Introduction to Rock Physics

Sections 1.1 – 1.3

Rock Physics Seminar

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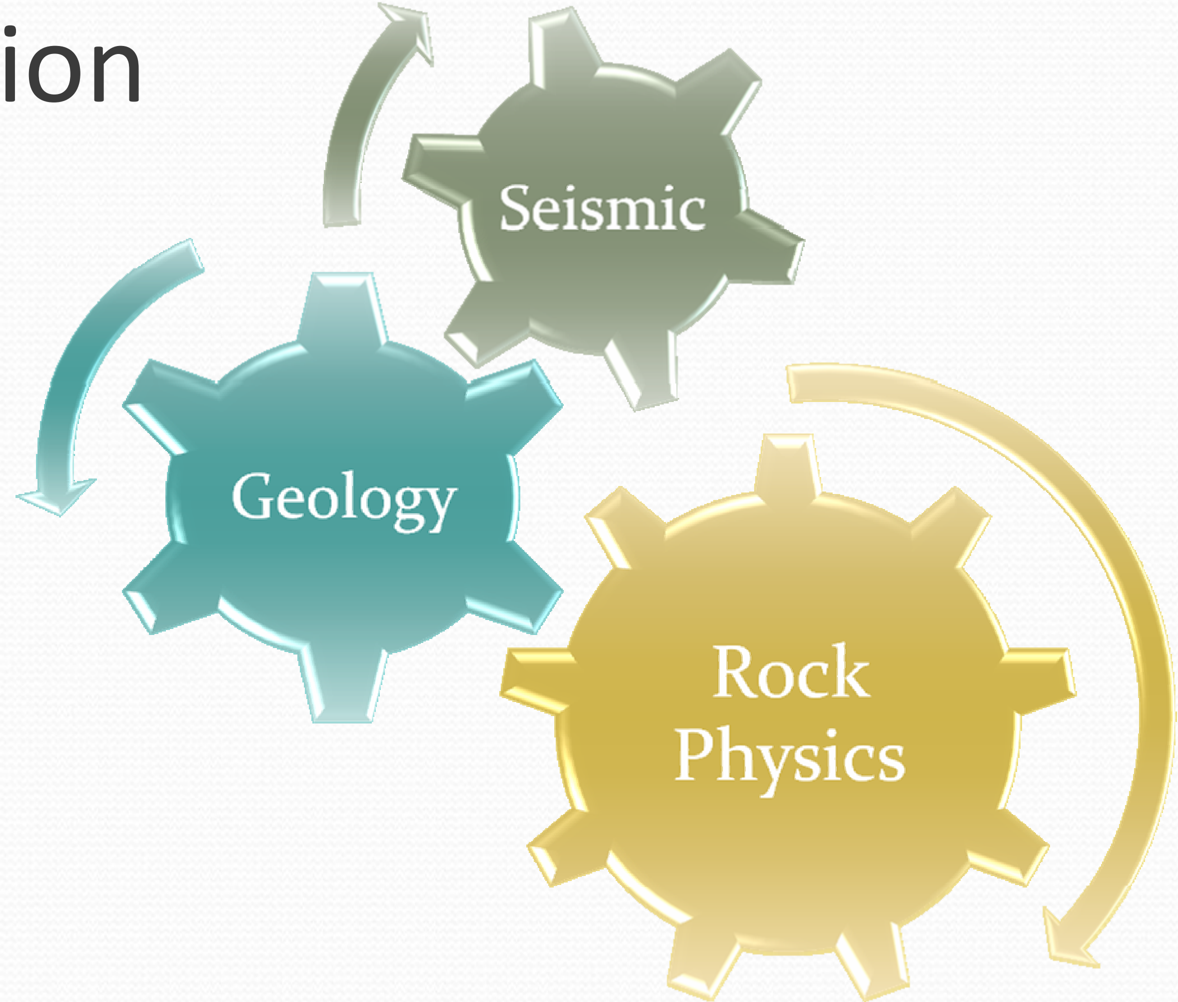
February 6th, 2009

