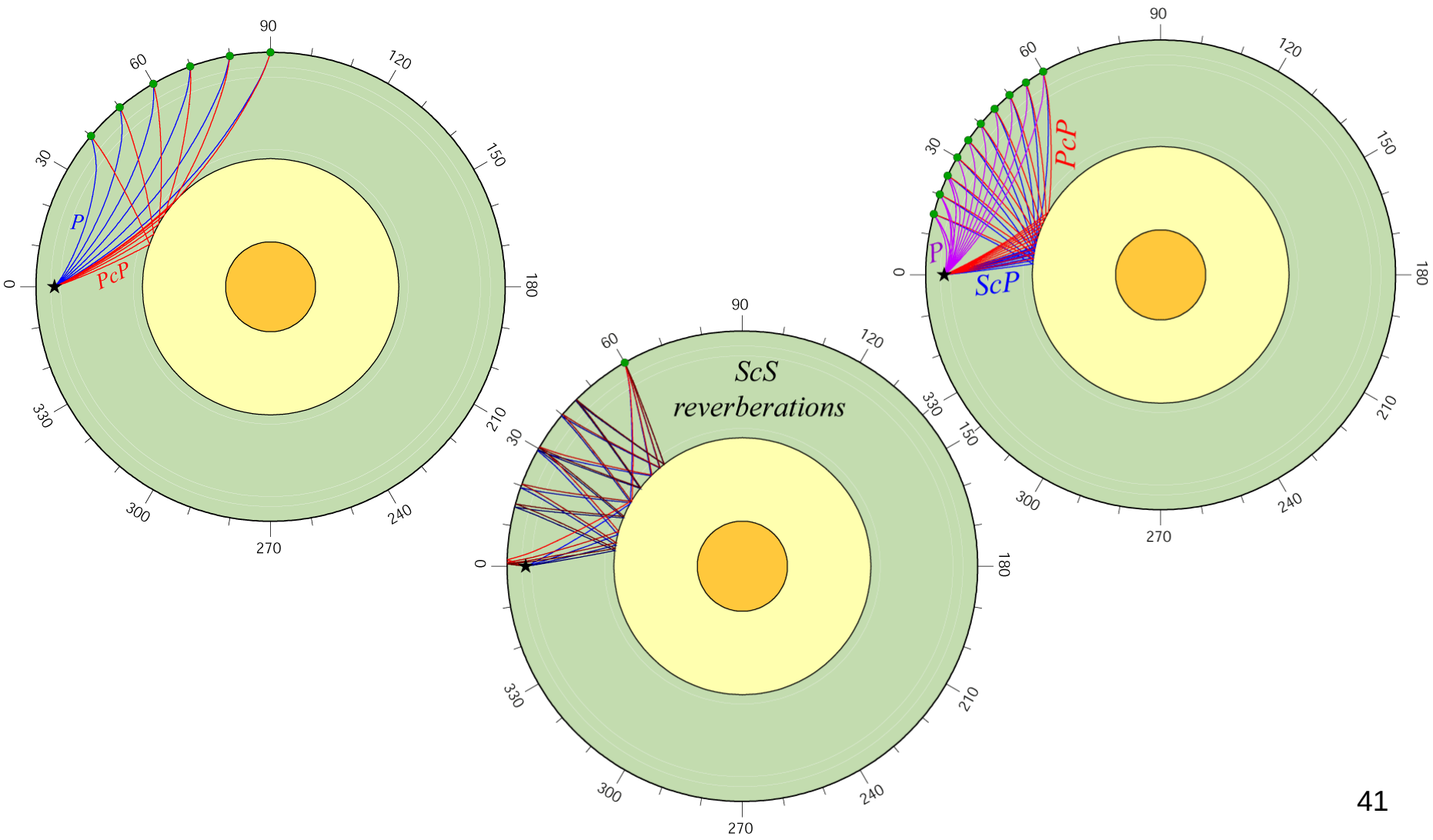
- En grense flate → Brytning og refleksjon

