Rock Physics Interpretation of microstructure
Chapter2.1-2.2-2.3

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- **Introduction**
- **Theory and models**
- **Example in North Sea**

Introduction

-- Theoretical models

- Inclusion models
- Contact models
- Computational models
- Bounds
- Transformations

- **Introduction**
- **Theory and models**
- **Example in North Sea**

Models for Clay increase

- The friable – sand model
- The contact- cement model
- The constant-cement model

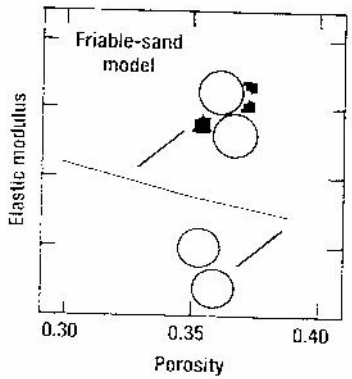
Models for shales

- The constant-clay model for sandy shale
- Dvorkin-Gutierrez silty shale model
- Yin-Marion silty shale model

Models for shaly sands

- The constant-clay model for shaly sands
- Yin-Marion shaly sand model
- Dvorkin-Gutierrez shaly sand model
- Jizba's cemented shaly sand model

The friable – sand model

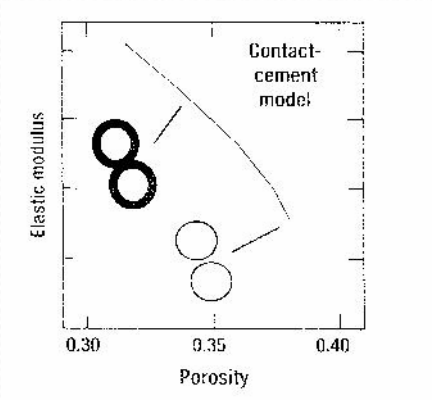


Adding smaller clay deposited in the pore space, deteriorate sorting, decrease porosity, slightly increase the stiffness

$Ø_c$ is the point divide the two end member, around $Ø_c$, use Hertz-Mindlin theory to calculate dry rock bulk and shear moduli.

Around zero porosity, use Hashin-Shtrikman bound to calculate dry rock bulk and shear moduli.

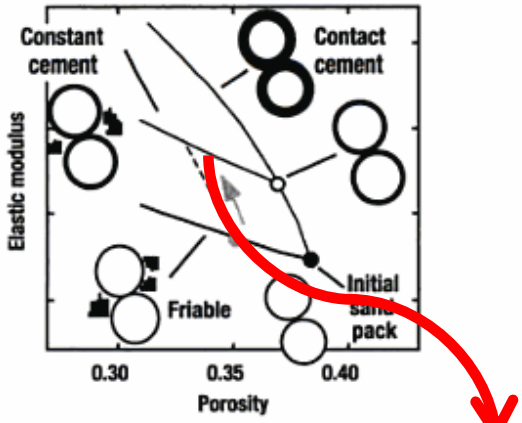
The contact- cement model



clay deposited at the crack spaces near the grain contacts, so the stiffness of rock rapidly increase with very little change in porosity.

This mathematical model is soluted by Dvorkin et al, to get the day bulk and shear moduli.

The constant-cement model



Assume that sands of varying sorting, all have the same amount of contact cement, porosity reduction is solely due to noncontact pore-filling material.

First get the well-sortd end-member porosity Φ_b

The equation for dry-rock bulk and shear moduli at a smaller porosity see Page 58

Models for shales

--shale is a sheet like structure and bound water

- The constant-clay model for sandy shale
- Dvorkin-Gutierrez silty shale model
- Yin-Marion silty shale model

The constant-clay model for sandy shale

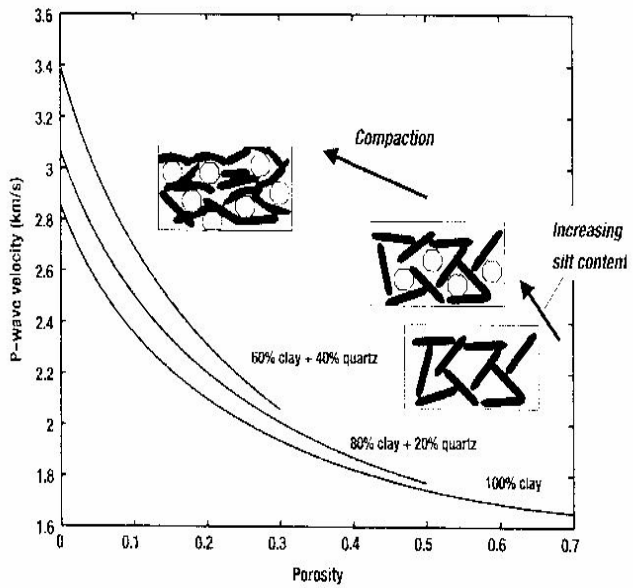
silt grains are suspended in the shale matrix