Outline

- ✓ Introduction
- ✓ Velocity –Porosity relations for mapping porosity and facies
- ✓ Fluid substitution analysis

1.1 Introduction

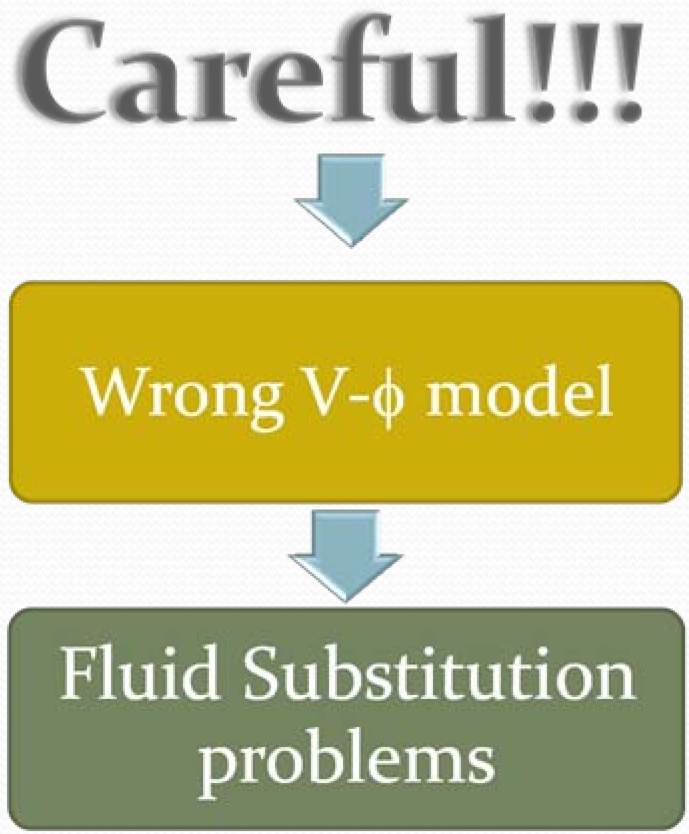


" Discovering and understanding the seismic-to-reservoir relations has been the focus of rock physics research"