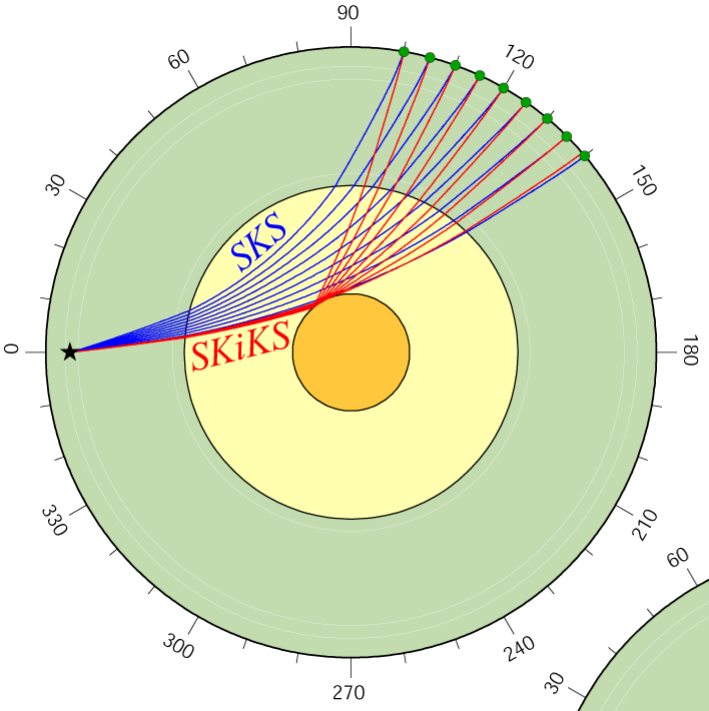


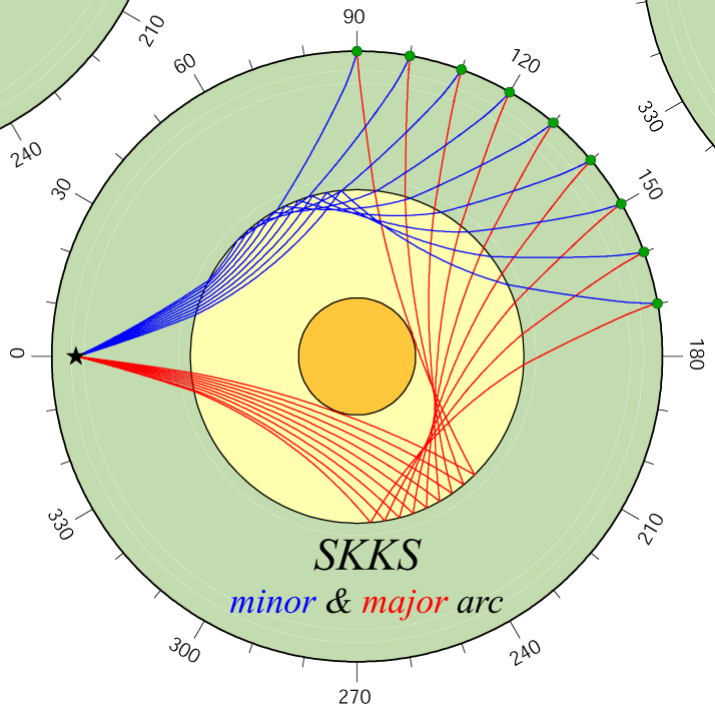


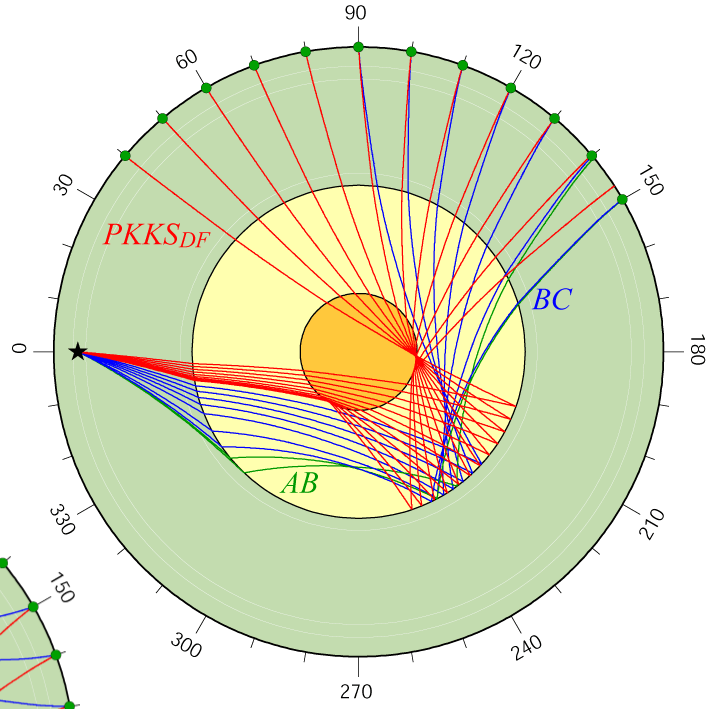

SSS
SS
S4
90
60
120
30
150
0
180
330
210
300
240
270

Strålebaner til forskjellige bølger med refleksjon

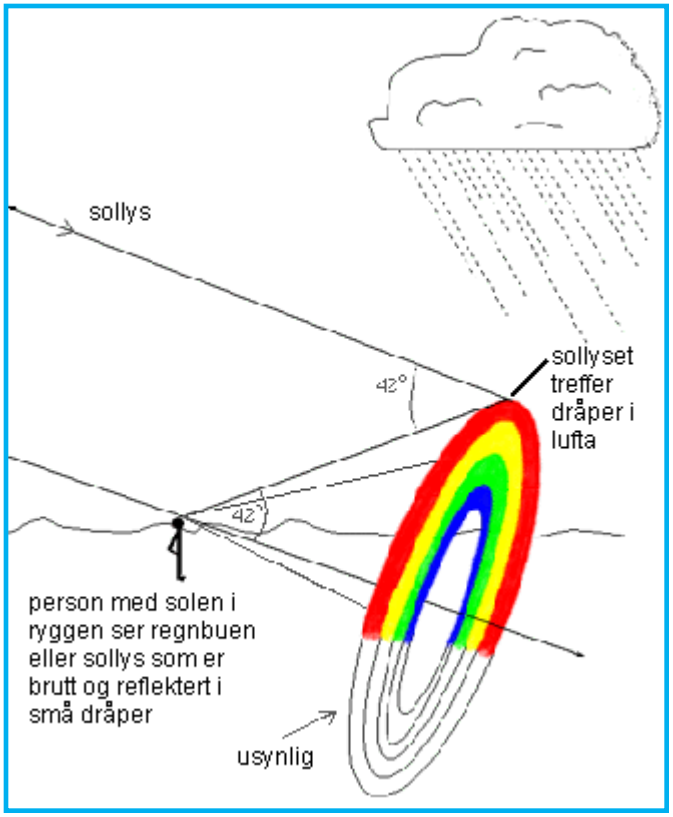








”regnbue”
bølger



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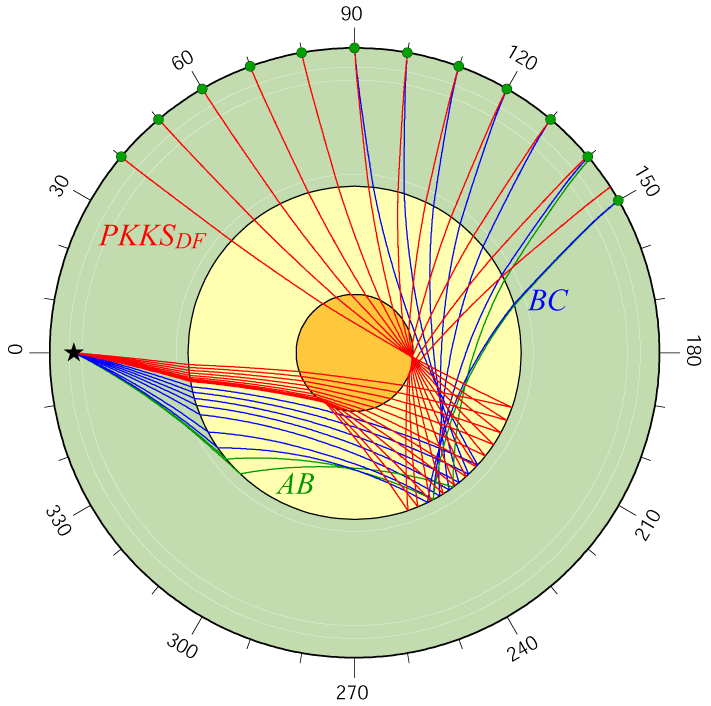
