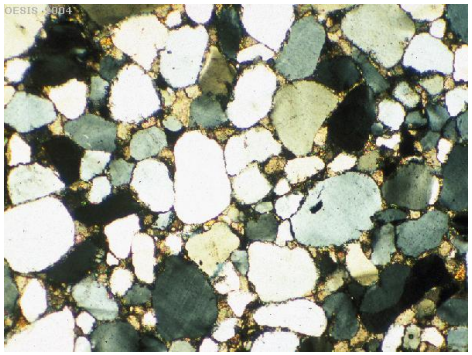
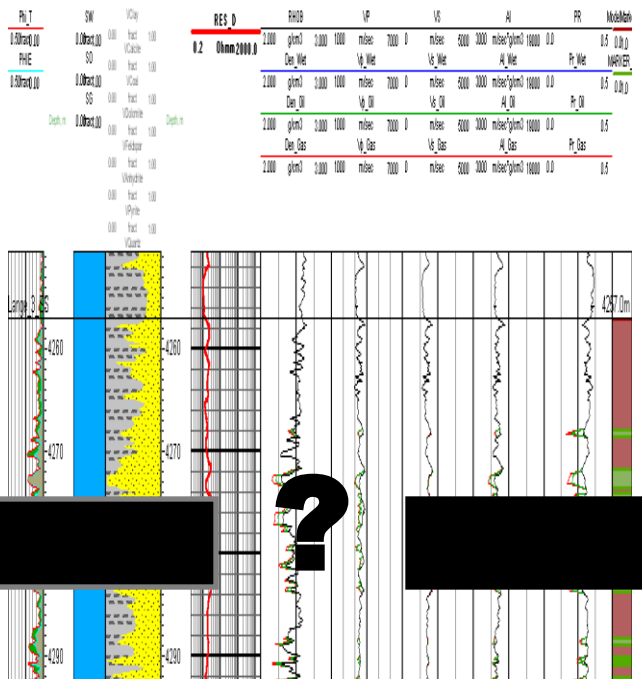
AVA, EEI and AVA Inversion

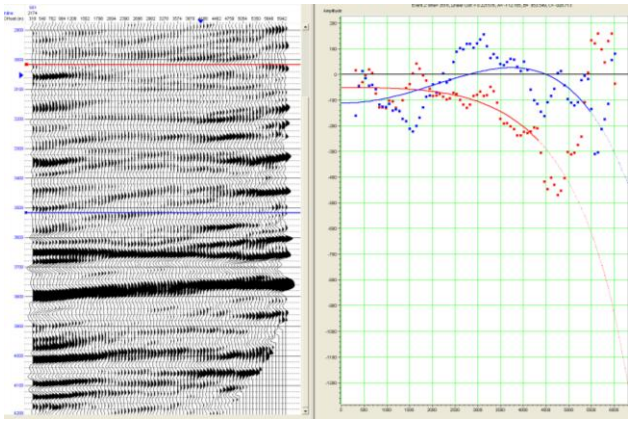
Peter Harris
Deep Vision Ltd and Sharp Reflections

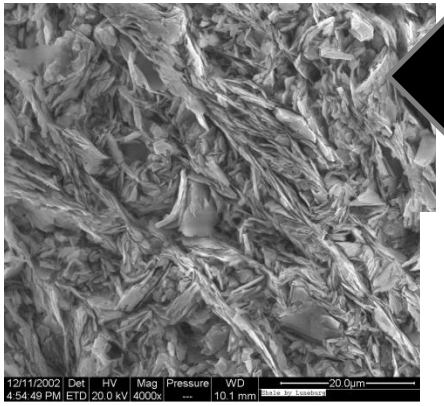
The One Slide Summary



http://www.earth.ox.ac.uk/~oesis/micro/index.html







http://www.westga.edu/~geosci/webdata/wgmc/Images/Gallery%20Pictures/Minerals%20and%20Rocks/Shale2.jpg

