

Ray modelling

B. Arntsen

NTNU

Department of Geoscience

`borge.arntsen@ntnu.no`

UNIS, Svalbard April 2025

Content

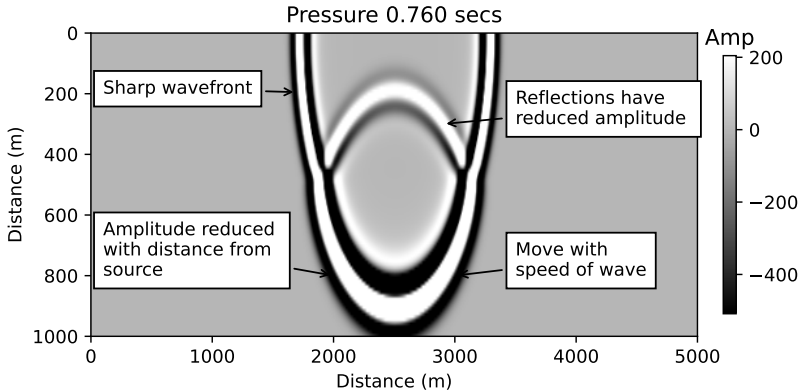
1. Waves, Rays and Wavefronts
2. Ray modeling in simple models
3. Ray modeling for complex structures
4. Seismic imaging using rays

Ray modeling

- ▶ The objective is to model (simulate) a seismic experiment
- ▶ Seismic wave propagation is complex
- ▶ Ray modeling is an attempt to simplify

Structure of wavefields

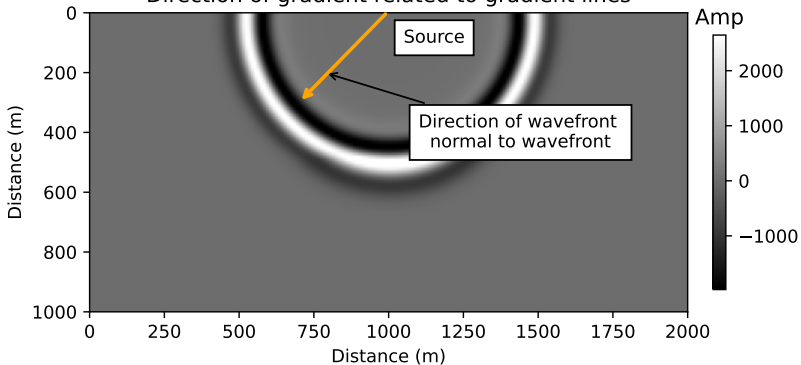
Snapshots reveals the structure of seismic waves



Rays

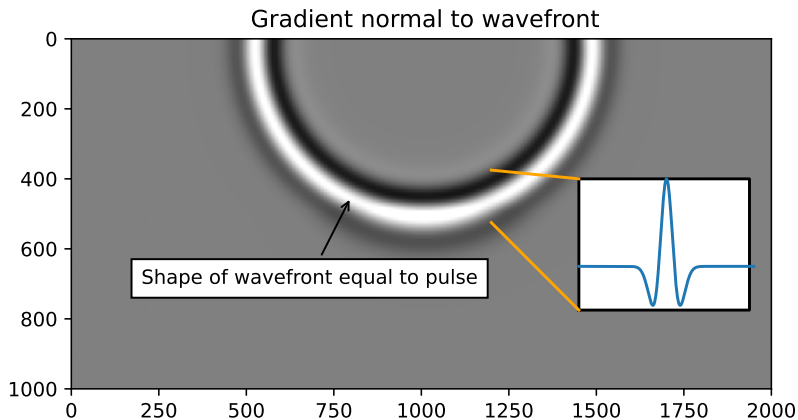
Direction of wave related to gradient

Direction of gradient related to gradient lines



Rays

Wavefront width related to source pulse



Ray modelling

Putting this together we can compute the wavefield generated by a seismic source by

- ▶ Draw a line from the source to the wavefront
- ▶ The shape of the wavefront is simply the source pulse
- ▶ The amplitude of the wavefront decays inversely proportional to distance (Energy conservation)
- ▶ All of this can be expressed with an equation