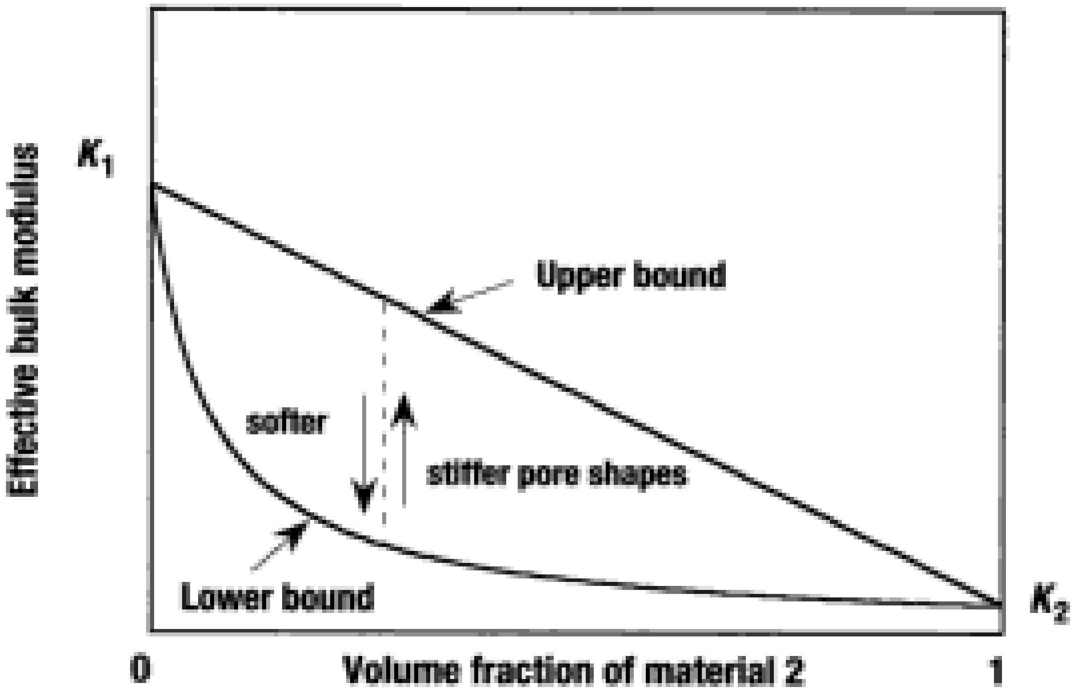
1.2 Velocity – Porosity relations

Classical models:

- Wyllie time average
- Raymer - Hunt - Gardner
- Raiga – Clemenceau
- Critical porosity



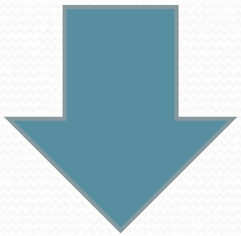
Bounds: framework for V-ϕ models



Avseth et al., 2005

For each constituent:

1. Volume fraction
2. Elastic moduli



Upper and lower bounds

3. Geometric arrangement

Elastic bounds

- ✓ Voigt and Reuss:
  - Simplest bounds

$$K_v = \sum_{i=1}^{n} x_i K_i \ , \ \ \mu_v = \sum_{i=1}^{n} x_i \mu_i$$

$$1/K_r = \sum_{i=1}^{n} x_i / K_i \ , \ \ 1/\mu_r = \sum_{i=1}^{n} x_i / \mu_i$$

- ✓ Hashin-Shtrikman:
  - Best bounds for an isotropic mixture without specifying geometric arrangement.
  - Applicable to more than 2 phases.