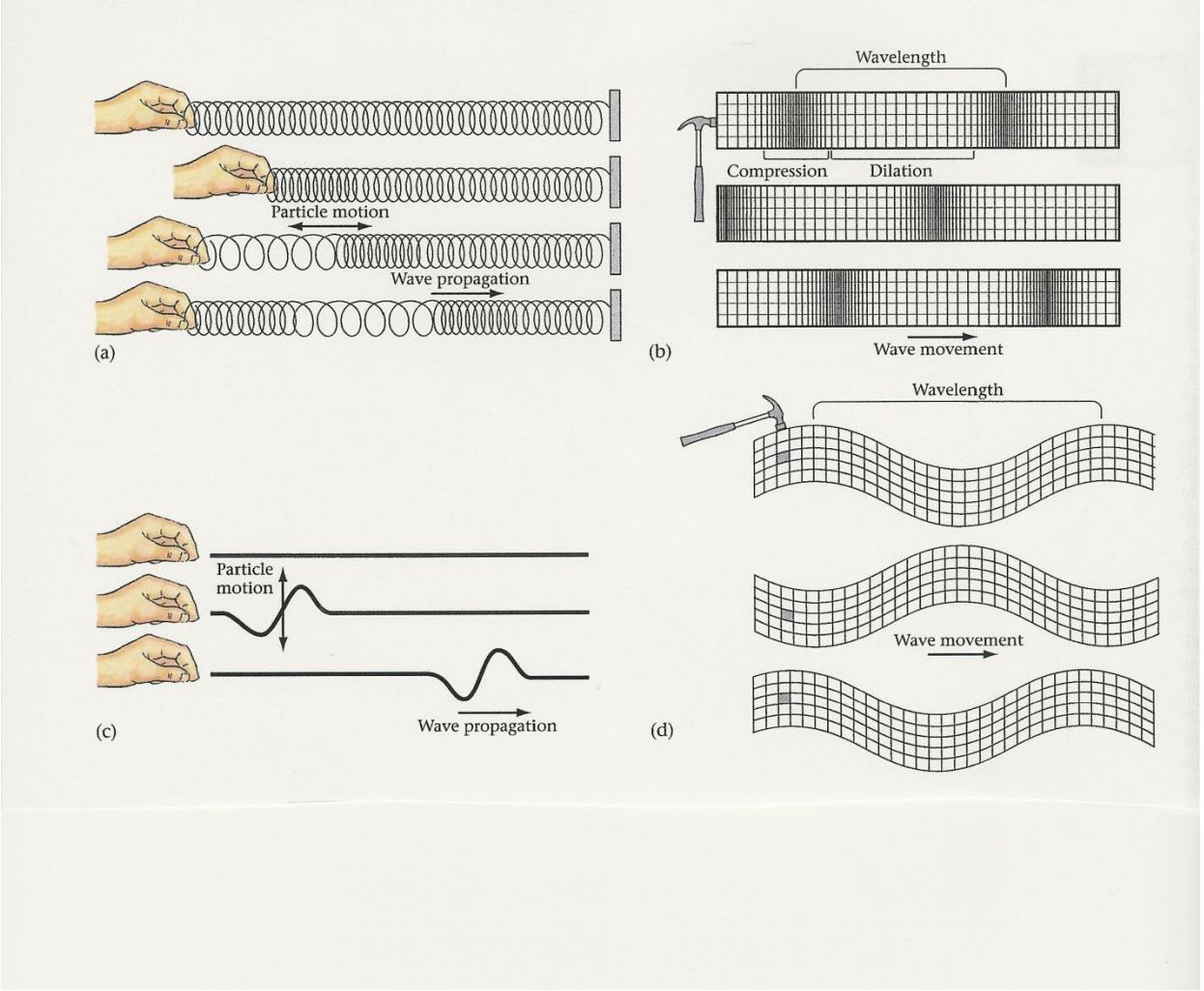


”regnbue”
bølger

P-bølger og S-bølger



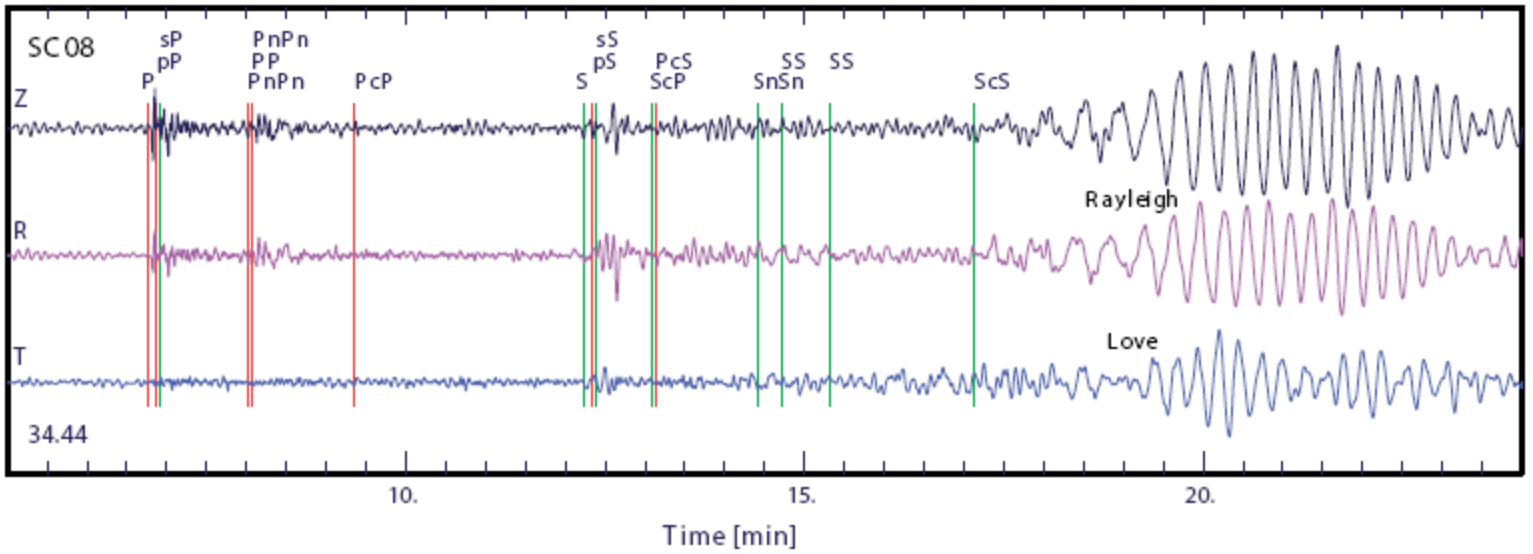


Figure 1: Example of a 3-component (Z, R, T), broadband seismic record, with particularly prominent surface wave signal; epicentral distance $\sim$ 34°. A few phases have been identified on the seismograms. I took this and some of the following images from http://wwwrses.anu.edu.au/seismology/SHon2002/