Dvorkin-Gutierrez silty shale model

Model the velocity-porosity trend of decreasing clay content

Yin-Marion silty shale model

Use the Reuss bound to calculate the elastic moduli of shales with dispersed quartz grains



Models for shaly sands

--slope of v-Ø in sandstone depends largely on the geologic processing porosity variations controlled by diagenesis

- The constant-clay model for shaly sands
- Yin-Marion shaly sand model
- Dvorkin-Gutierrez shaly sand model
- Jizba's cemented shaly sand model
- The laminated sand-shale model

The constant-clay model for shaly sands

Constant clay-quartz ratio

High Ø --- function of clay content
Low Ø --- function of quartz and clay

The constant-clay lines are calculation equations

$$K_{mixed}=(1-C)K_{qz}+CK_{clay}$$

$$\mu_{mixed}=(1-C)\mu_{qz}+C\mu_{clay}$$

$$\rho_b=\Phi\rho_{fl}+(1-\Phi)\rho_{min}$$

Yin-Marion shaly sand model

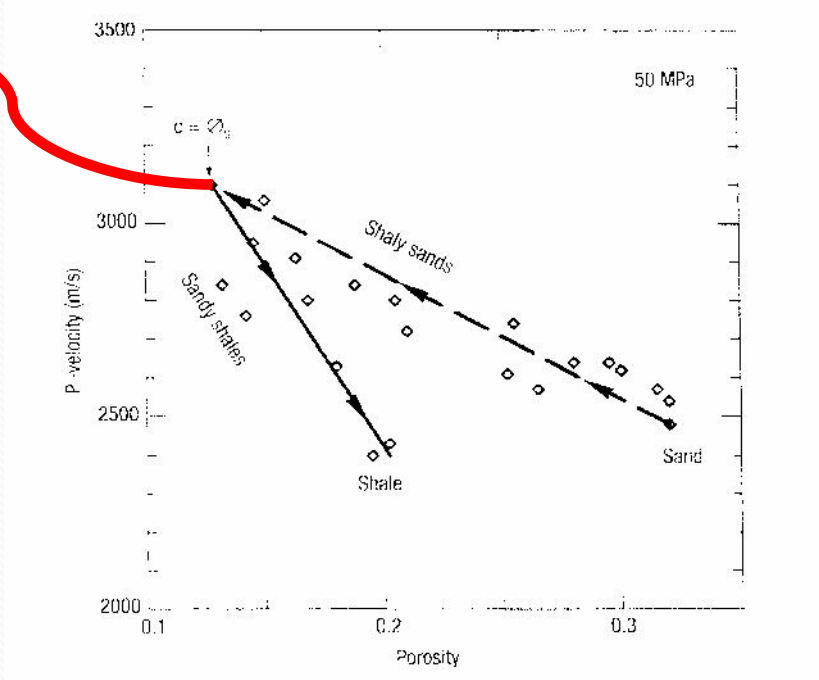
in unconsolidated rock, increasing clay content (C), then total porosity will
Decrease linearly.