$K_{HS+} = f\,(K_i, \mu_{max}, X_i)$

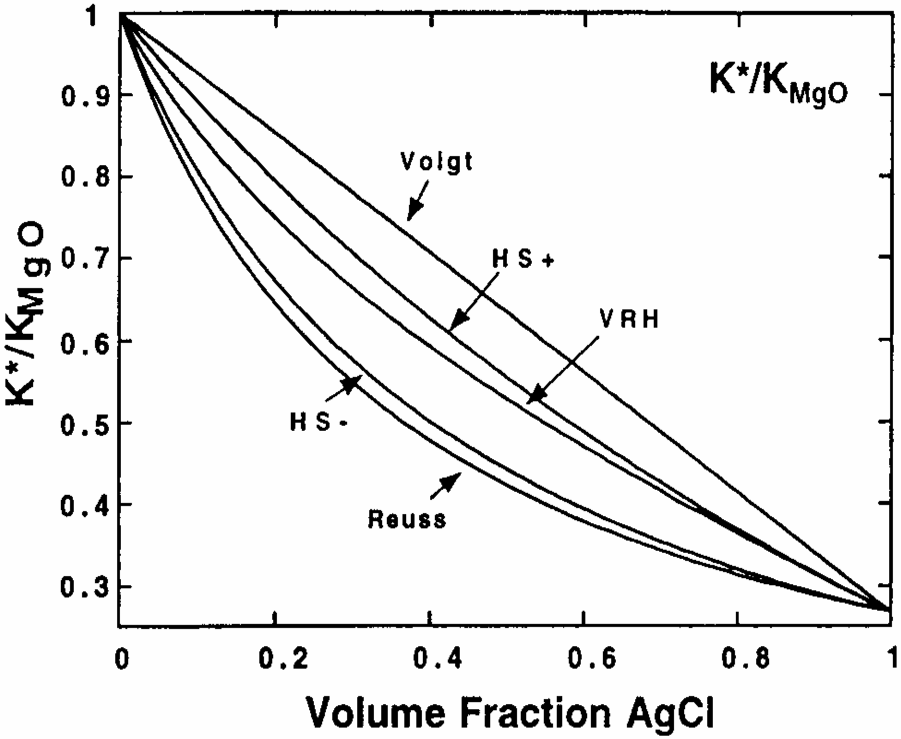
$K_{HS-} = f\,(K_i, \mu_{min}, X_i)$

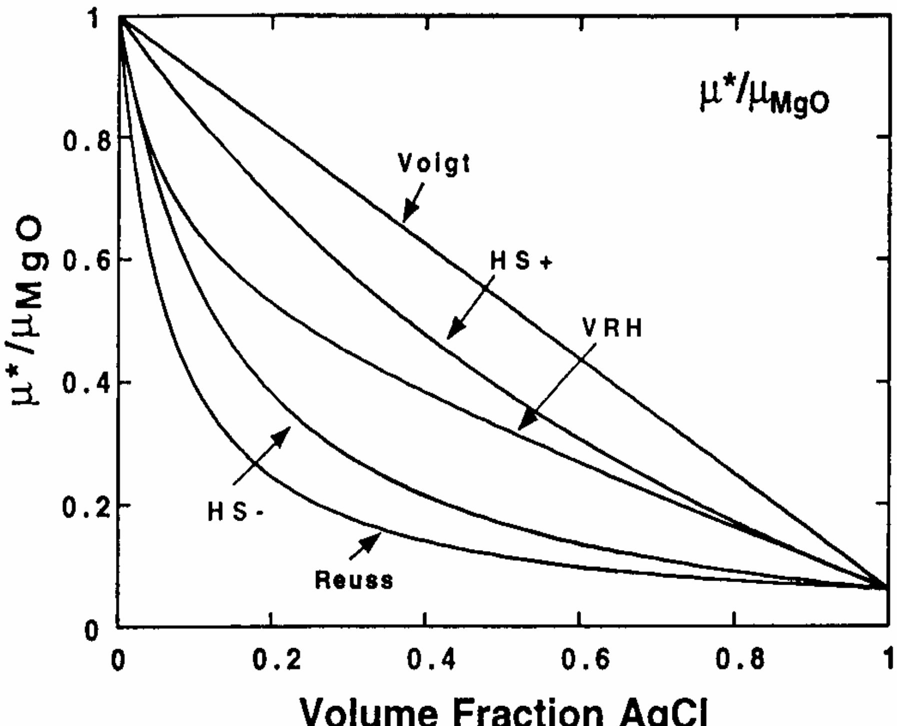
$\mu_{HS+} = f\,(\mu_i, \mu_{max}, K_{max}, X_i)$

$\mu_{HS-} = f\,(\mu_i, \mu_{min}, K_{min}, X_i)$

Upper and lower bounds depend on how different the constituents are.