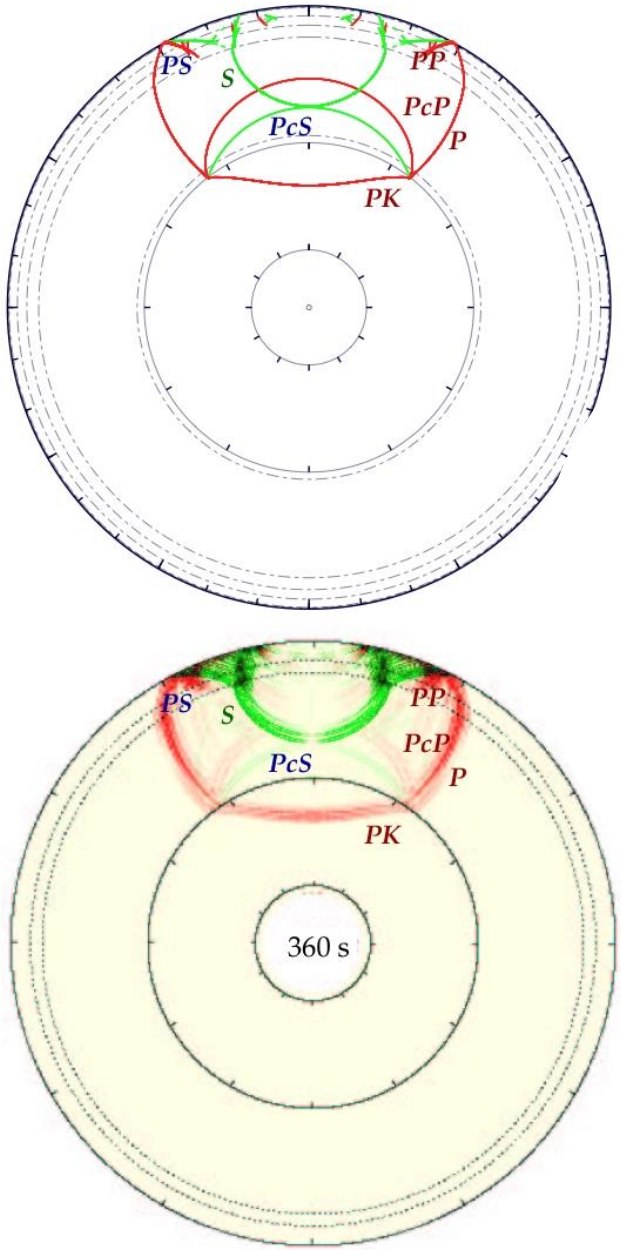


Figure 1.6. Wavefronts for the Peruvian event at 360 s after source initiation, together with a snapshot of the wavefield from a numerical simulation.