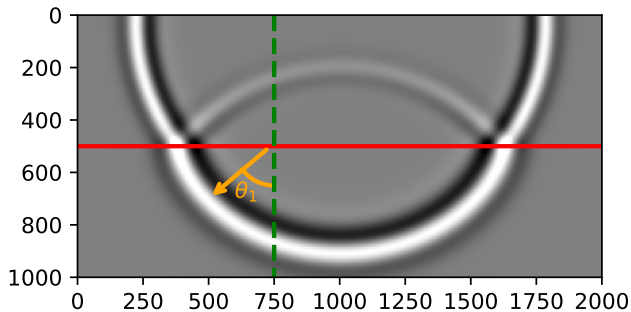
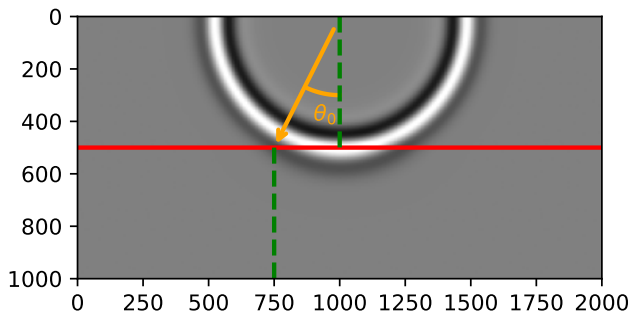
Ray modelling

$$p(r, t) = \frac{s(t - \tau)}{r},$$

where

- ▶ t : Time
- ▶ r : Distance
- ▶ v_p : P-wave velocity
- ▶ $p(r, t)$: Pressure
- ▶ $s(t)$: Source pulse
- ▶ $\tau = r/v_p$: Travelttime

Transmission through interface



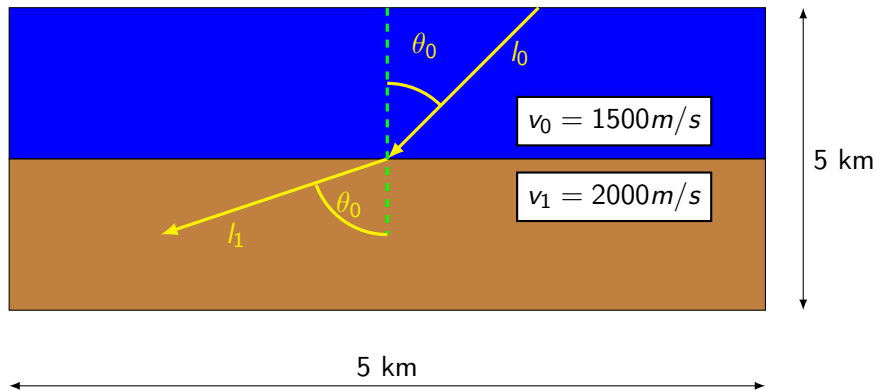
The transmitted ray follows Snell's law

$$\frac{\sin(\theta_0)}{v_0} = \frac{\sin(\theta_1)}{v_1}$$

where

- ▶ v_0 : P-wave velocity above interface
- ▶ v_1 : P-wave velocity below interface

Rays

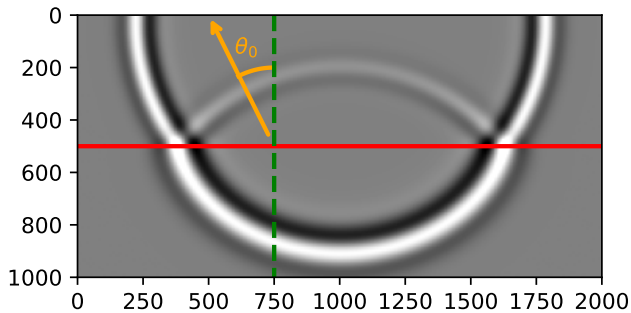
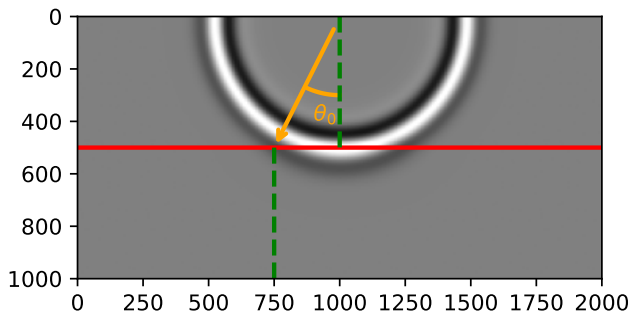