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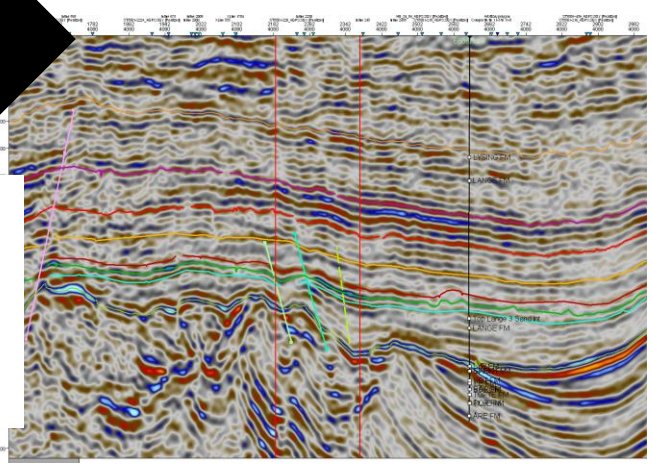


What can we say about the relationship between these pictures?

Acknowledgement

The data examples come from the Odin Field, PL573S. I am grateful to the licence partners,

- Det norske oljeselskap ASA
- Svenska Petroleum Exploration AS
- Dana Petroleum Norway AS
- Bayerngas Norge AS

for permission to show the data.

Outline

- Introduction
  - Why do inversion?
  - What is it?
  - Types of inversion
- Theory
  - AVO
  - EEI
  - AVA inversion
  - Assumptions
  - Anisotropy
- Rock physics
- Practicalities
  - Seismic data quality
  - Well log quality
  - Well-tie
  - Noise and resolution
- Examples and applications
  - QC
  - Examples
  - More applications

What is inversion?

Geophysics:
The process of transforming geophysical data into a quantitative description of rock properties.

Mathematics:
The process of solving a set of equations $G(m) = d$ for the unknown m. G is the modelling operator, m is the rock properties, d is the known data.

Why do inversion?