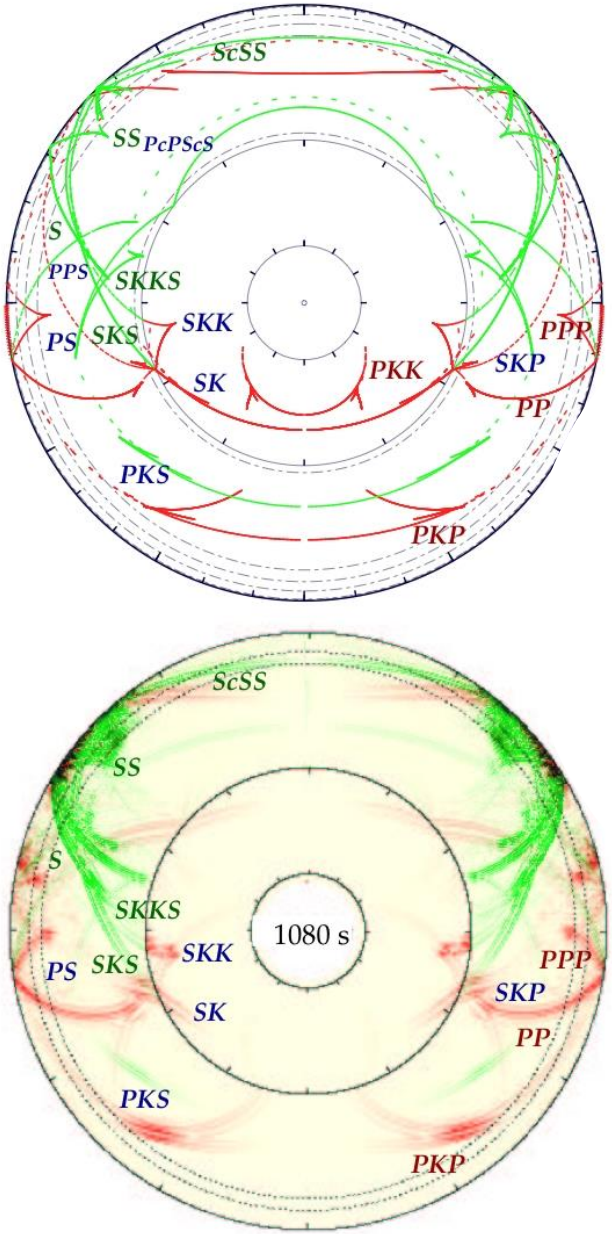
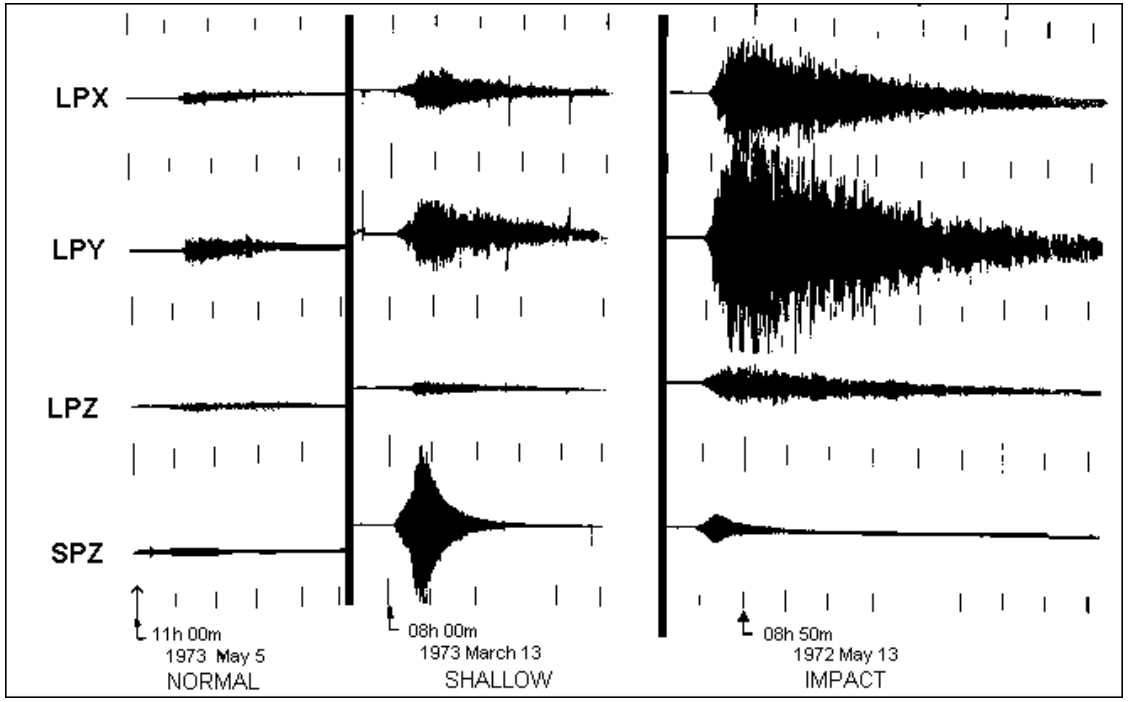
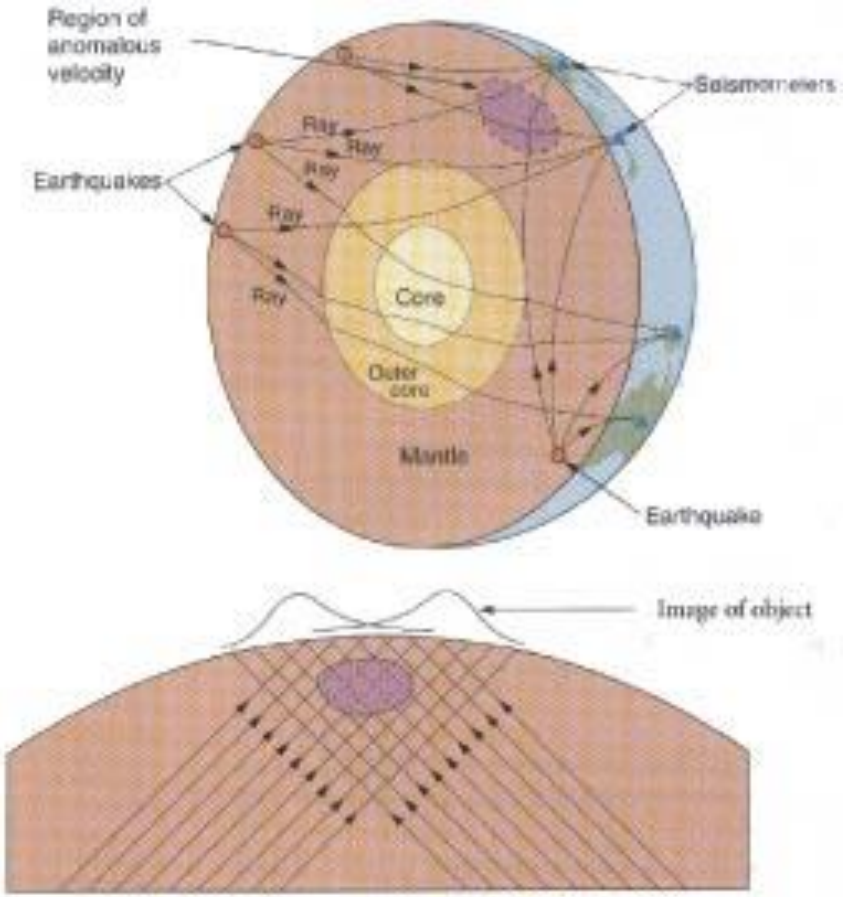


Figure 1.10. Wavefronts for the Peruvian event at 1080 s after source initiation, together with a snapshot of the wavefield from a numerical simulation.

- Alle disse ekkoene gjør at man kan kartlegge Jorden ganske nøyaktig
- Det er mer heterogent på Månen:

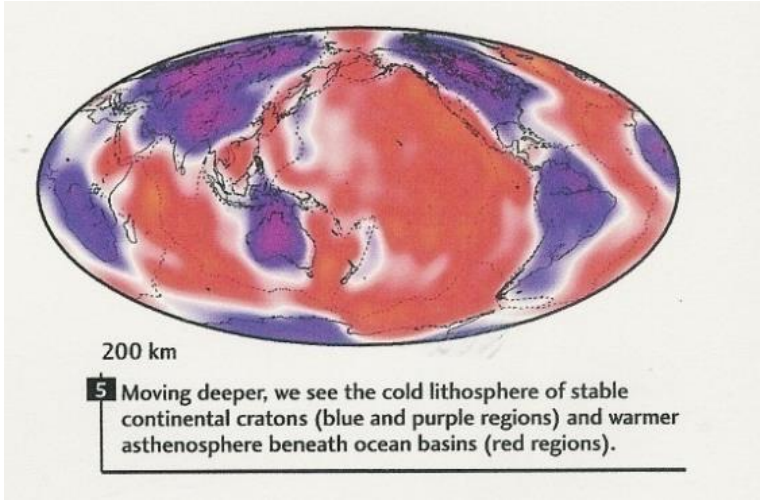


Å kartlegge flere detaljer: Prinsipp til seismisk tomografi

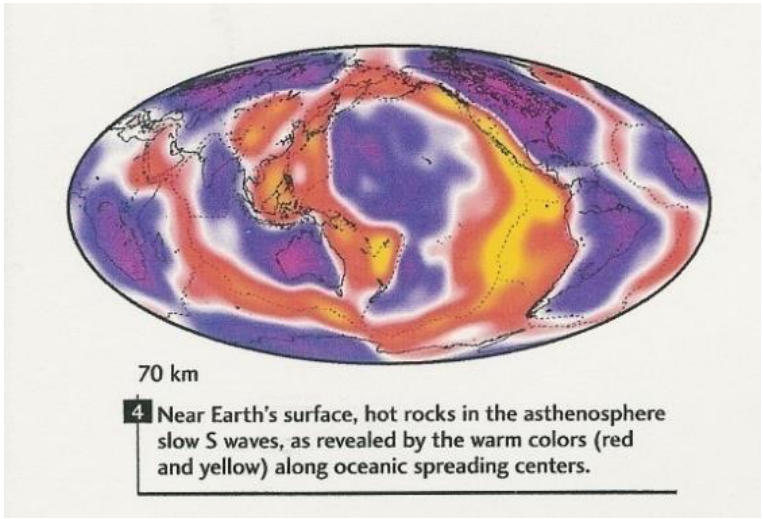


Laterale variasjoner i S-hastigheten

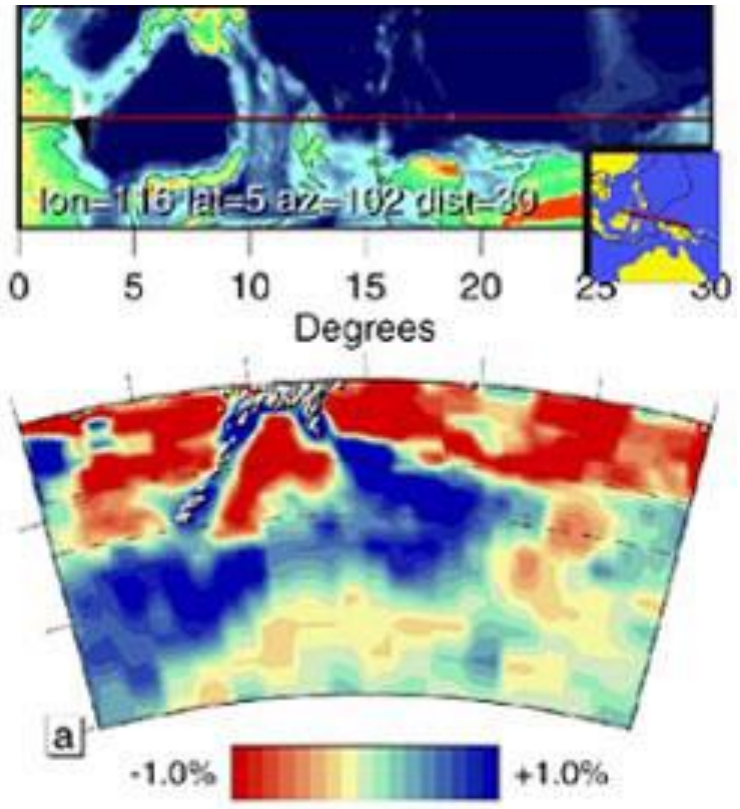
ved 200 km dyp

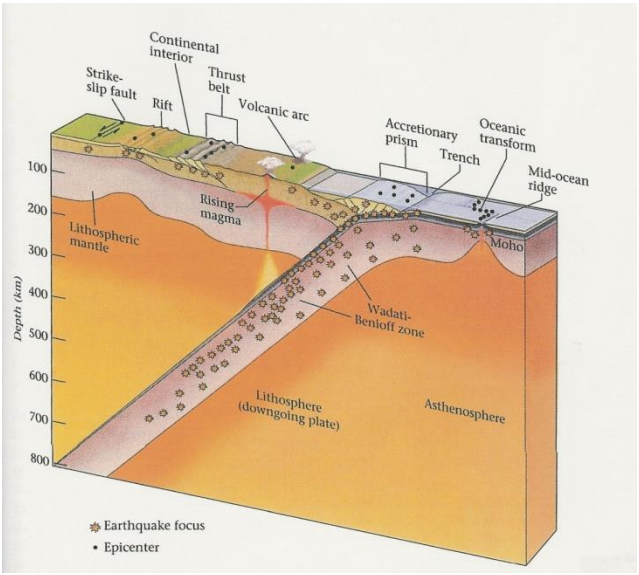


ved 70 km dyp

