

Seismic modelling - how and why

B. Arntsen

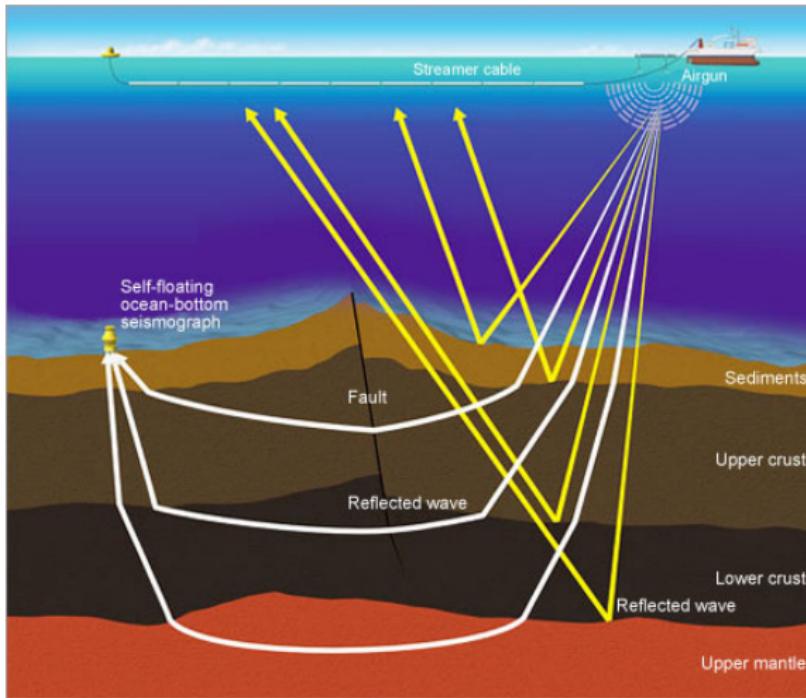
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UNIS, Svalbard April 2024

Content

1. What is seismic modeling?
2. What is it used for?

What is seismic modelling

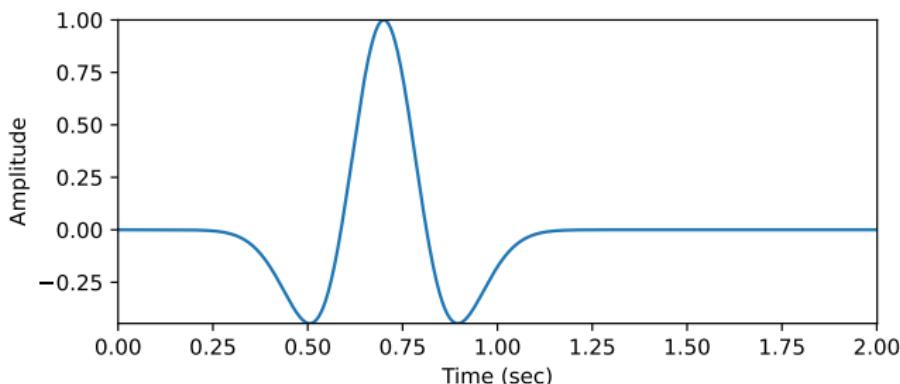
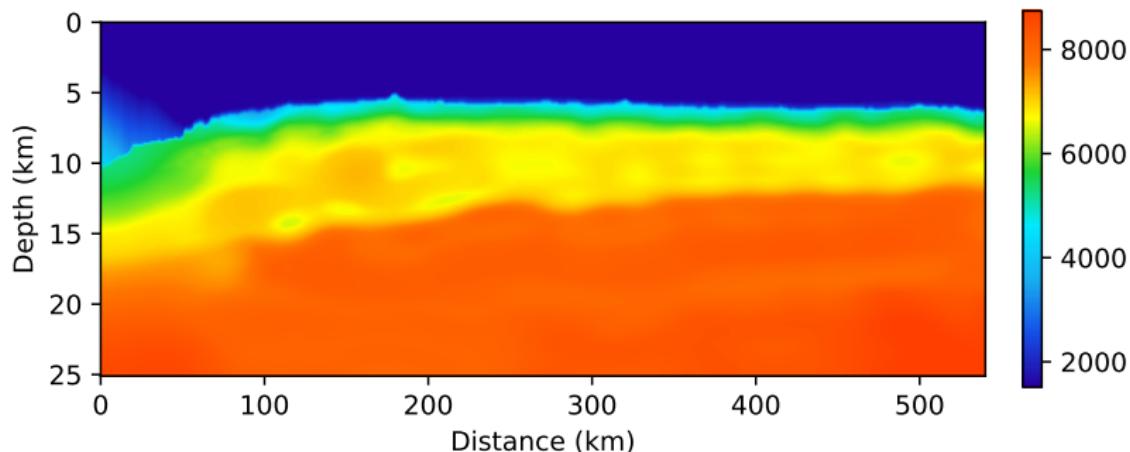


Credit: Japan Agency for Marine-Earth Science and Technology

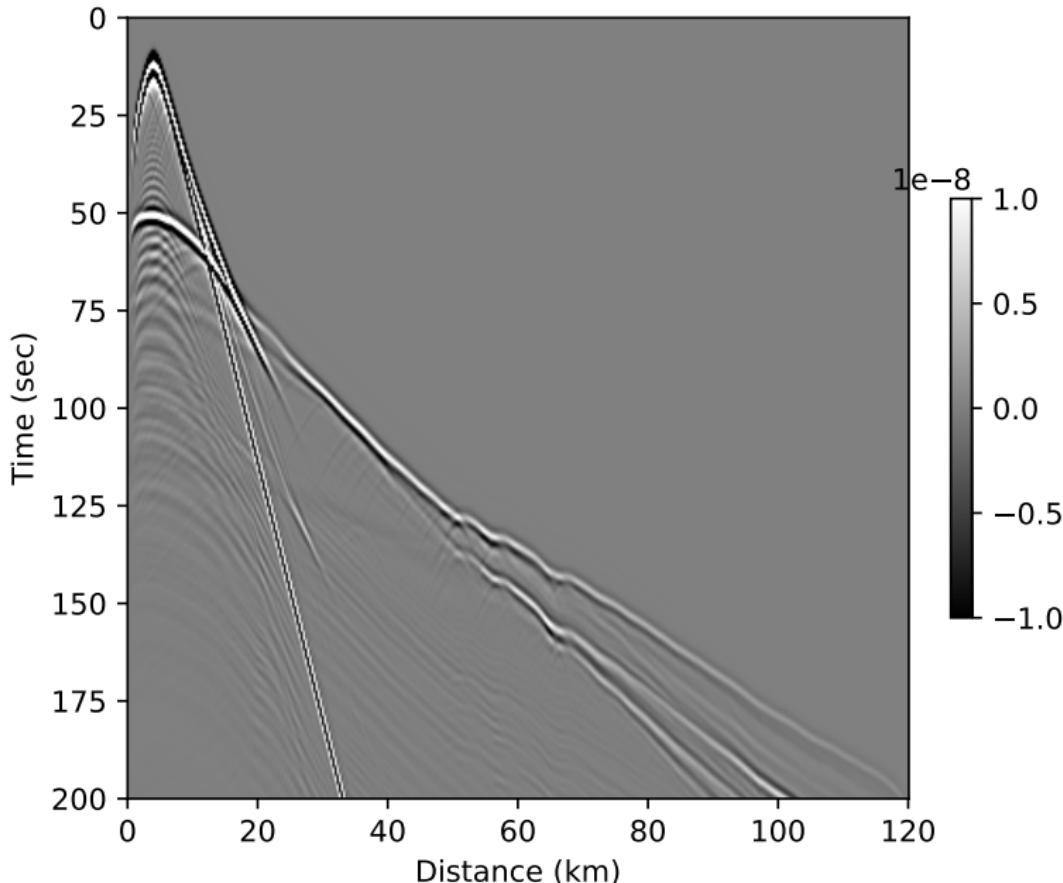
What is seismic modeling?

- ▶ Simulation of seismic data
- ▶ Numerical solution of equations describing elastic waves in rocks
 - ▶ Newtons law: $Force = mass \times acceleration$
 - ▶ Hooks law: $Stress = stiffness \times displacement$
- ▶ Input is a numerical model of stiffness, density and description of seismic source
- ▶ Output is simulated data

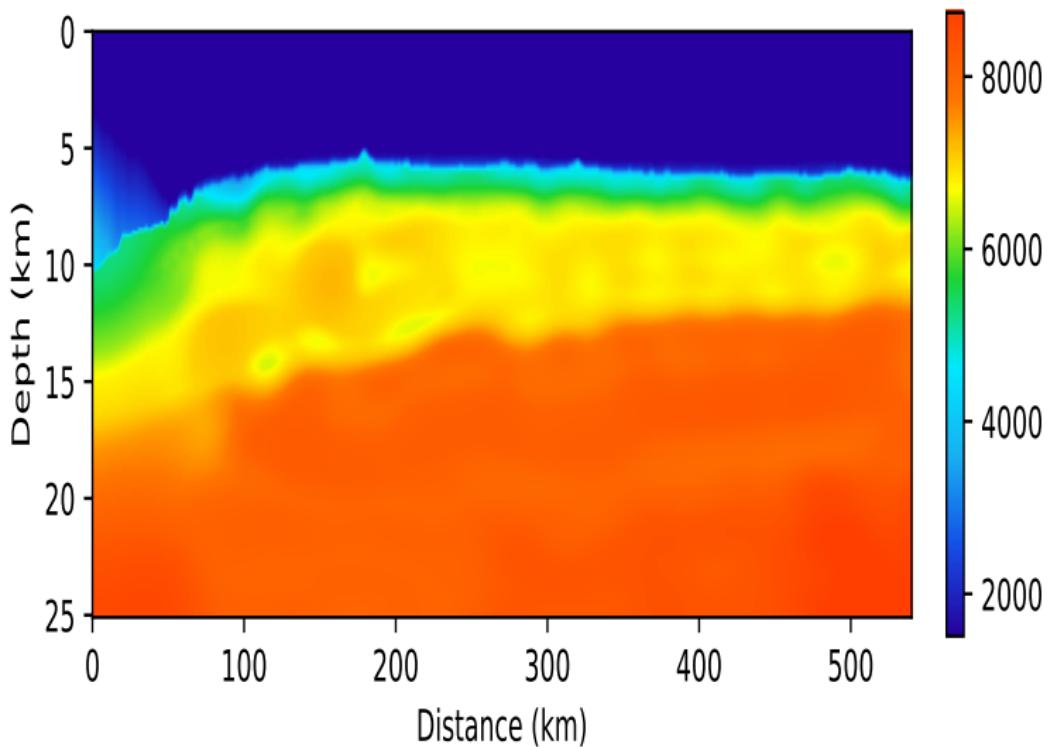
What is seismic modeling?