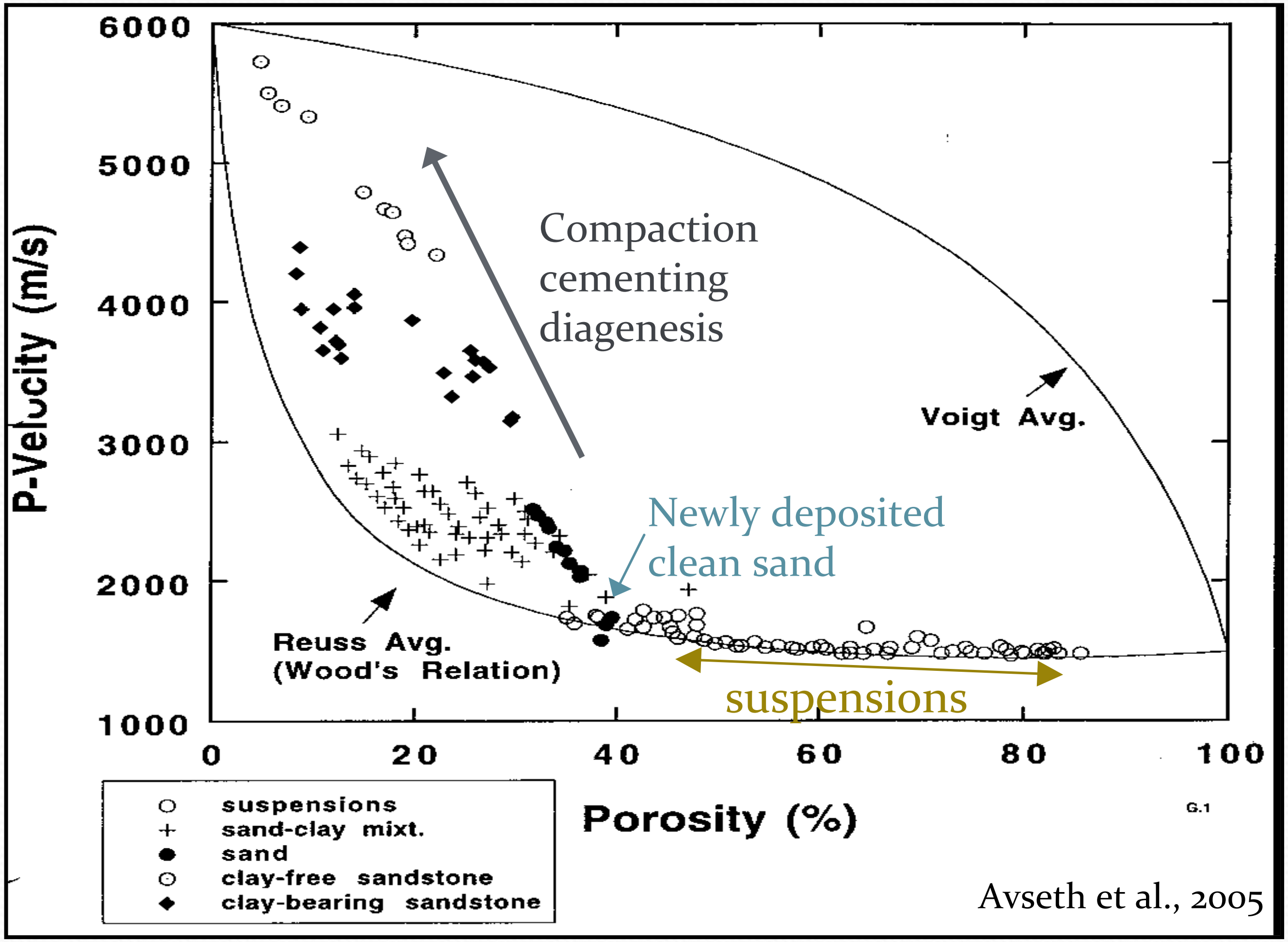
Voigt-Reuss vs. Hashin-Shtrikman





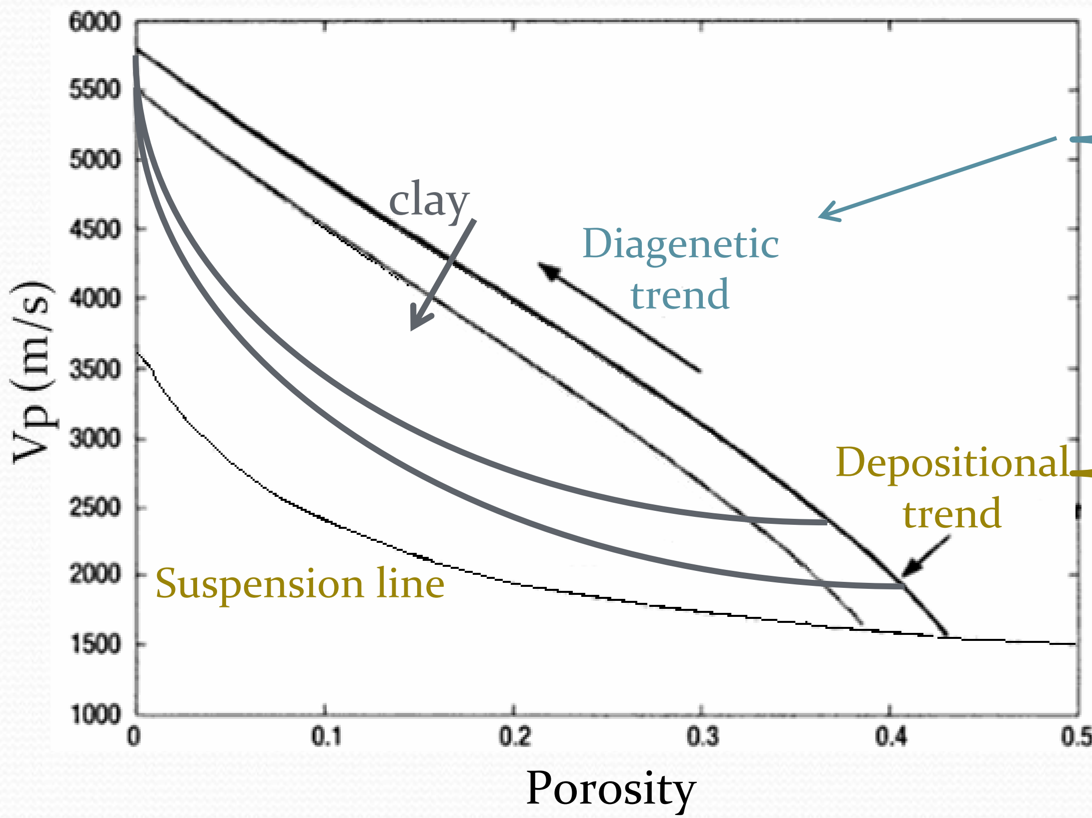
Watt, Davies, and O'Connell, 1976

Using bounds to describe diagenesis



Avseth et al., 2005