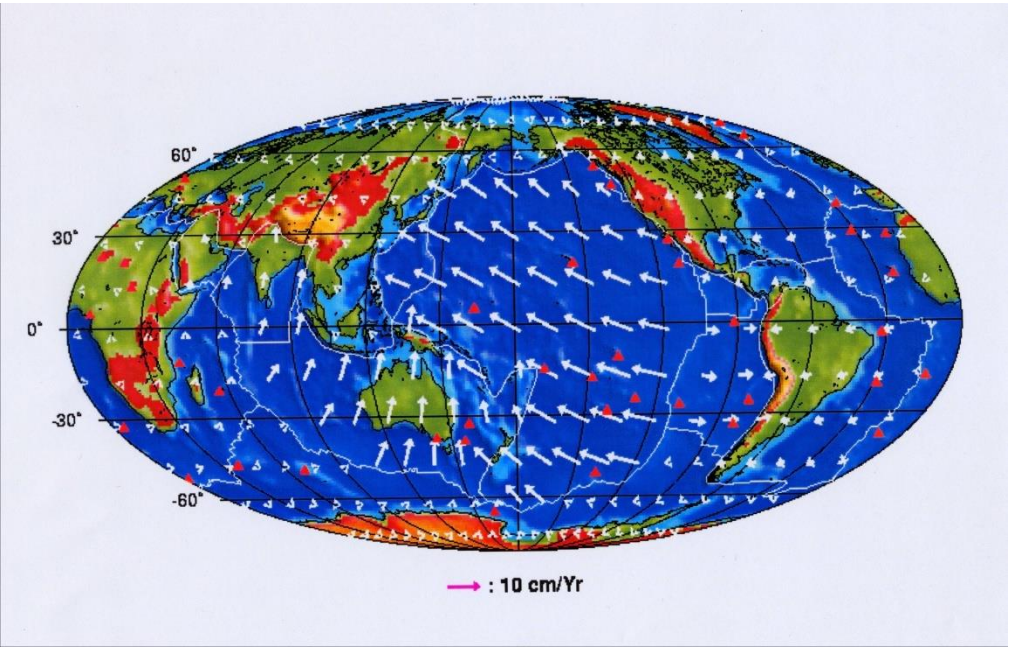


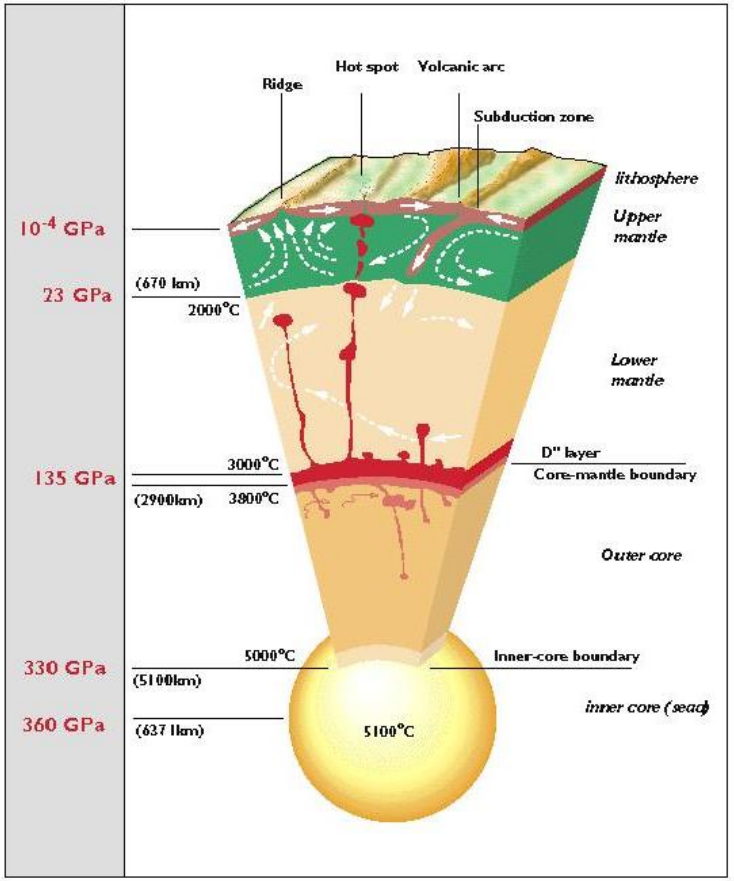
P-bølge tomografi (Spakman, vd Hilst)



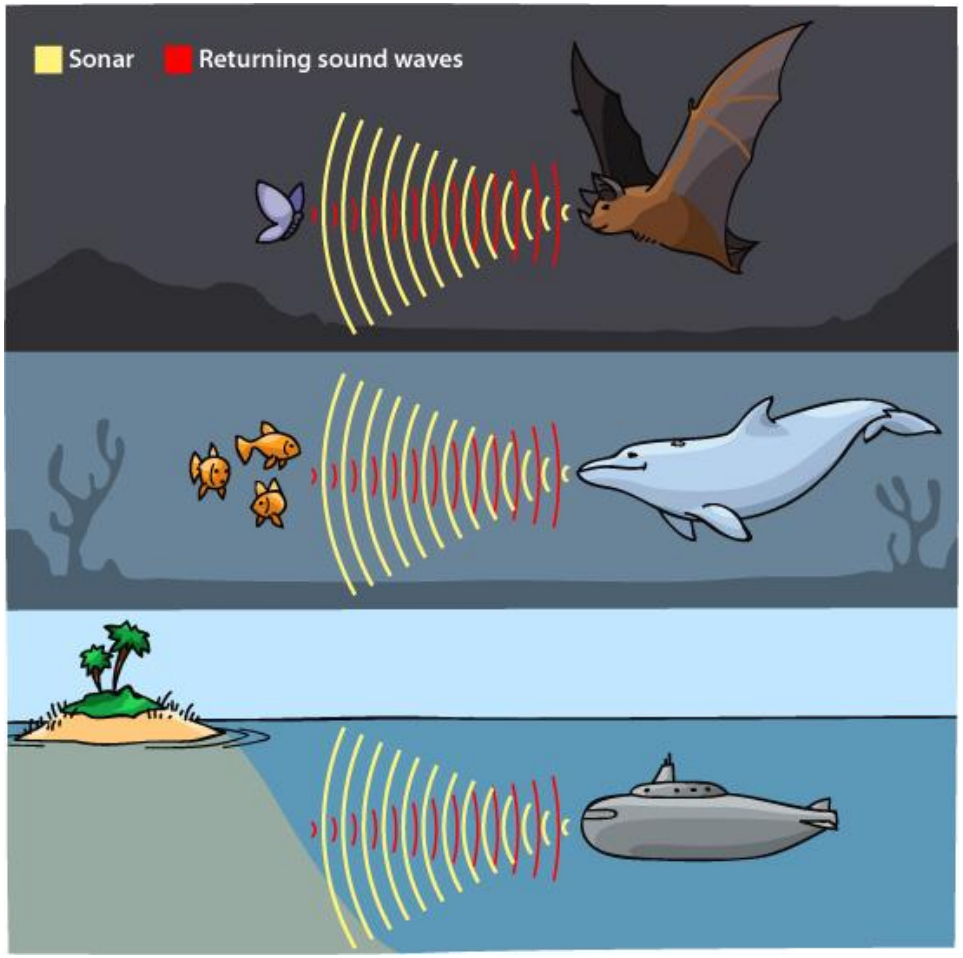


Danner basis for forståelse av platetektonikk og hvordan Jorda fungerer





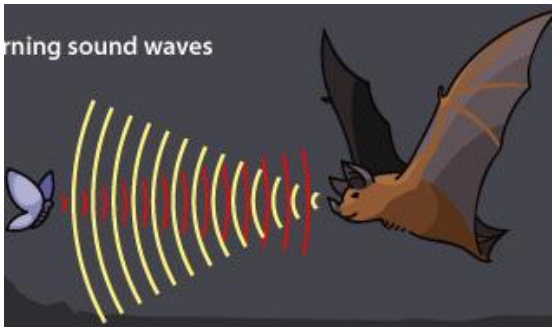
Konklusjon: er seismologer som flaggermus?