What is seismic modeling?



What is seismic modeling?



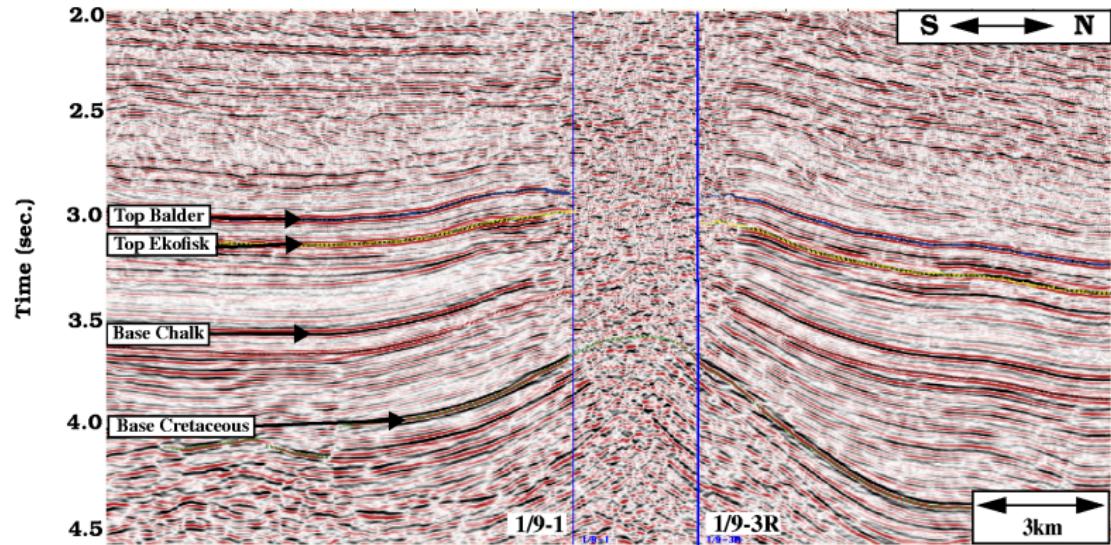
What is seismic modeling used for

Interpretation of seismic data in terms of

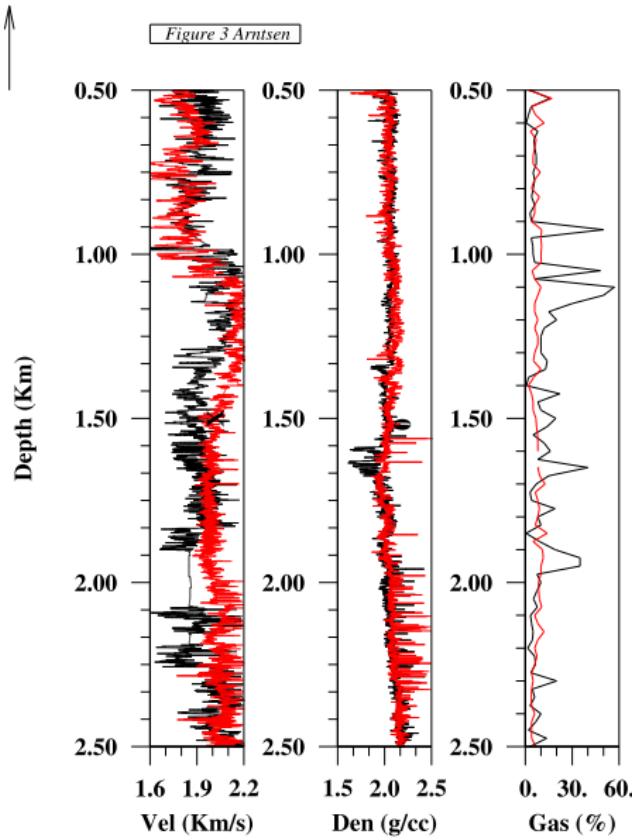
- ▶ Geological structures'
- ▶ Geological processes
- ▶ Geometry of geological bodies
- ▶ Rock types
- ▶ Fluids

In the following we show three examples of the use of seismic modelling.