$\Phi=\Phi s-C(1-\Phi sh)$, for $C<\Phi s$

$\Phi=\Phi s\Phi sh$, for $C=\Phi s$

$\Phi=\Phi shC$, for $C>\Phi s$, intrinsic clay Φ

For calculation, use Gassman
to replace porous fluids with
pore-filling clay



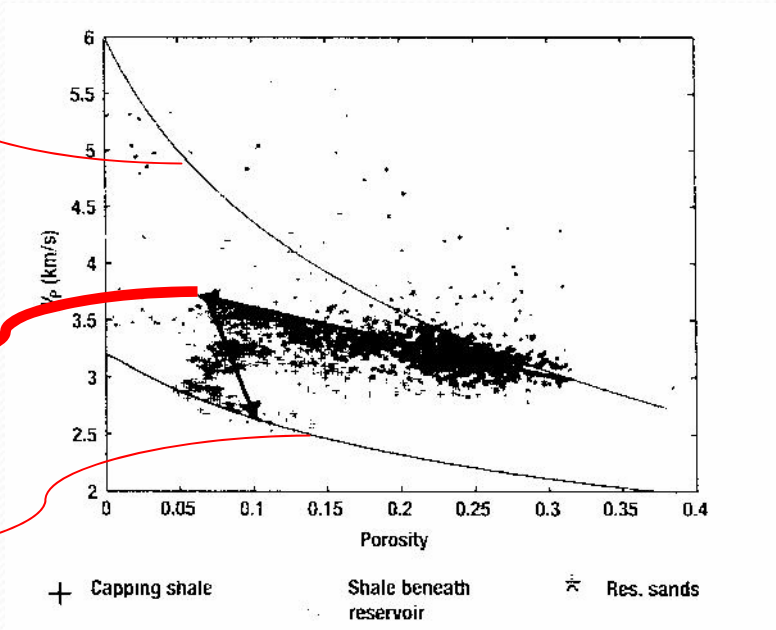
Dvorkin-Gutierrez shaly sand model

Instead of using Gassmann theory, we can use the lower bound Hashin-Shtrikman to calculate velocity-porosity trends for sands with increasing clay content
Formula see page66

Clean sand line

from grain-support sediment
to clay-supported sediment

Shale line

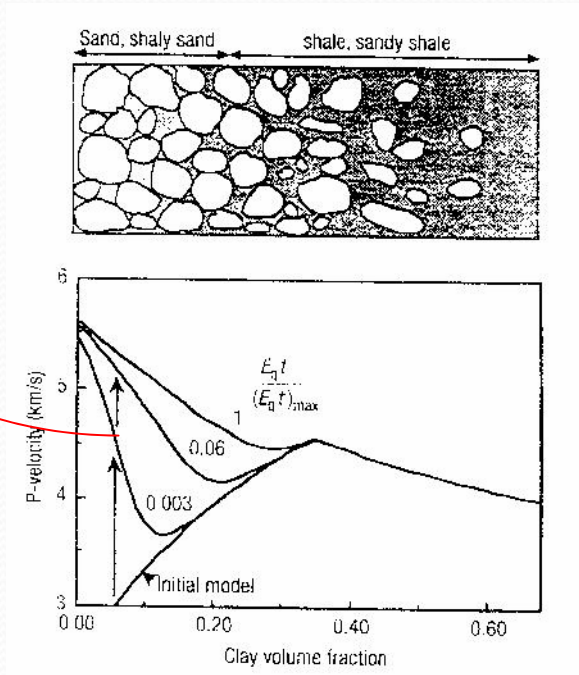


Jizba's cemented shaly sand model

The model same with Yin-Marion shaly sand model, just considered quartz(function of clay content) cementation

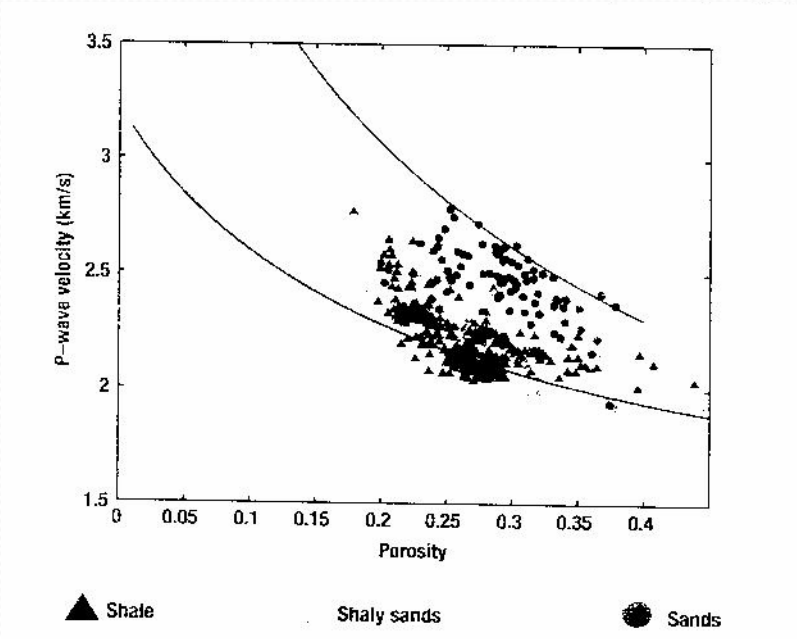
Empirical equation V-Ø --- function of quartz volume and clay content