To transform the geophysical data into something more geological

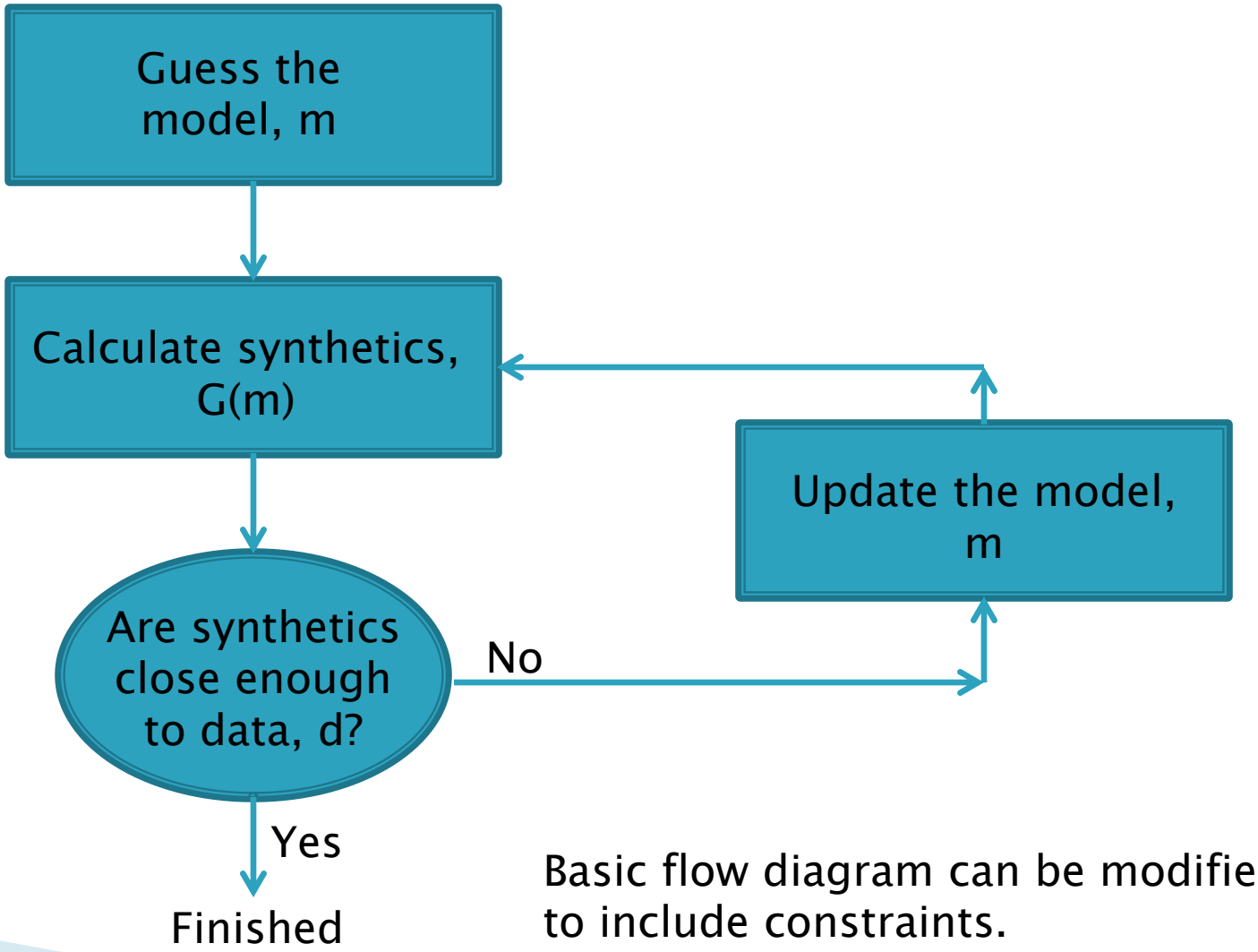
To answer geophysical questions:

- Where is the sand?
- How thick is the sand?
- Can we map the porosity?
- What is the gross rock volume?
- Are there hydrocarbons present? Where? How much?
- What is the net-to-gross?
- Is that bright spot an interference effect or a gas accumulation?
- Etc ...

There are no absolute answers to these questions, but inversion may help to reduce the risk in evaluating them.

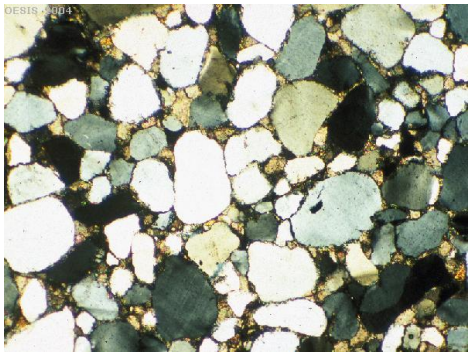
Any inversion is an *interpretation*.

Generic deterministic inversion flow



Basic flow diagram can be modified to include constraints.

1.1 Physical properties and responses



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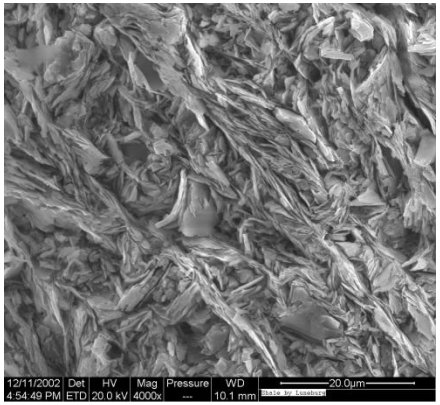

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Description of rocks

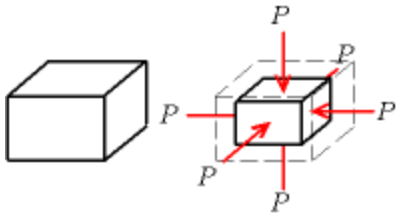
Grains:
Properties: mineralogy
Geometry: size, shape, sorting, angularity, orientation