Gas chimneys



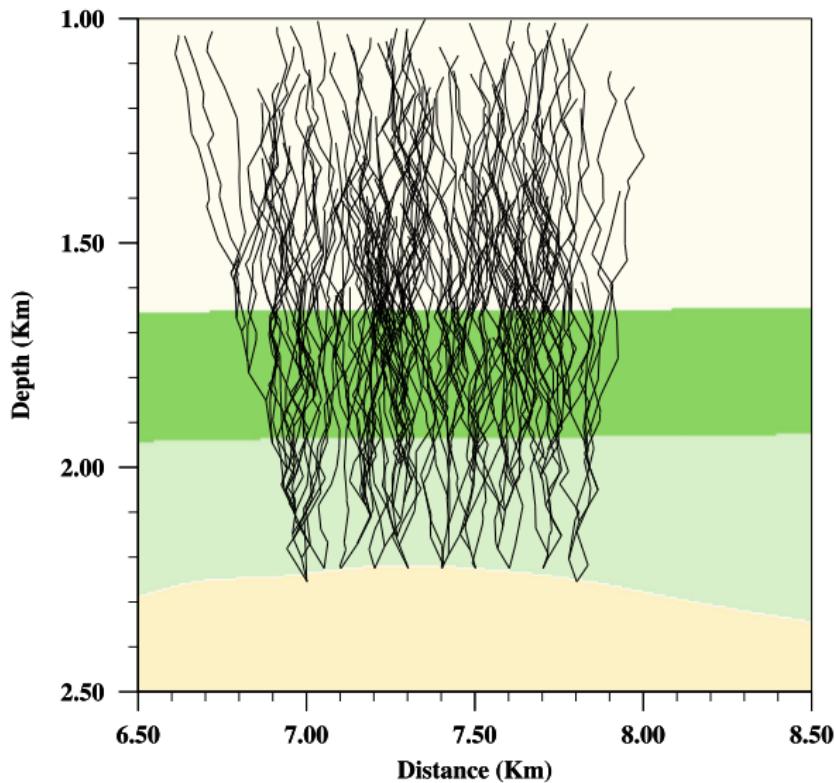
Well logs show free gas



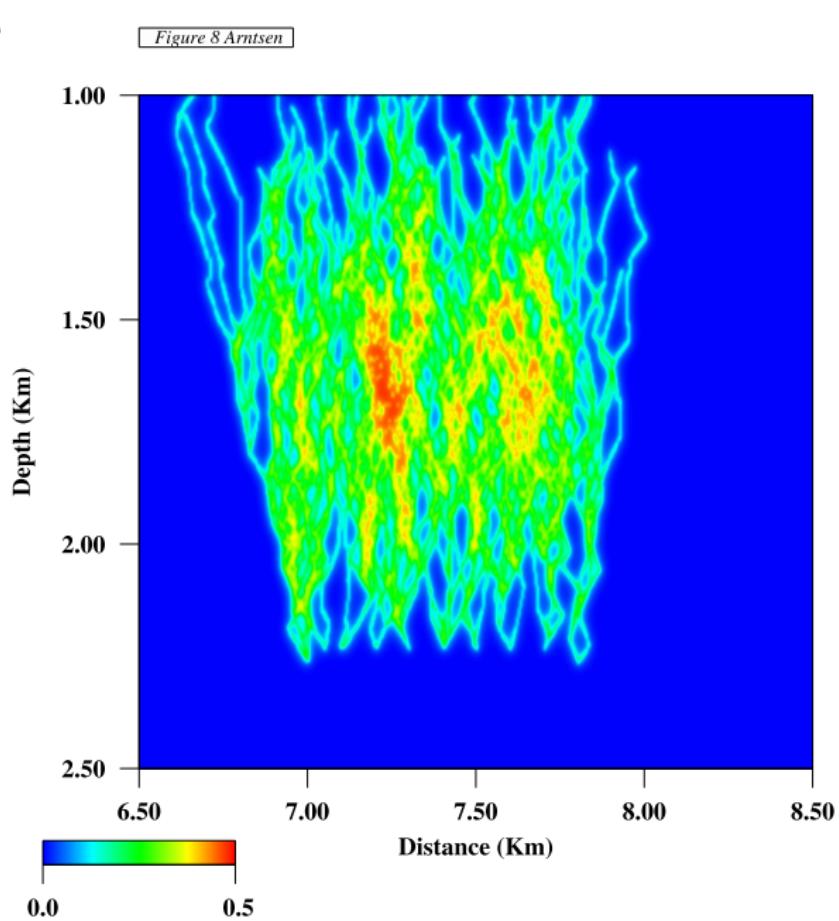
Fracture network



Figure 4 Arntsen



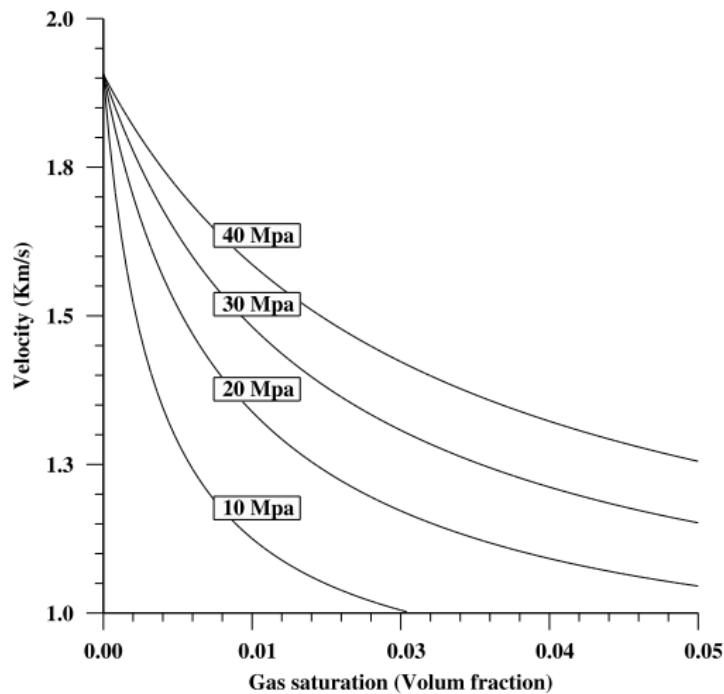
Gas saturation



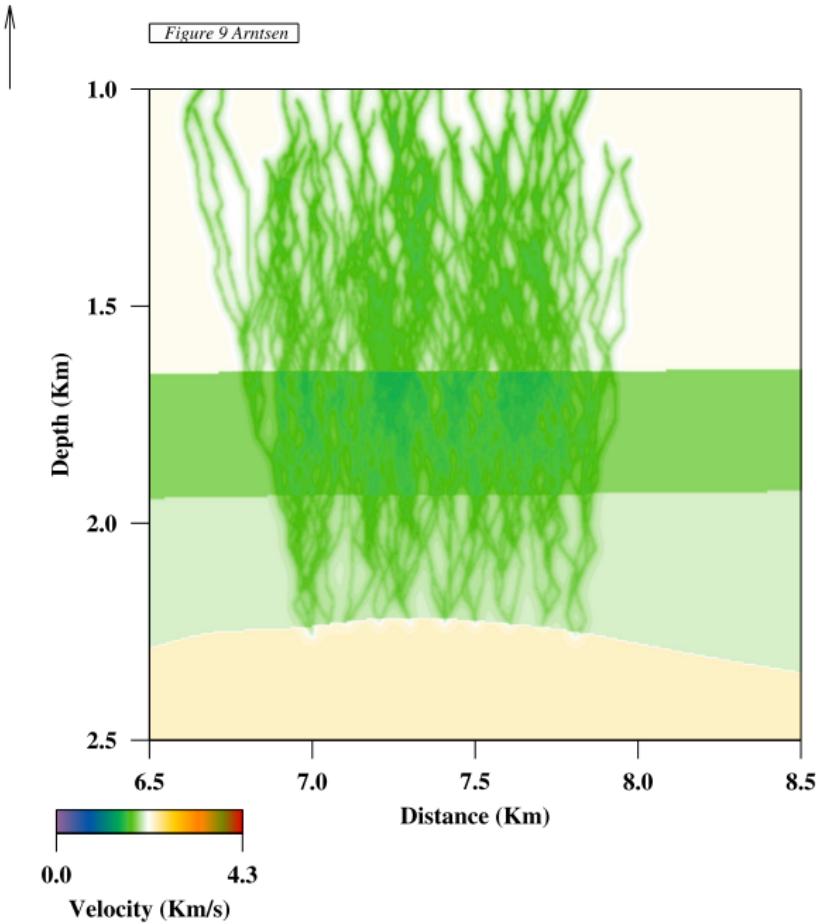
Seismic Velocity and gas saturation