Those curves represent increasing degree of diagenesis as indicated by the elapsed time $E_q t$



The laminated sand-shale model

'it is a gradual spread from clean sands via shaly sand to shales, porosity-independent transition with increasing clay content, the shaly sands to be laminated sand-shale unit'



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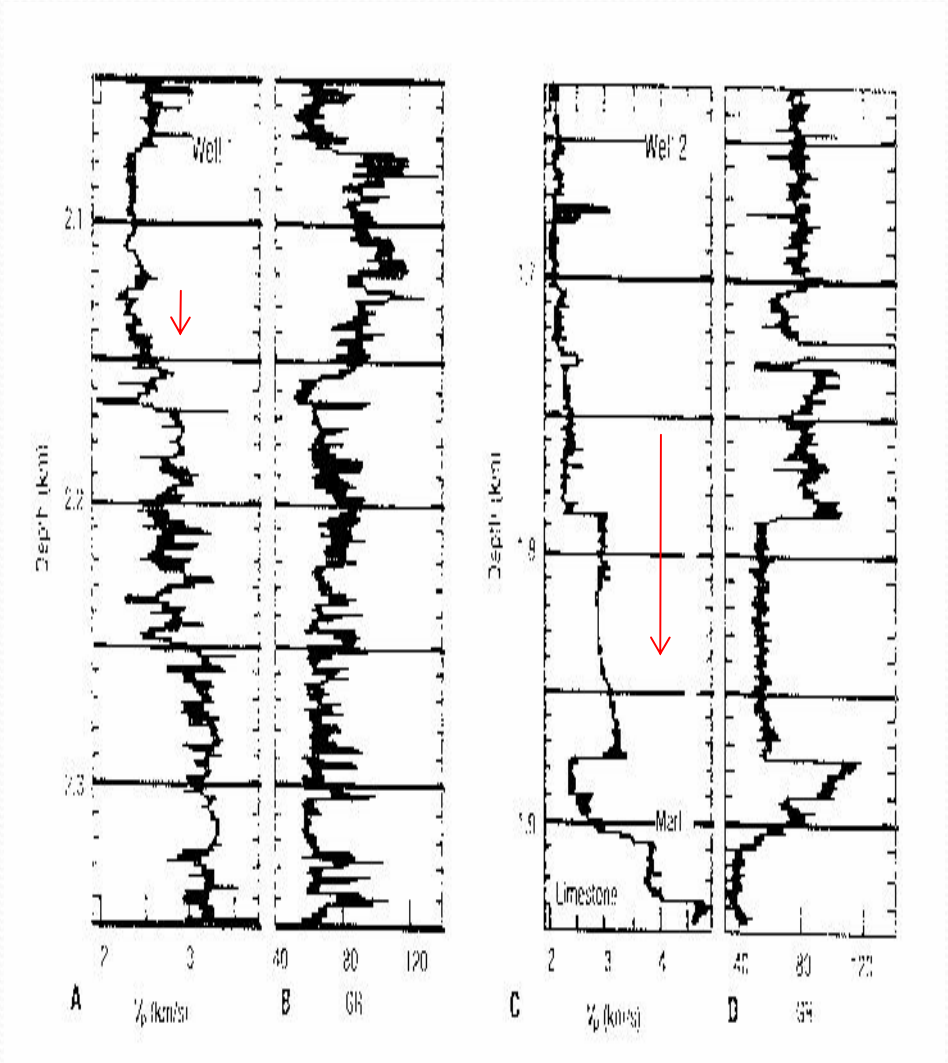
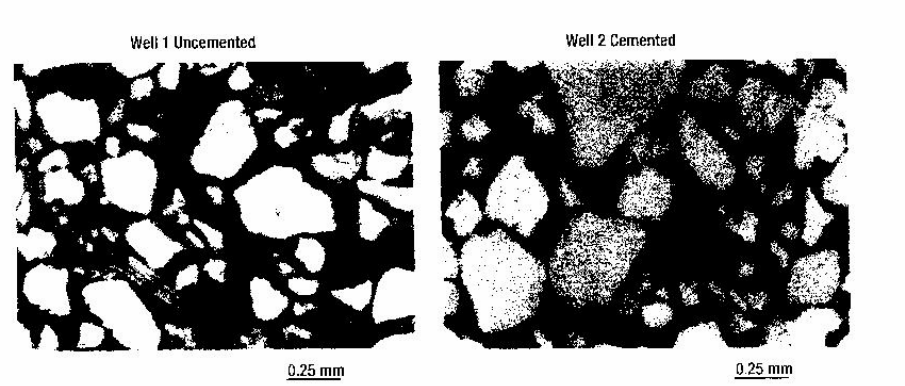
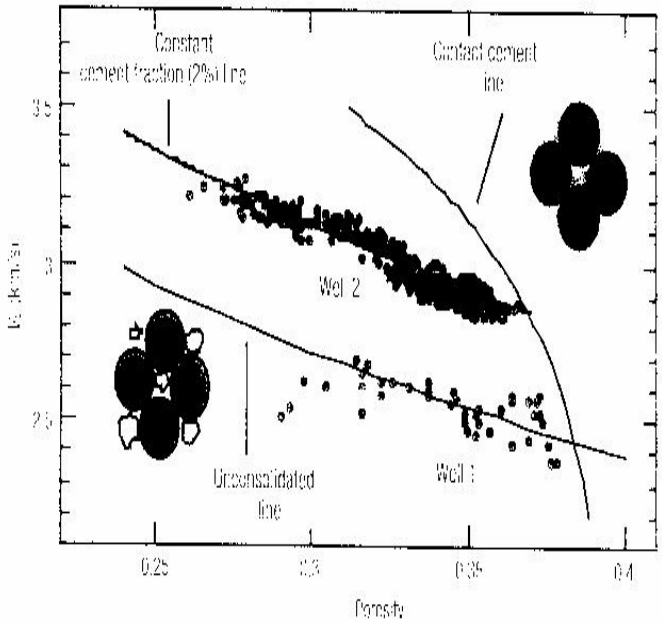
Both wells represent the same stratigraphic unit, the pay zones are marked by red arrows.