Cement:
Properties: mineralogy
Geometry: volume, distribution

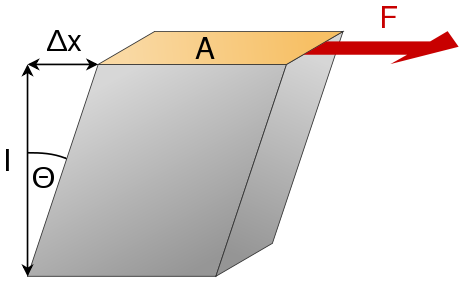
Pore space:
Properties: fluid types
Geometry: volume, connectivity, orientation

Fluids:
Properties:
Geometry: distribution in pore space

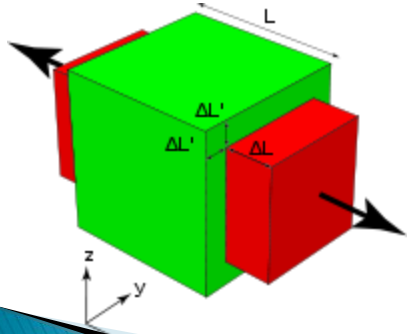
1.1 Elastic responses



Bulk modulus, K: how much pressure it takes to change the volume by a given percentage.



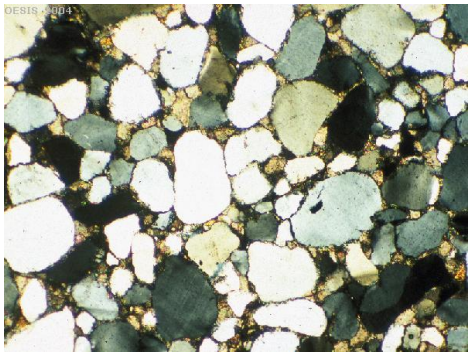
Shear modulus, μ: $(F/A) / \tan \Theta$



Poisson's ratio, ν: ratio of transverse contraction to axial extension

Elastic properties and density control seismic wave behaviour

1.1 Physical properties and responses



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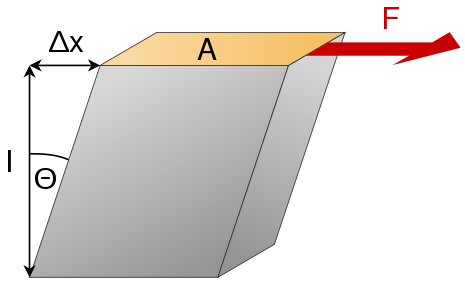
Rocks are obviously heterogeneous

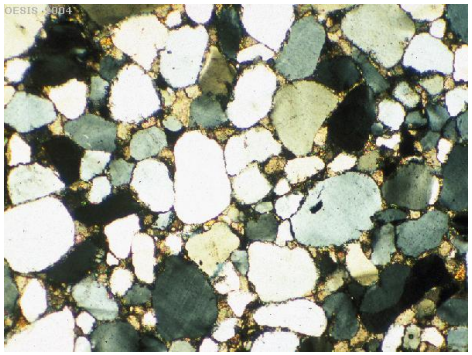
Elastic theory assumes homogeneous medium



Assume that, on average over a large enough volume, any given kind of rock has consistent properties.

Need ROCK PHYSICS MODELS and UPSCALING

1.1 Physical properties and responses



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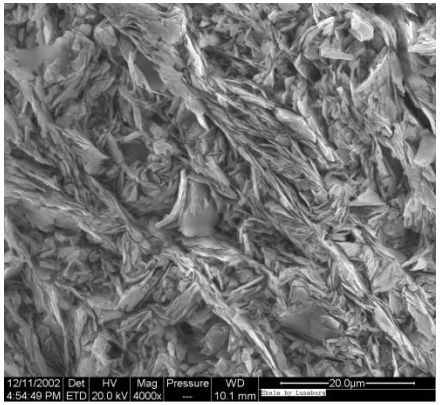
No obvious orientation

Does this have an effect on elastic properties?