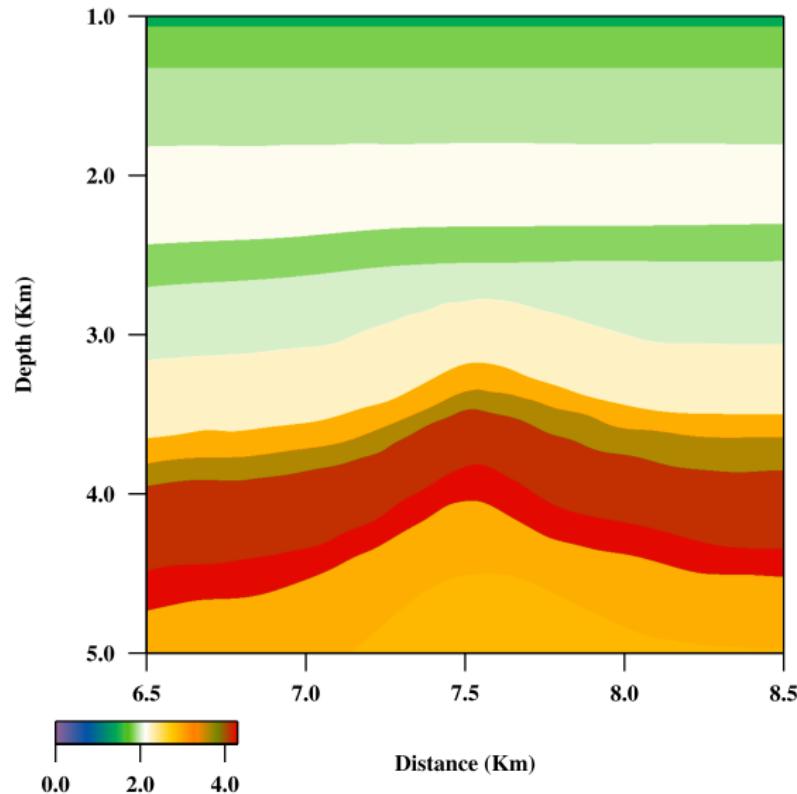
Figure 5 Arntsen



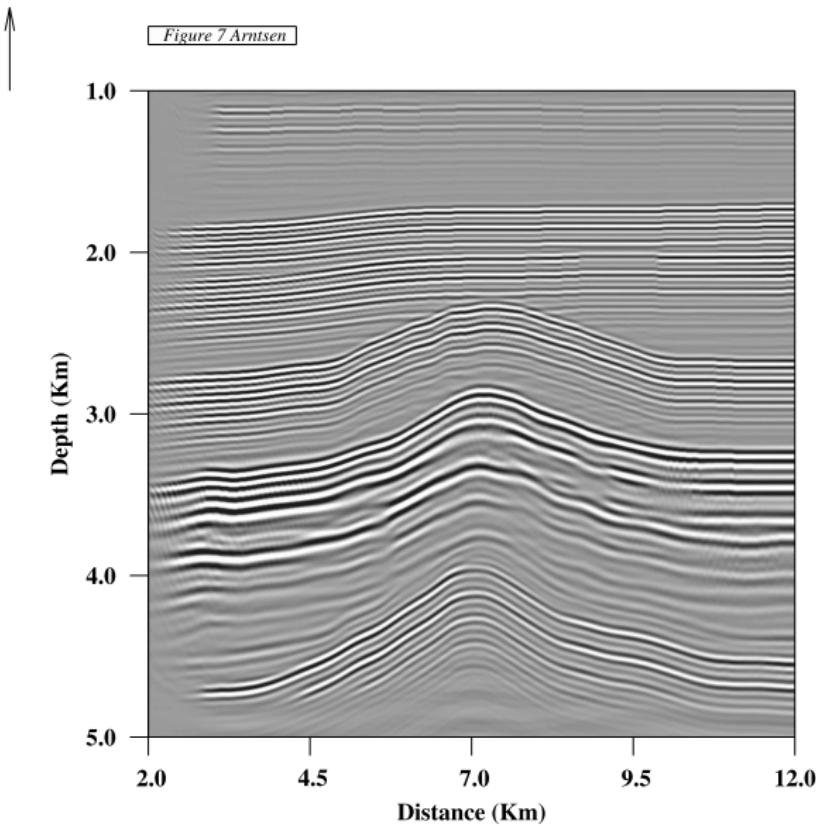
Seismic Velocity model for chimney



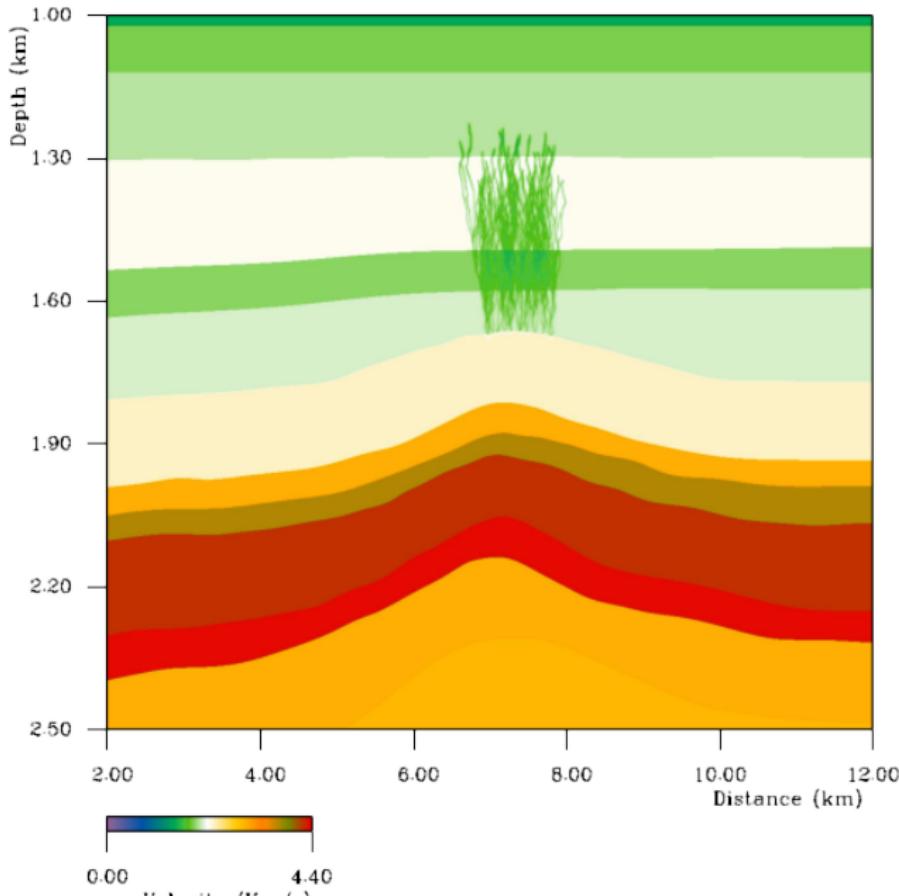
Seismic Velocity model (no chimney)



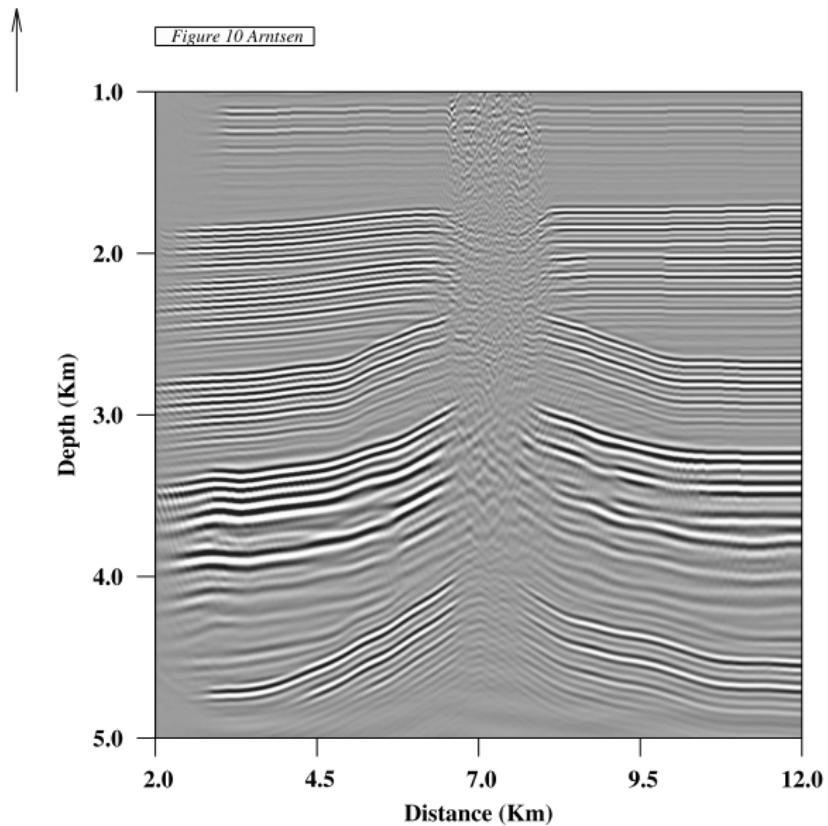
Seismic section (no chimney)