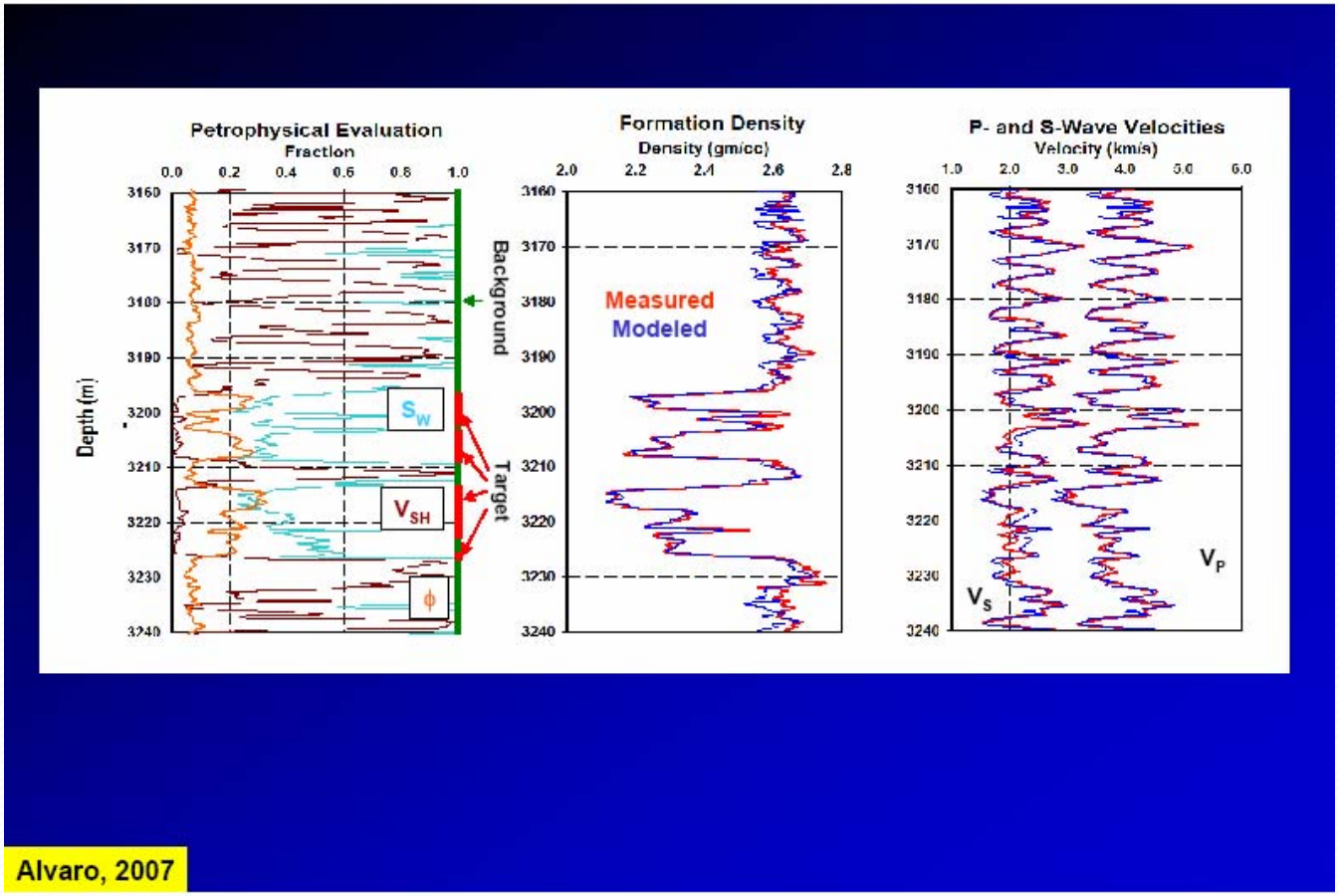
Why the velocity difference in the two wells of the pay zones?