Diagenetics vs. depositional trends



Porosity is controlled by diagenesis (cementation, compaction, pressure solution)

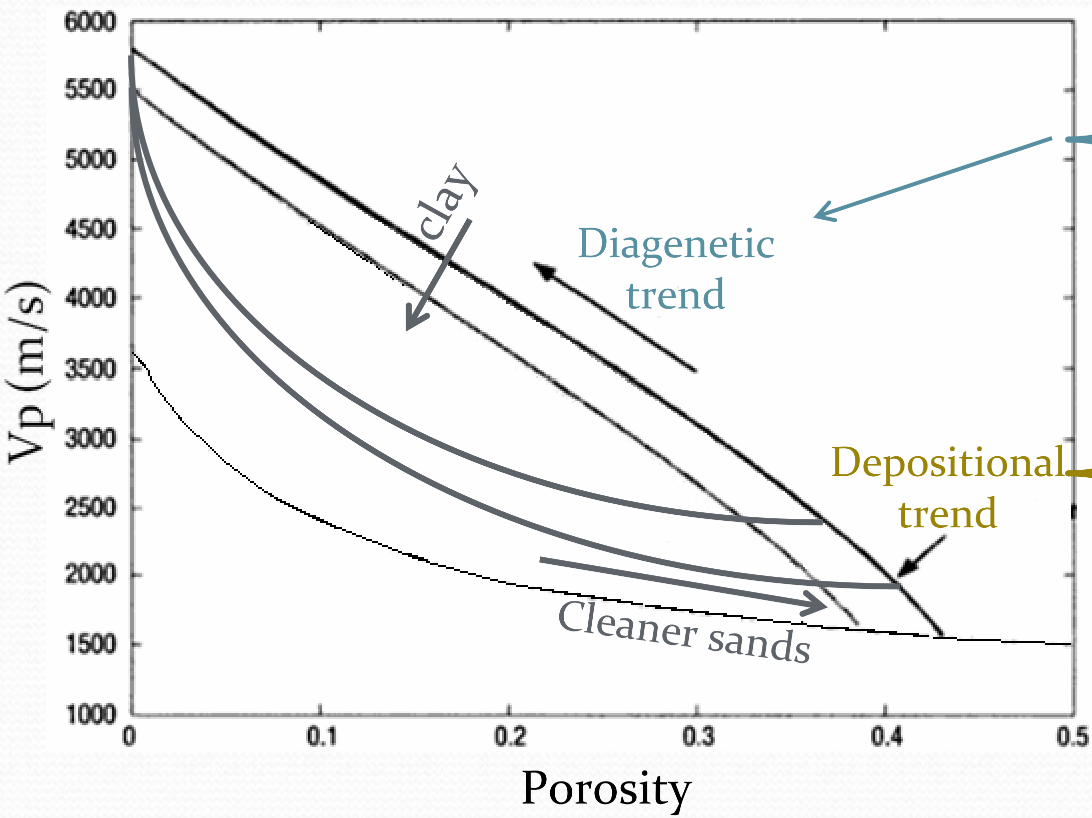
Porosity is controlled by sedimentation (sorting and clay content)