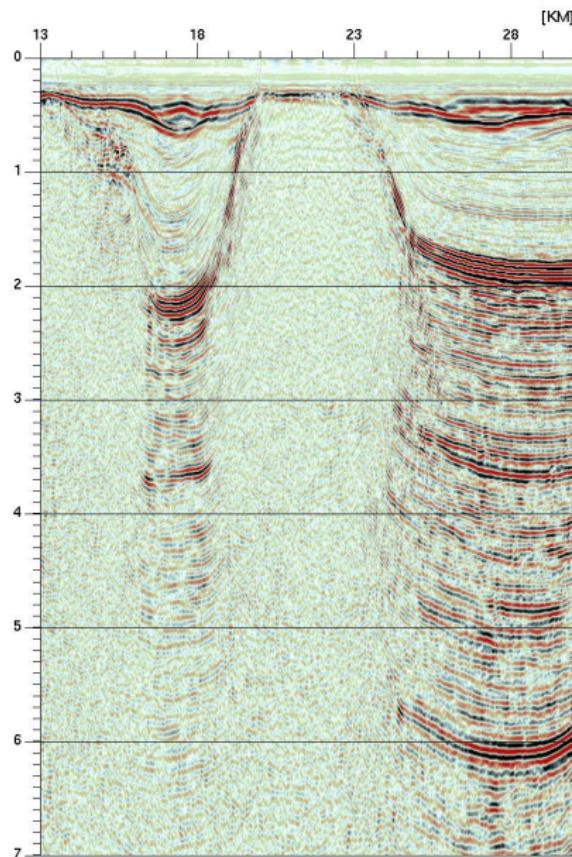
Seismic Velocity model for chimney



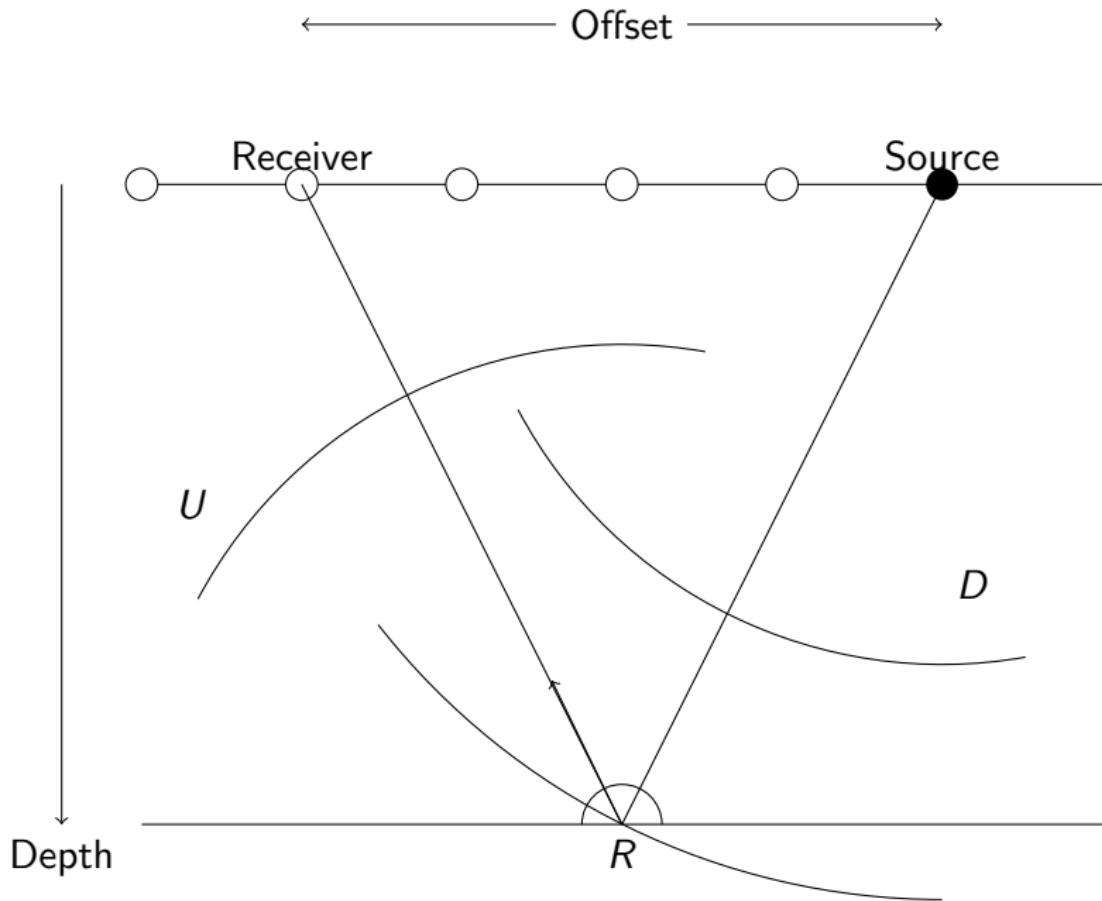
Seismic section for gas chimney



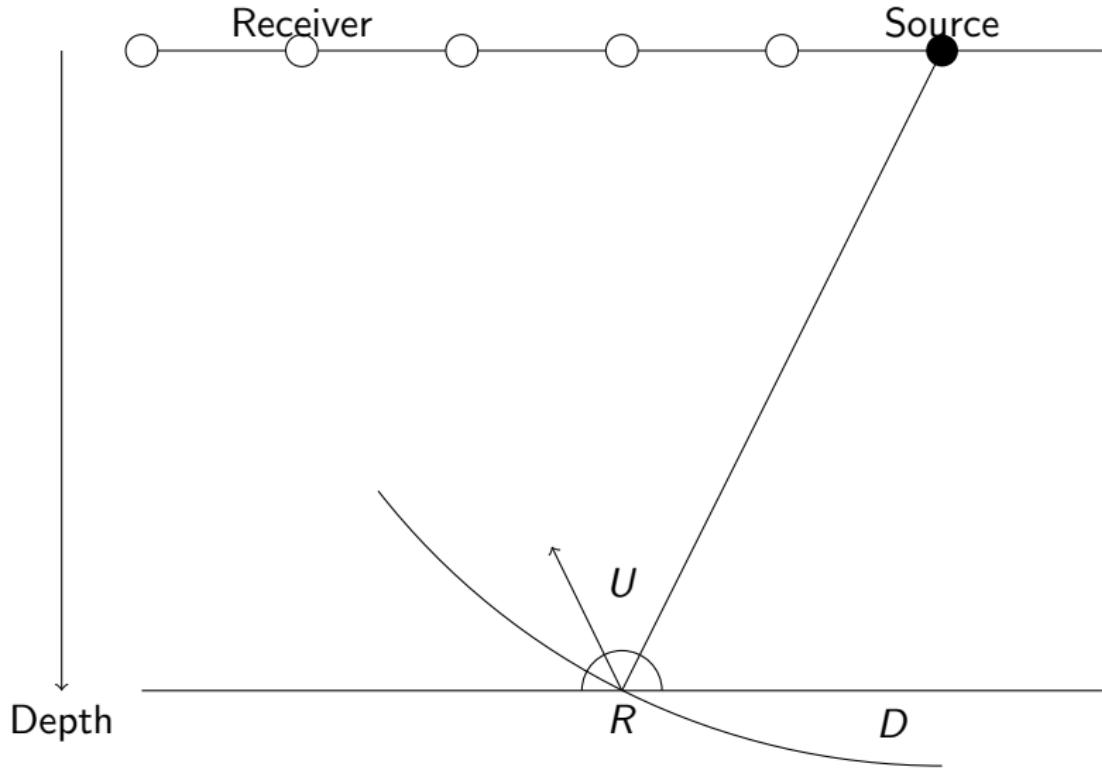
Seismic Imaging



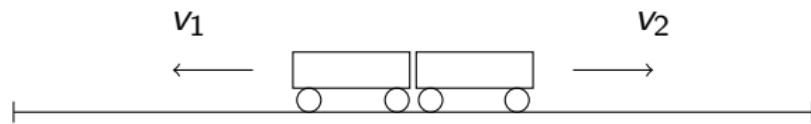
Seismic Imaging



Migration principles



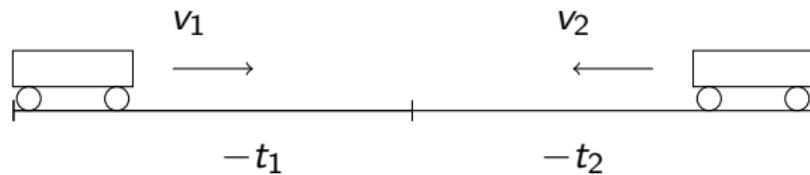
Time reversal 1



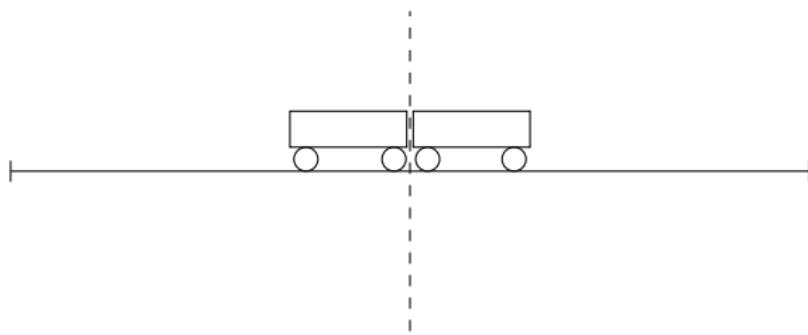
Time reversal 2



Time reversal 3



Time reversal



Seismic imaging

Forward modeling

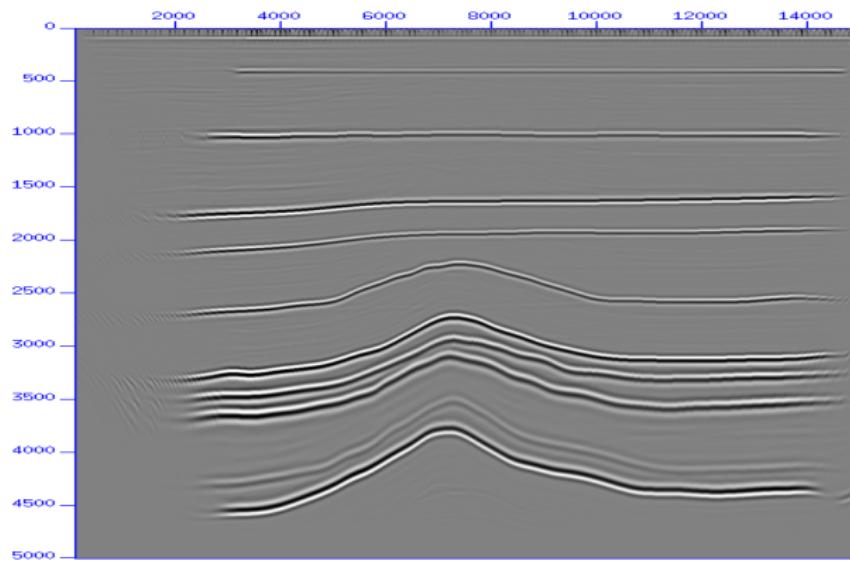
Time reverse modeling

Backward modeling

Cross correlation

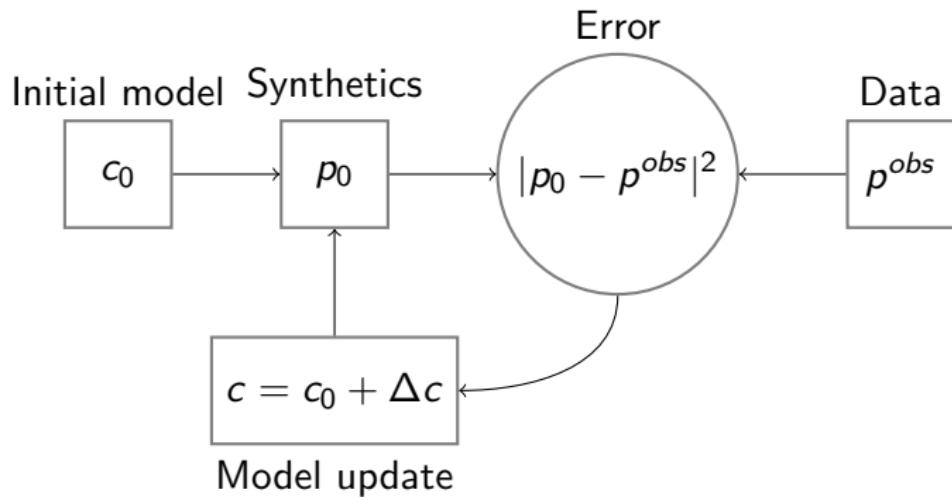
Imaging

Complete image

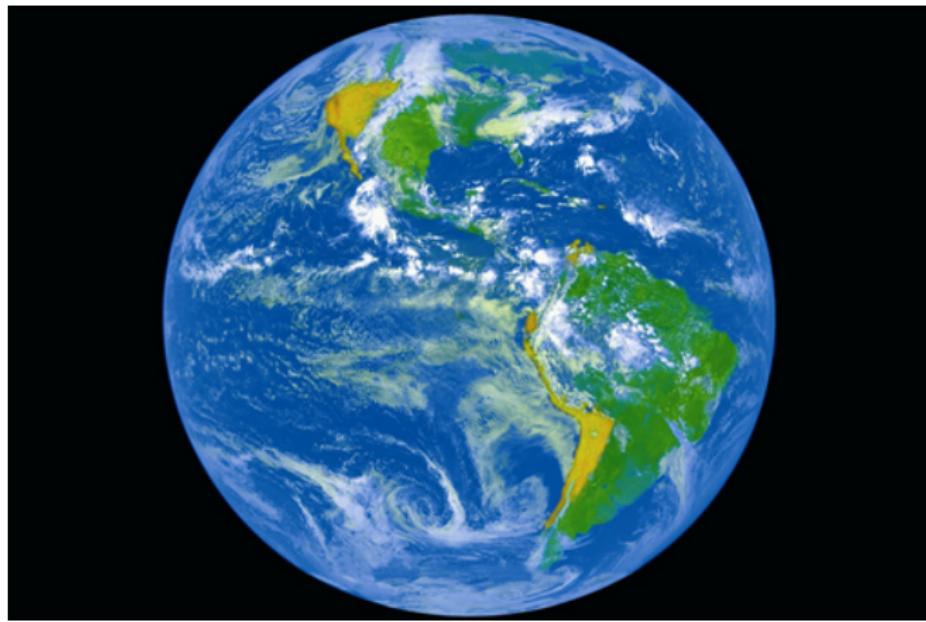


Introduction

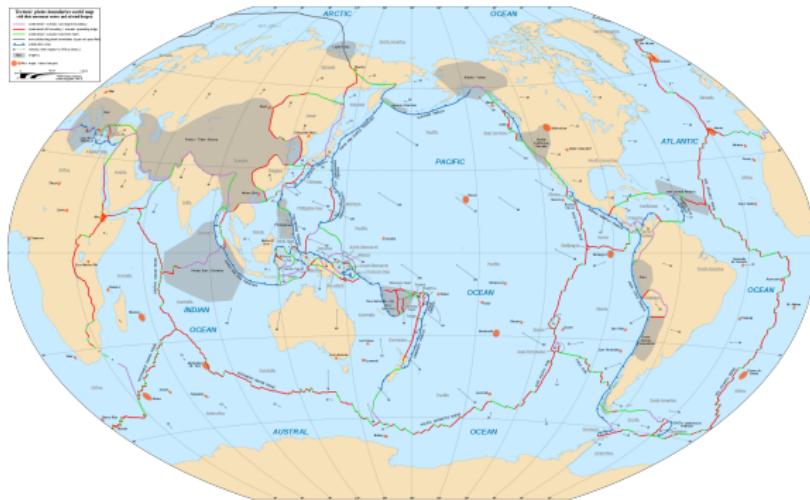