Traveltime

The time to reach the wavefront is called the traveltime and can be calculated as:

$$\tau = \frac{l_0}{v_0} + \frac{l_1}{v_1}$$

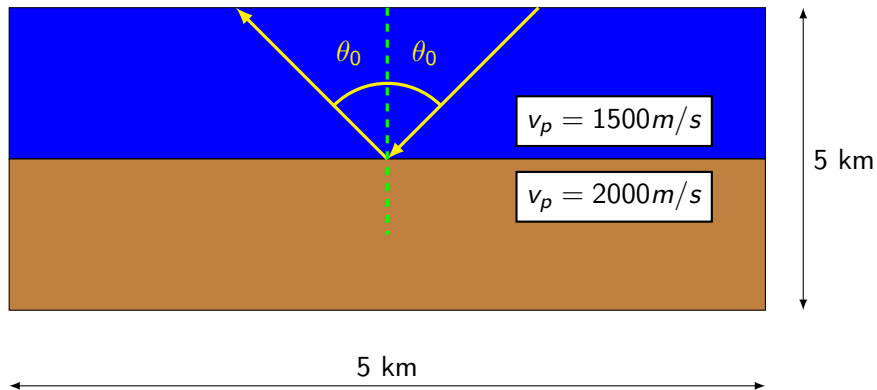
Reflection



Reflected ray

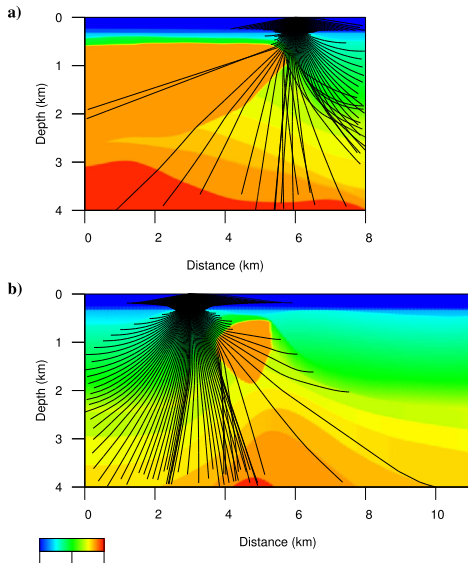
The reflected ray follows Snell's law implying that the angle with the vertical is the same for the reflected as for the incoming ray.

Rays



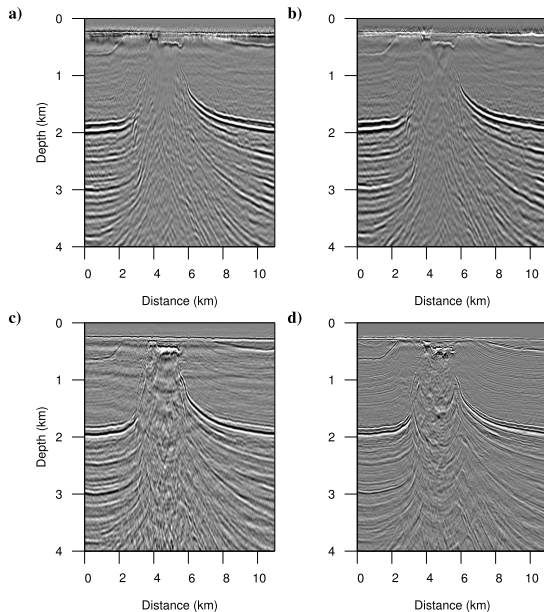
Rays

Ray modeling is very useful to calculate traveltimes and visualize seismic waves in a simple way



Seismic imaging with rays

Ray modeling is also used for seismic imaging



Seismic imaging with rays

Ray modeling is also used for seismic imaging