Think of a pile of playing cards.



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Preferred directions of grain alignment

ANISOTROPY

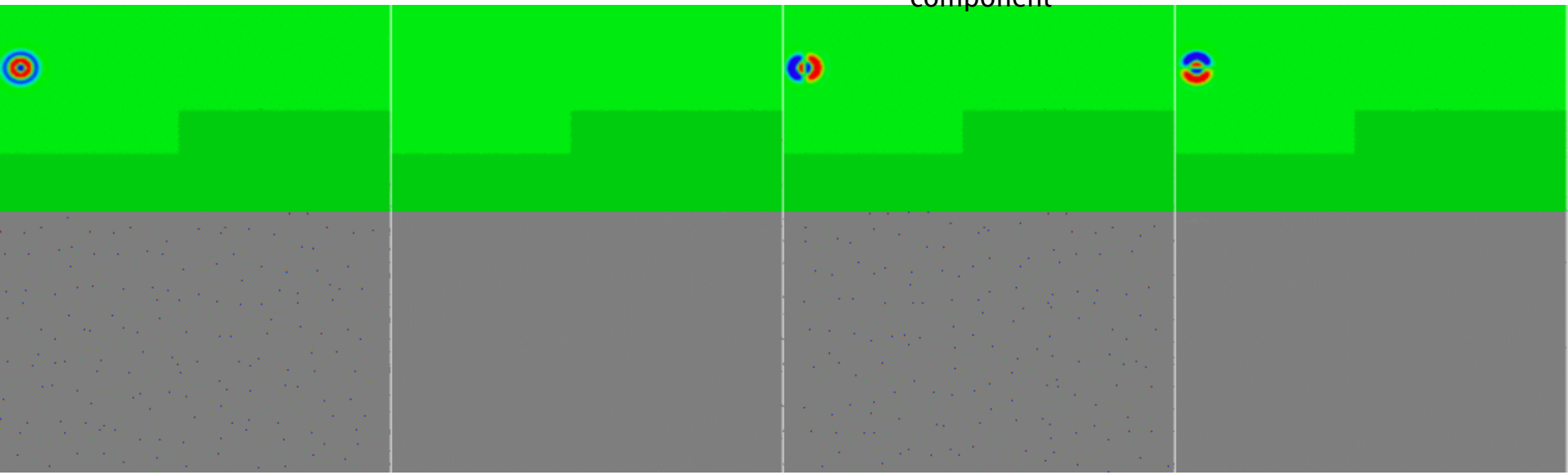
Wave propagation