Full Waveform Inversion loop



Full Waveform Inversion

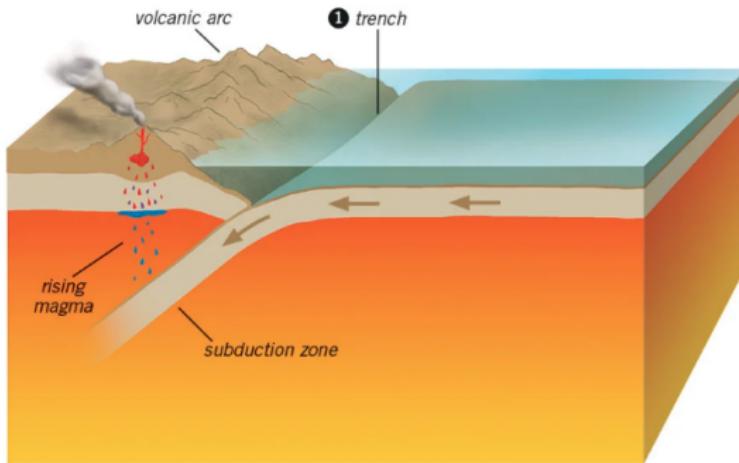


Full Waveform Inversion



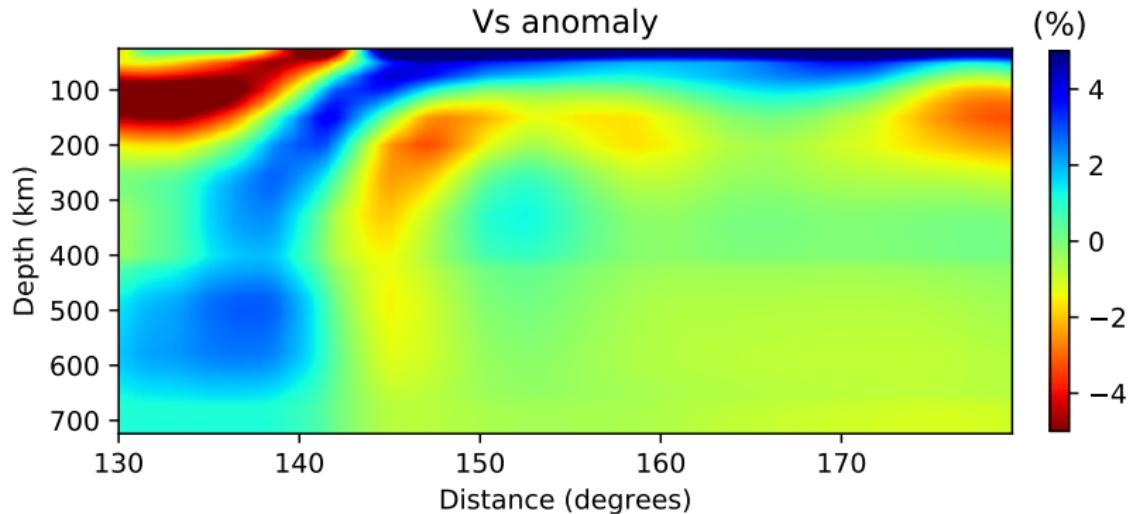
Credit: *Wikipedia*

Full Waveform Inversion



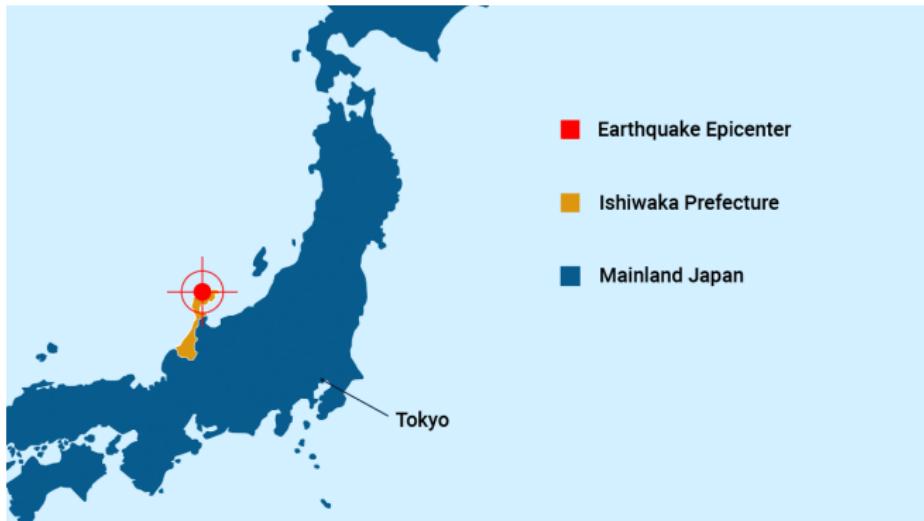
Credit: <https://answersingenesis.org/geology/plate-tectonics/plate-tectonics-reality-behind-theory/>

Full Waveform Inversion



Credit: Schaeffer, A.J. and S. Lebedev: "Global shear speed structure of the upper mantle and transition zone",
Geophysical Journal International, 194, pg 417-449, 2013. doi:10.1093/gji/ggt095.

Full Waveform Inversion

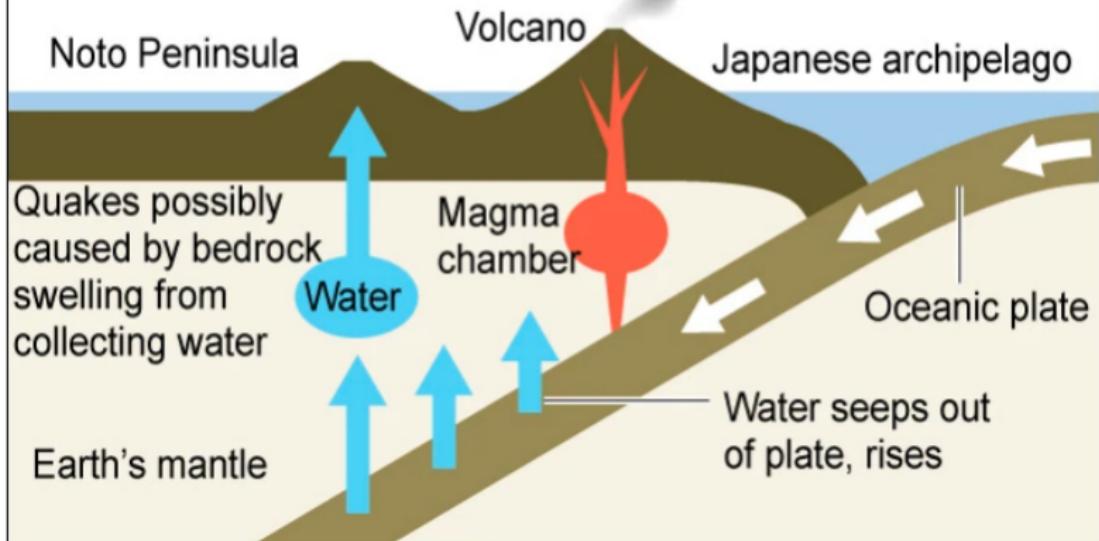


Credit: Wikipedia

Full Waveform Inversion

Crustal deformation beneath Noto Peninsula

(As hypothesized by Takuya Nishimura)