Han's relations

"Diagenesis is the stiffest way to reduce porosity"

Avseth et al., 2005

Diagenetics vs. depositional trends



Porosity is controlled by diagenesis (cementation, compaction, pressure solution)

Each line has constant depth but variable texture, sorting, clay content.

"Diagenesis is the stiffest way to reduce porosity"

Avseth et al., 2005

Factors affecting velocities

- P and S velocities depend greatly on porosity.
- Porosity can be estimated from impedance.
- Clay increases VP/VS ratio (consolidated sands).
- Clay stiffens rock (unconsolidated sands).
- Pore shape cause variable V-ϕ trends (crack-like aspect ratio has similar signature than high clay content and poor sorting)

1.3 Fluid Substitution

→ "How seismic velocity and impedance depend on pore fluids"

2 fluid effects:

Change in rock bulk density

Change in rock compressibility

↓

K_ϕ

"Seismic fluid sensitivity is determined by a combination of porosity and pore-space stiffness"

1.3 Fluid Substitution

How to do fluid substitution?
R: follow the steps in page 18.

How to calculate fluid properties?
R: Use Batzle and Wang (1992) formulas to calculate fluid moduli.

How to approximate dry rock condition?
R: air-filled rock with a pore pressure of 1 bar (don't use just gas).

How to relate Gassmann's equations and ultrasonic measurements?
R: use dry ultrasonic velocities and saturate them using Gassmann equations.

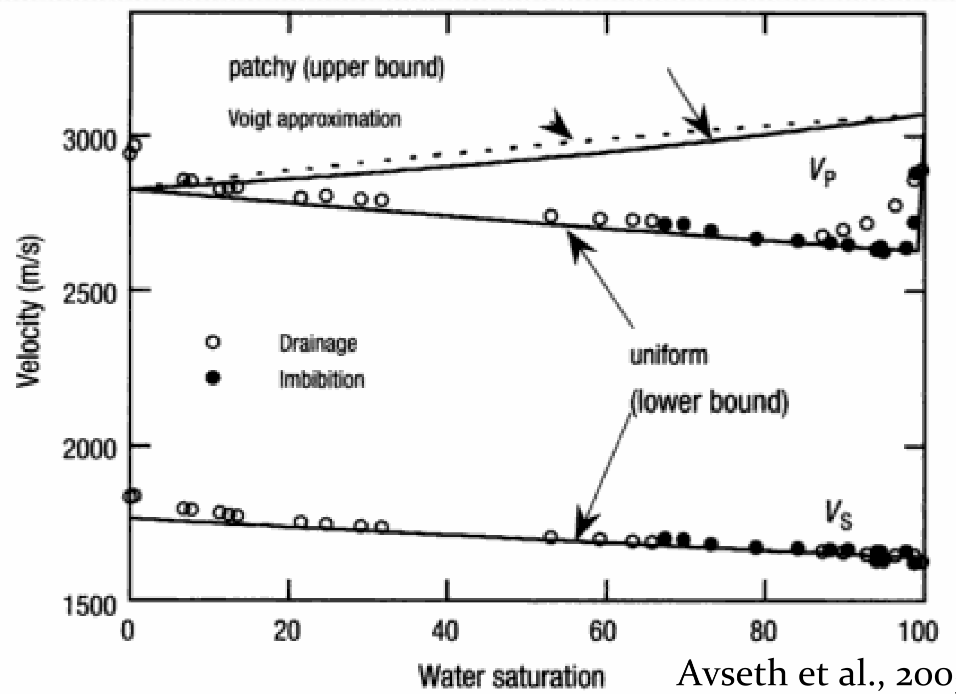
How to obtain mineral moduli for complex rocks?
R: Compute upper and lower bounds of the mixture of minerals and take the average. Or use Berryman and Milton equation.