well 1 small reducing porosity because of smaller grains deposite on the contact area, this sand has no contact cementation.

well 2 sand has initial contact cementation, so smaller grains fall in the pore space and have lager effect on the porosity.



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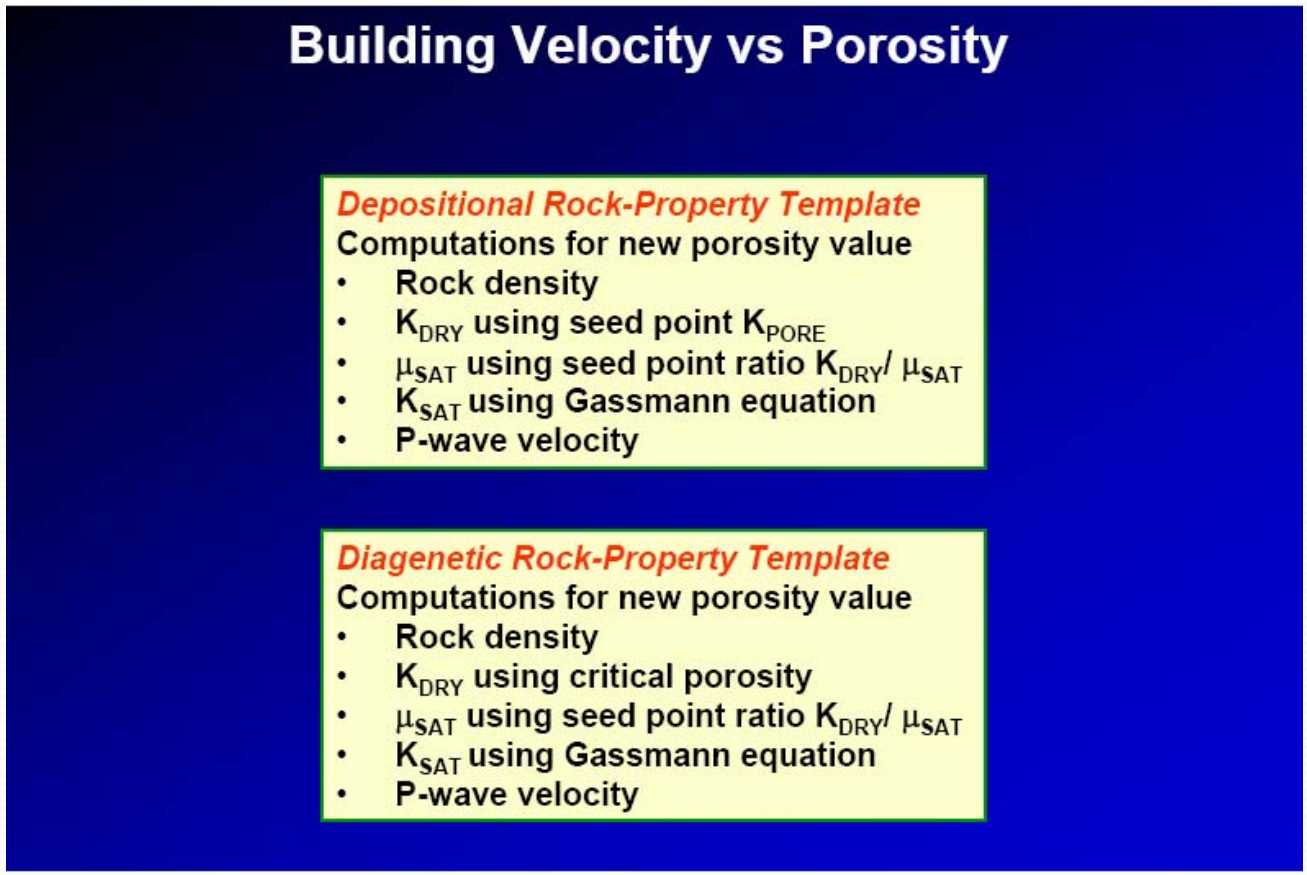