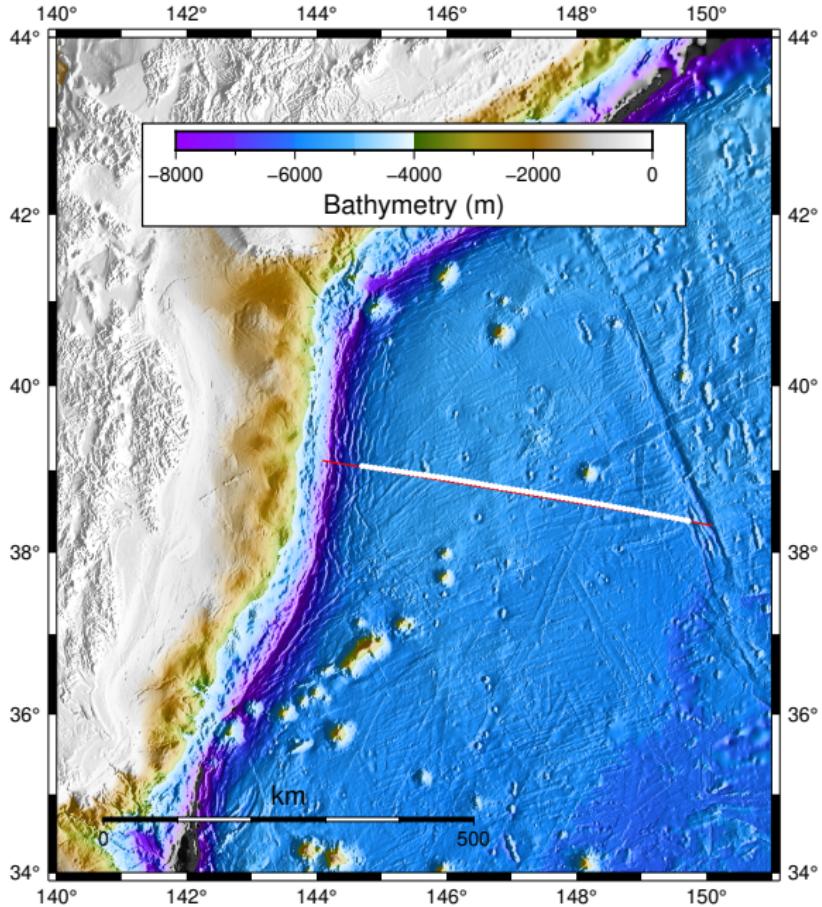


Full Waveform Inversion

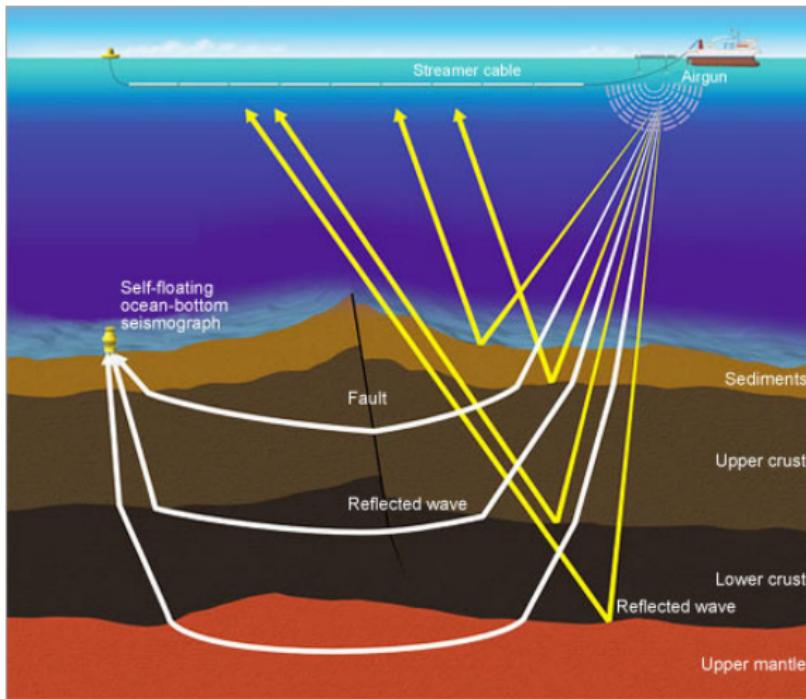


Credit:<https://www.z2data.com/insights/japans-2024-noto-peninsula-earthquake-impact-report>

Full Waveform Inversion



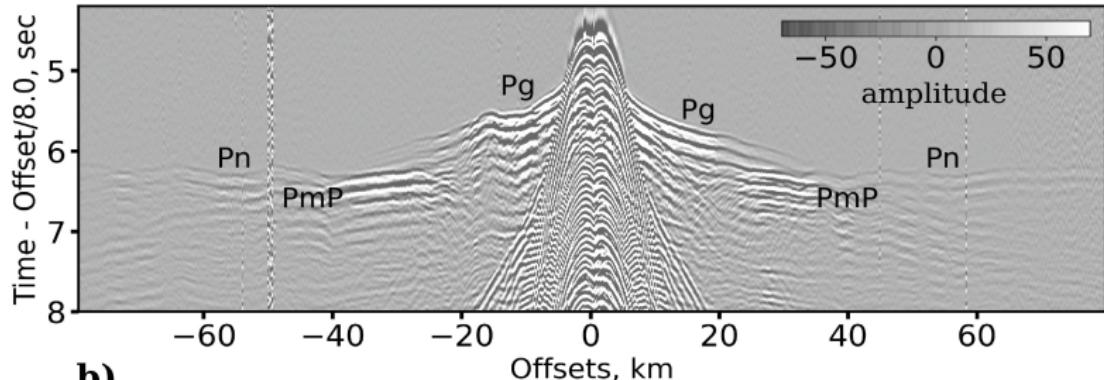
Full Waveform Inversion



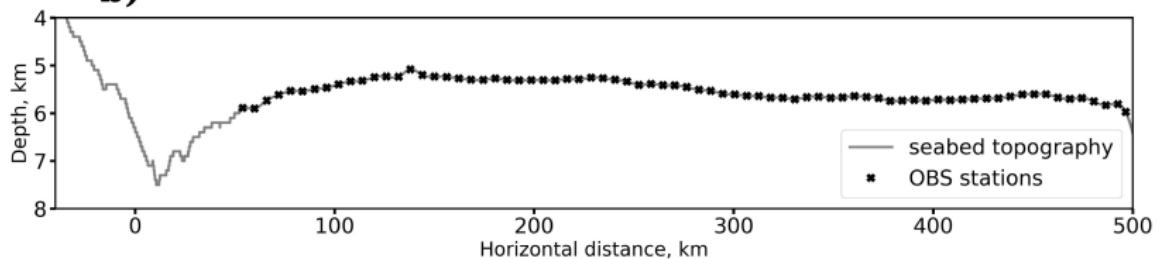
Credit: Japan Agency for Marine-Earth Science and Technology

Full Waveform Inversion

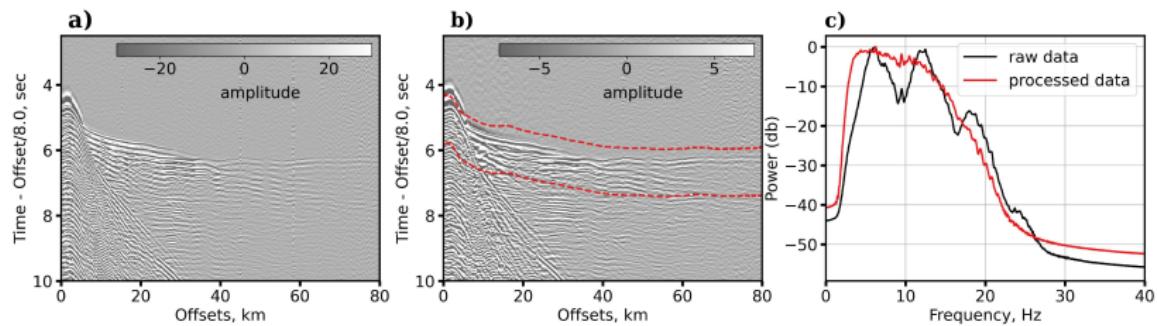
a)



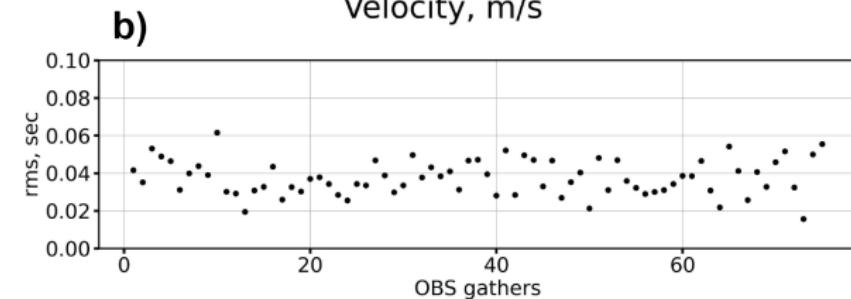
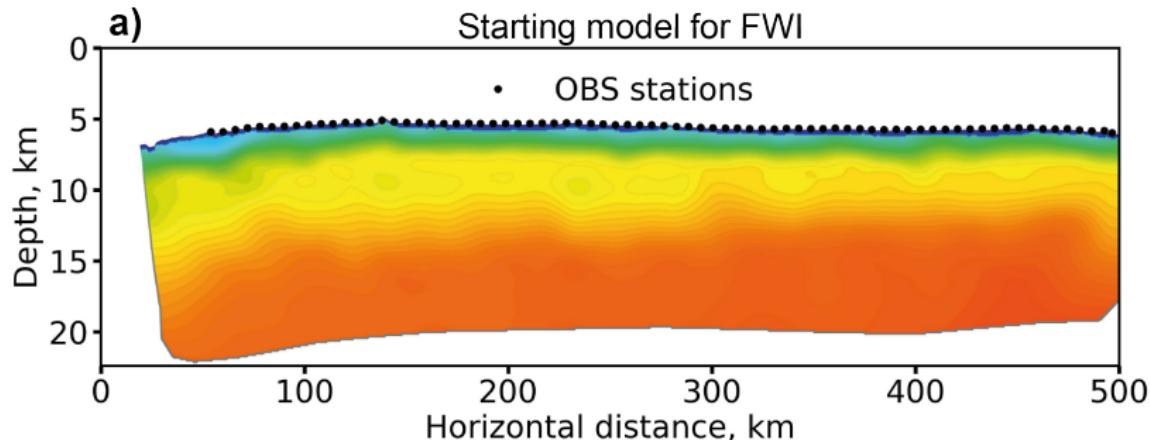
b)