flaggermus

hval

ubåt



Bruker lyd til å kartlegge

Lytter på jordskjelv

Lager lyden selv

Brytning

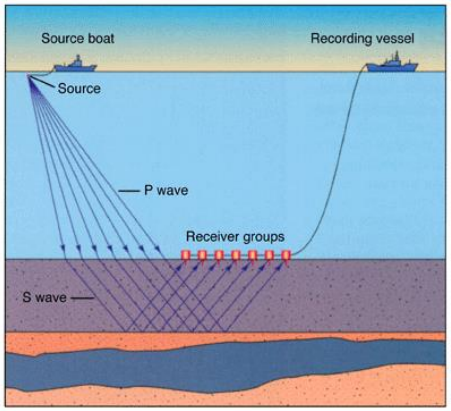
Reflekjon

Forplantning i heterogen media

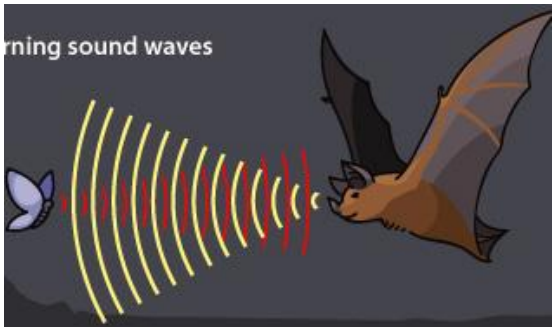
Forplantning i homogen media

P og S bølger

P bølger



Seismisk prospektering



Bruker lyd til å kartlegge

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Forplantning i heterogen media

Forplantning i homogen media

P og S bølger

P bølger

Hovedkilder:

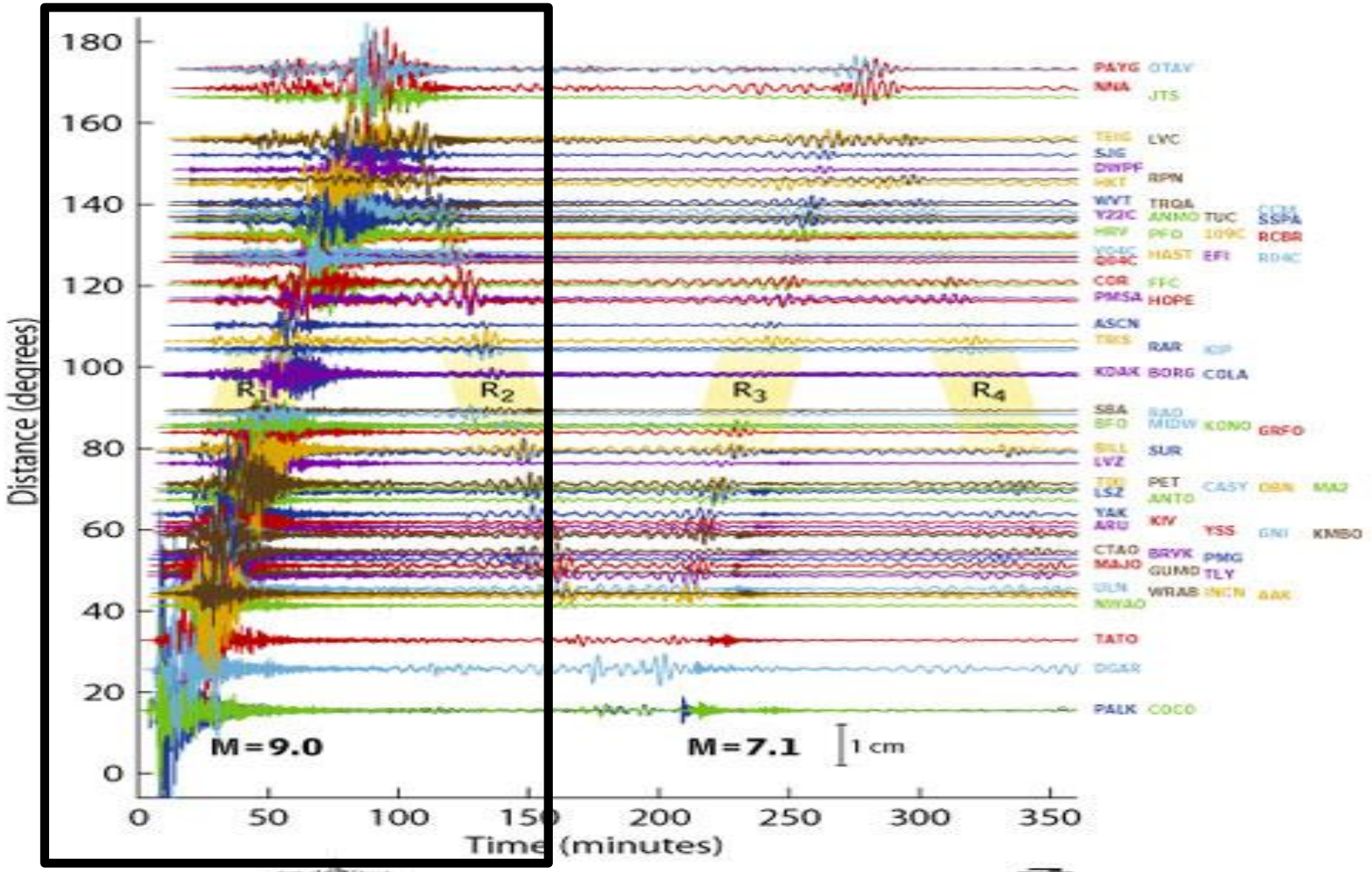
Mange figurer fra Ed Garnero (Arizona State University)

www.iris.edu (Incorporated research institutions for seismology)

www.forskning.no, www.nhm.no

Sumatra - Andaman Islands Earthquake (M_w=9.0)

Global Displacement Wavefield from the Global Seismographic Network



IRIS National Science Foundation USGS UCSD