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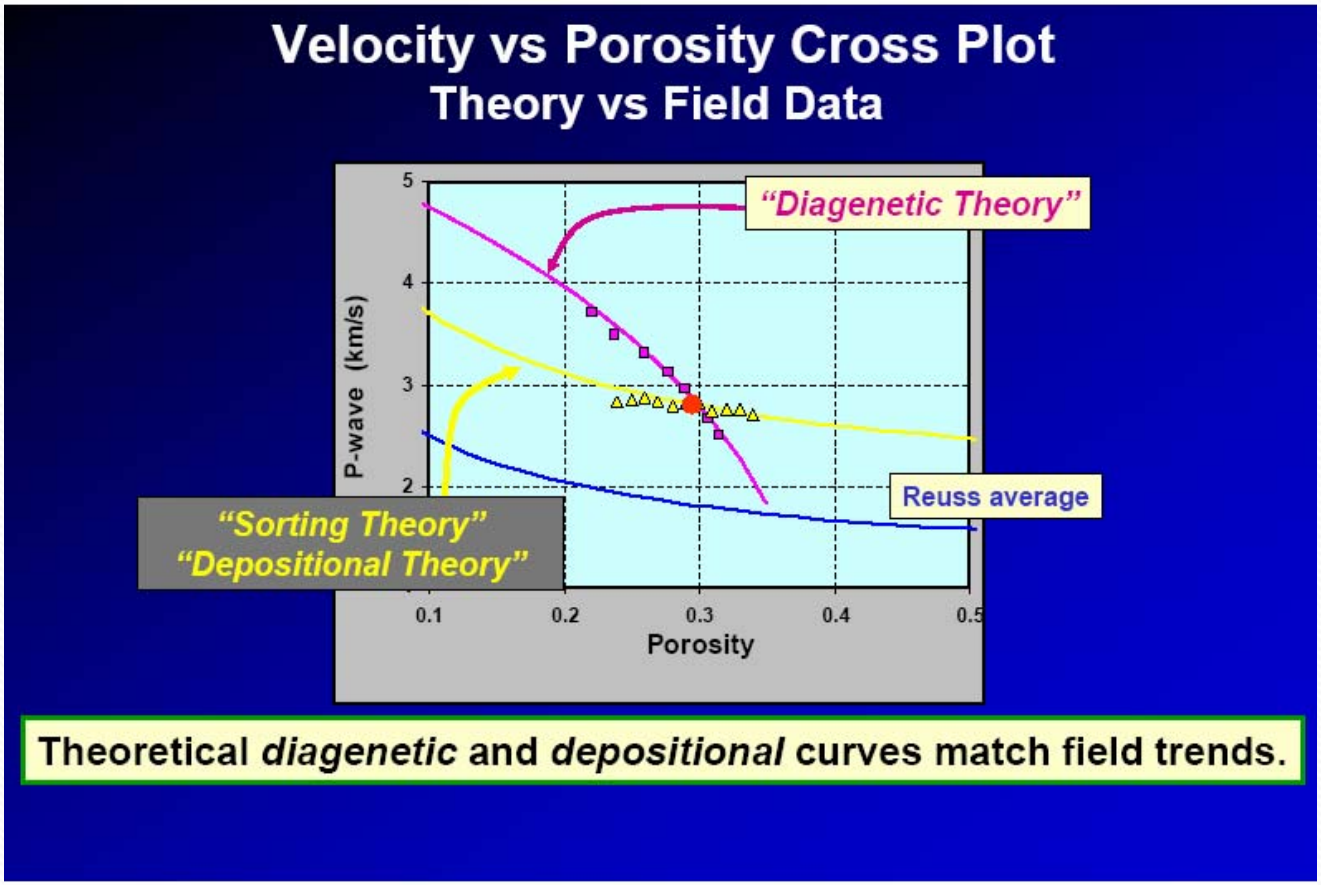