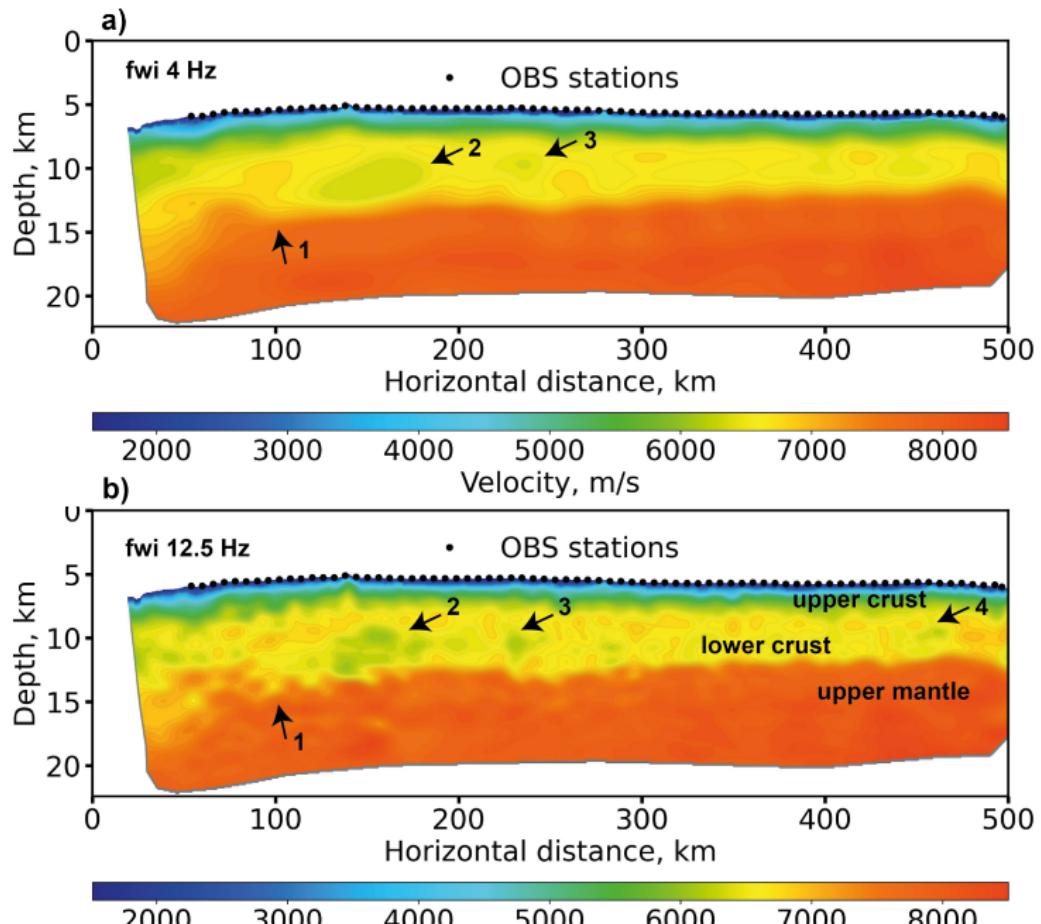
Full Waveform Inversion



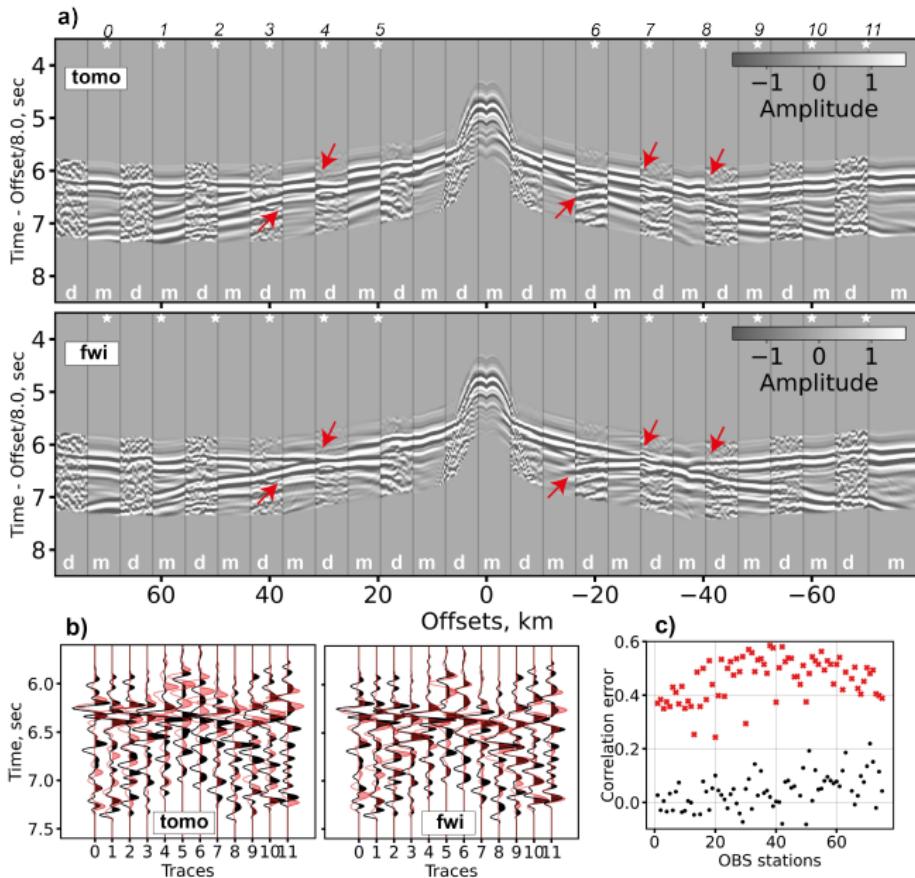
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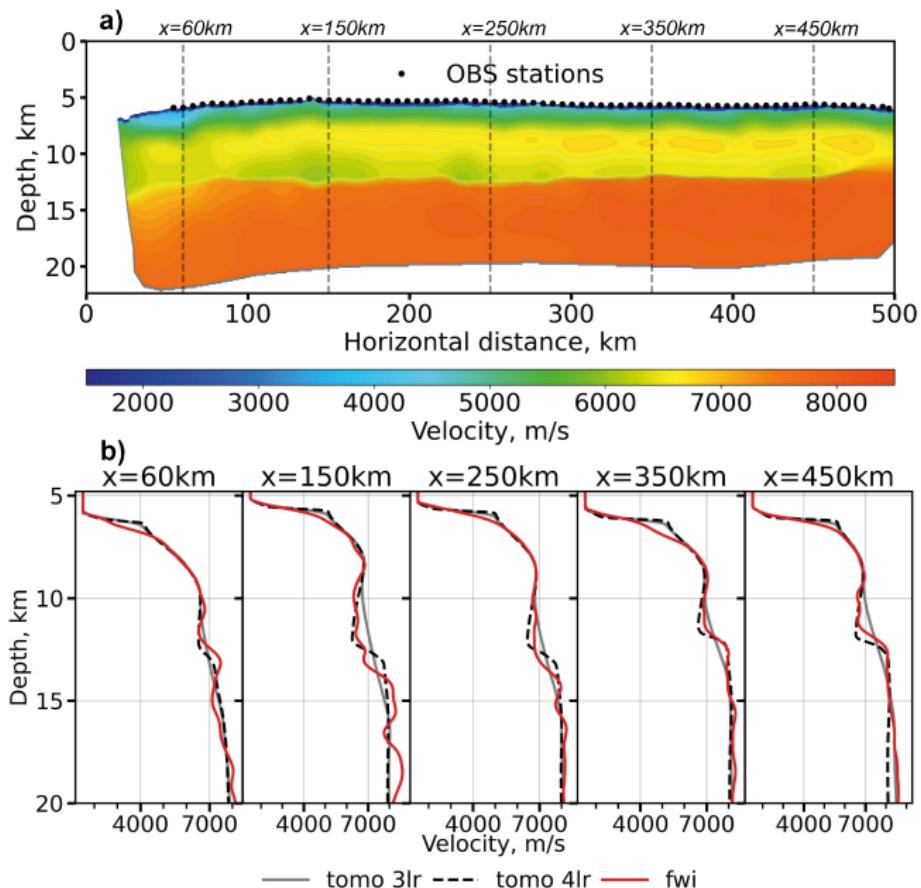
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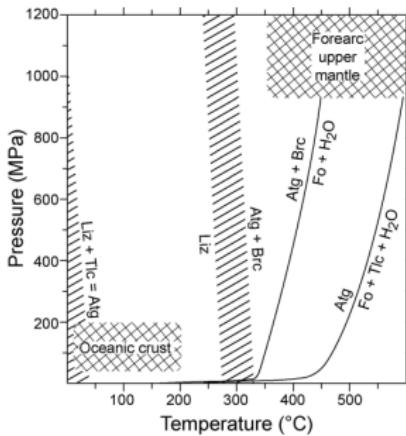
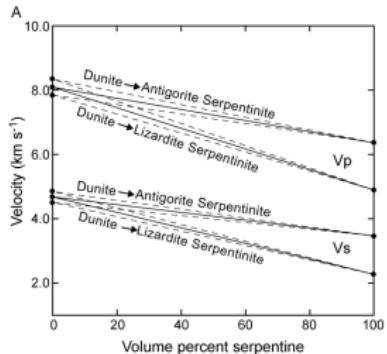
Full Waveform Inversion



Full Waveform Inversion



Full Waveform Inversion



Credit: Christensen, 2004, *International Geology Review*, p. 795-816