How to deal with mixed saturation?

1.3 Fluid Substitution

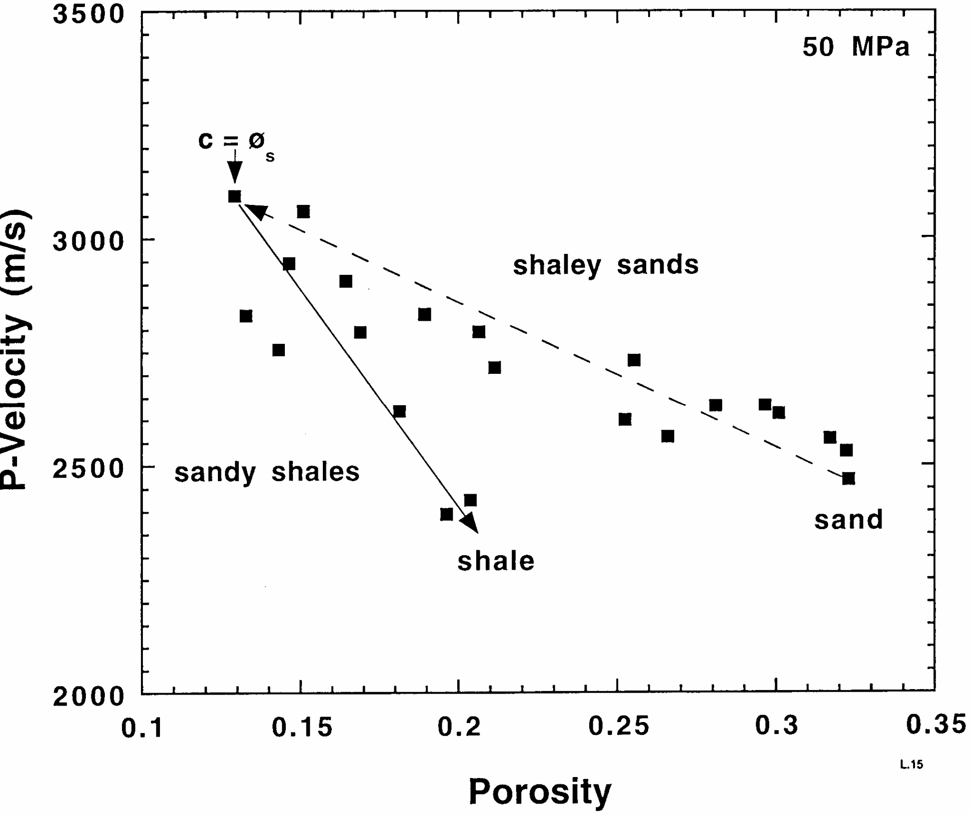
- Valid for seismic frequencies.
- Not appropriate for ultrasonic velocities, heavy oils and tight sands reservoirs.
- Valid for isotropic rocks
- Valid for uniform distribution of fluid

Rock modulus with patchy saturation can be approximated by using Voigt average to estimate effective fluid properties.



Avseth et al., 2005

Shaly Sands



Influence of clay content on velocity-porosity relationship at a constant confining pressure (50 MPa). Distinct trends for shaly sand and for shale are schematically superposed on experimental data on sand-clay mixture. From Dominique Marion, 1990, Ph.D. dissertation, Stanford University. ~ Data are from Yin, et al., 1988, and Han, 1986.