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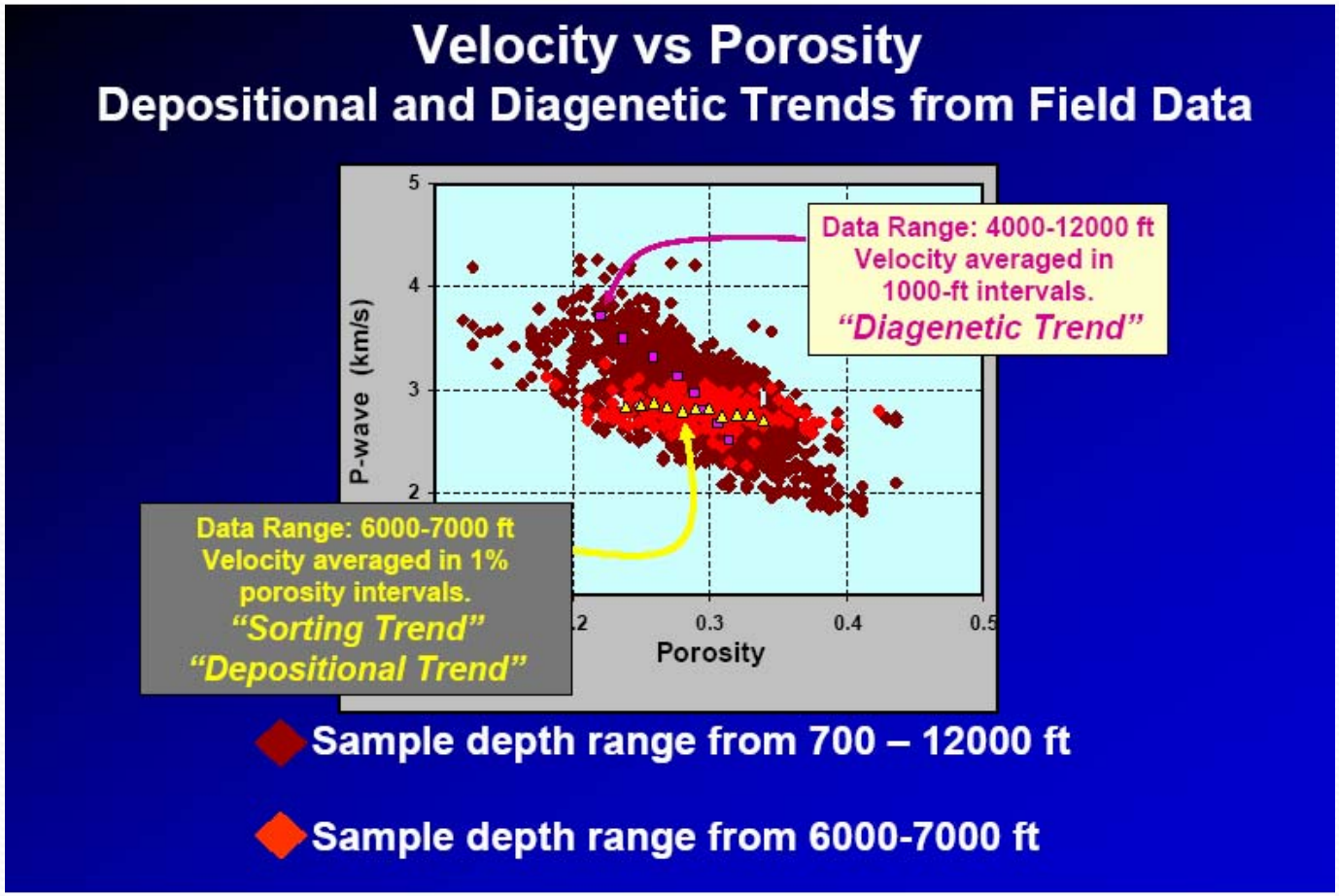

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