Pressure

In-plane shear

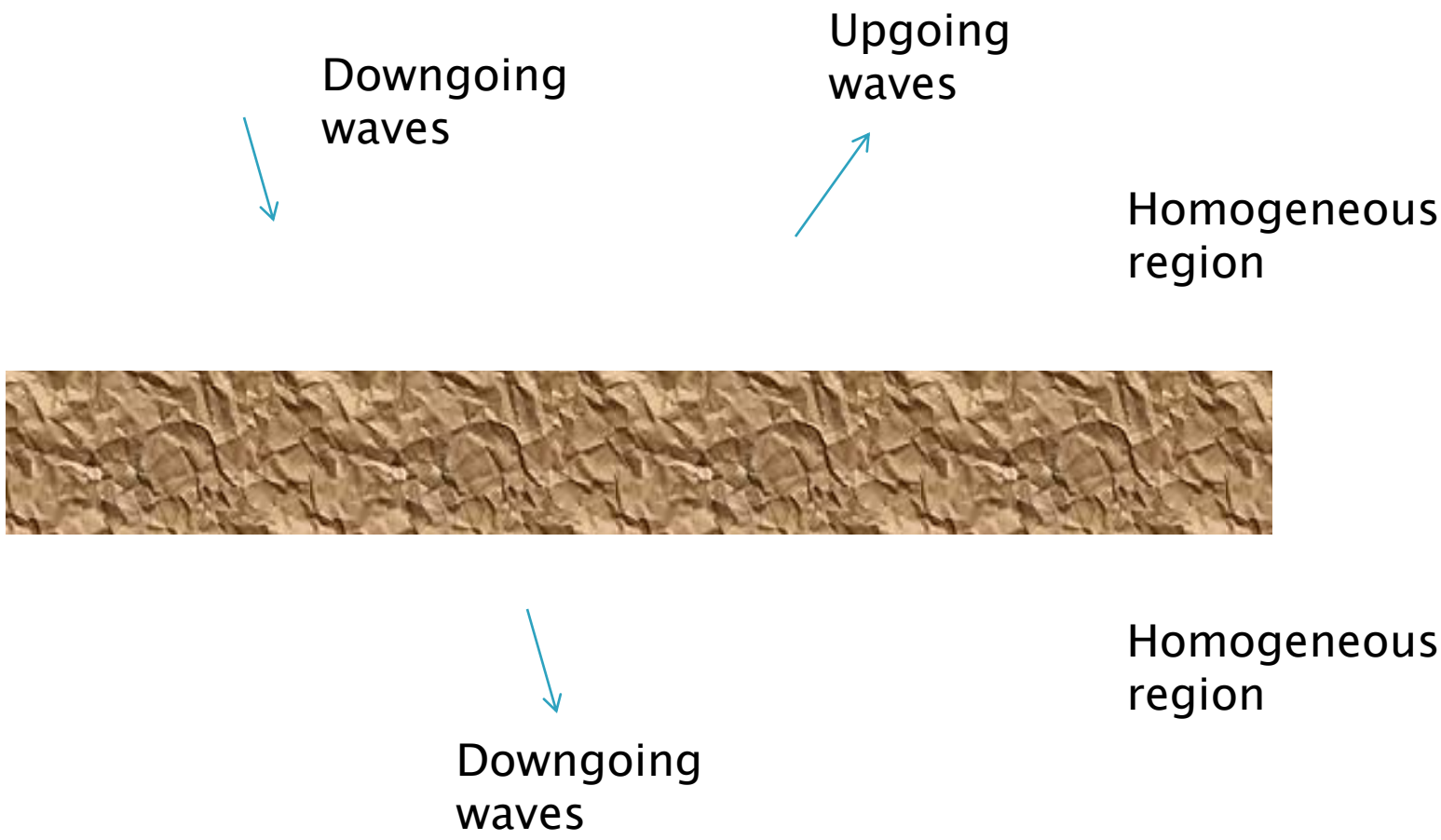
In-plane horizontal component

Vertical component



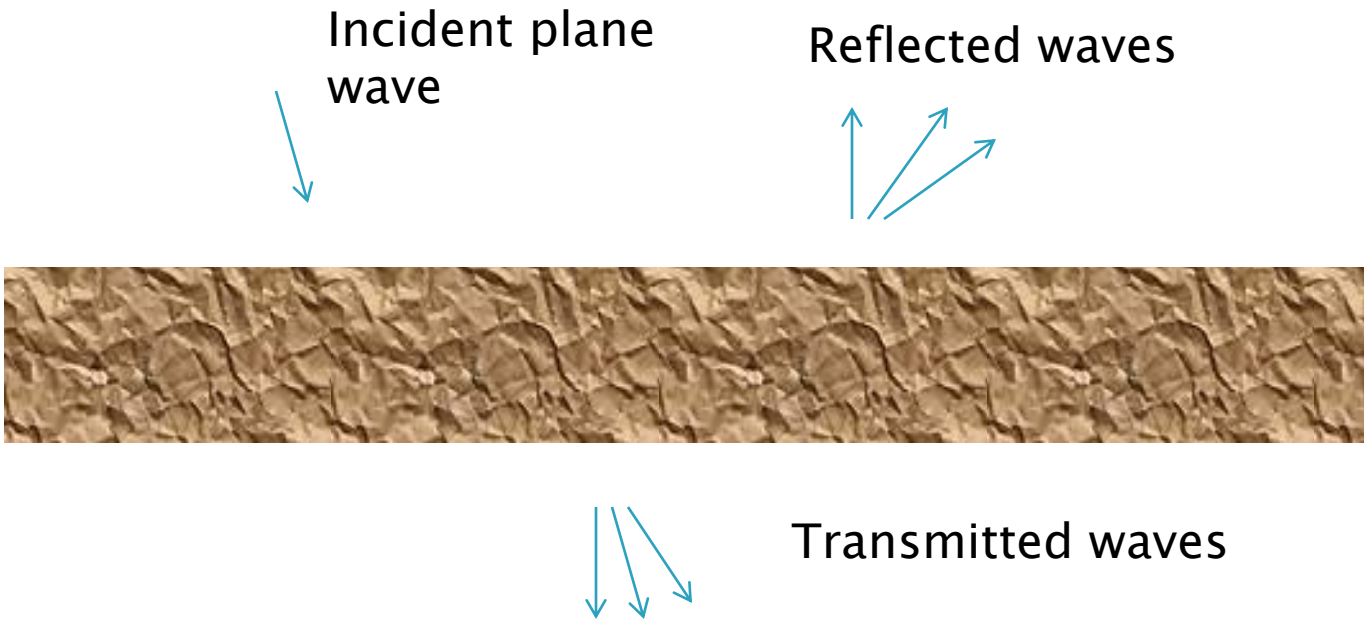
Courtesy Ekkehard Tessmer, University of Hamburg

Scattering



Concepts of “downgoing” and “upgoing” are unambiguous in the homogeneous regions

Scattering

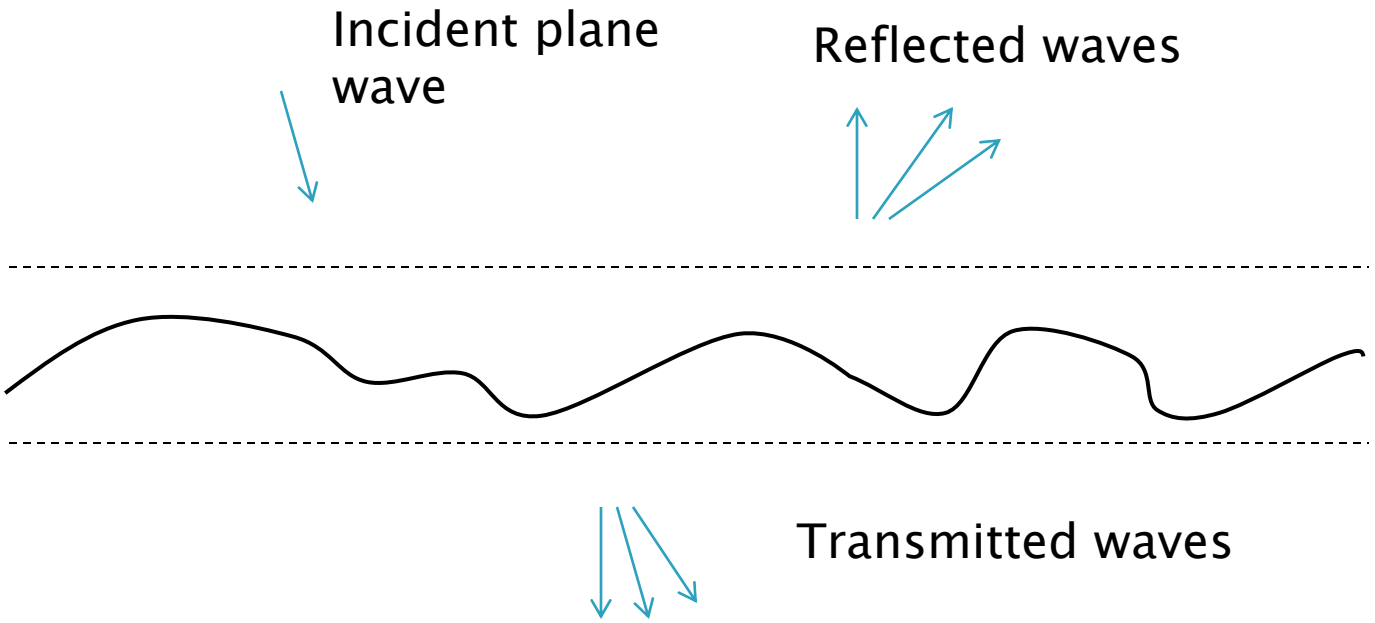


The theory says that the horizontal wavenumber spectrum of the reflected (or transmitted) waves is obtained from the horizontal wavenumber spectrum of combinations of elastic properties convolved with the spectrum of the incident wavefield.

Smoothly heterogeneous regions don't spread the reflected waves very far, but rough regions (broad wavenumber spectrum) cause a wide spread.

See Kennett, 1983, Wavenumber and wavetype coupling in laterally heterogeneous media, Geophys Jour Royal Astr Soc, 87, 313-3[illegible]

Scattering



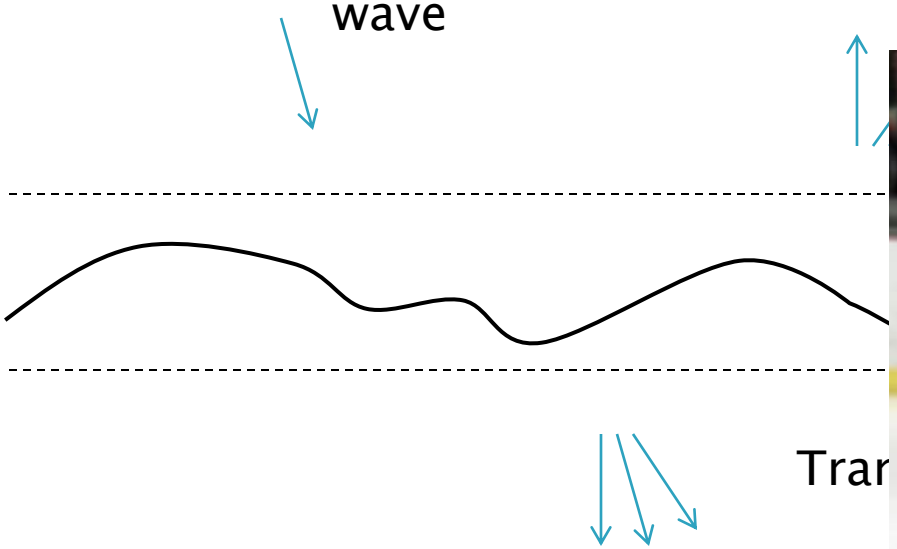
The same theory works for rough boundaries.

What are the implications for AVO, particularly on unconformities?
Topography on unconformity -> rough boundary
Palaeo weathering layer -> highly heterogeneous below unconformity

Effective reflection coefficients are frequency-dependent.
Energy is scattered into many wavenumbers: loss of coherence

We generally skate over this ...

Scattering



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Data analysis

Look at data!

Seismic sections, colour and wiggle traces
Horizons, maps, 3D views
Log curves
Cross plots
Spectral (or other types of) decomposition
Attributes

These views do not add new information to the data, but may make it easier to extract particularly interesting information.

Statistical analysis is merely a way to make the process more quantitative.

Cross plotting
Curve fitting
Correlations
Cluster analysis

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Types of inversion

- Linear / non-linear
- Deterministic / stochastic
- Which wave equation or approximation is used
- How the model space is parametrised
- Combination of different types of data