Reflectivity of Double Porosity Model: Practical Application

Gennady Goloshubin, ***University of Houston***

GGoloshubin@UH.EDU

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Background

- **A combination of Biot's poroelasticity and Barenblatt's dual medium (Biot-Barenblatt model) is applied to explain the dependence of seismic reflection on reservoir fluid saturation and provides tool for imaging of high fluid mobility zones.**

Overview

- Introduction
- Biot-Barenblatt model
- Reflectivity
- Seismic attributes
- Examples
- Development

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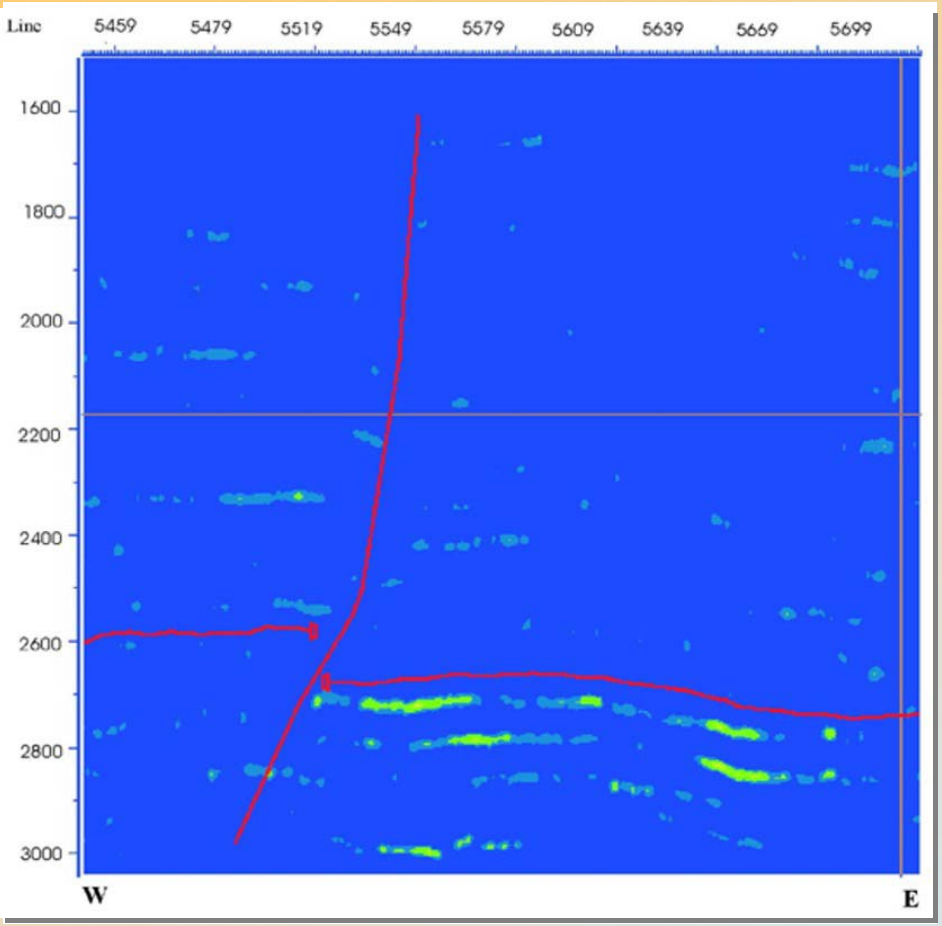
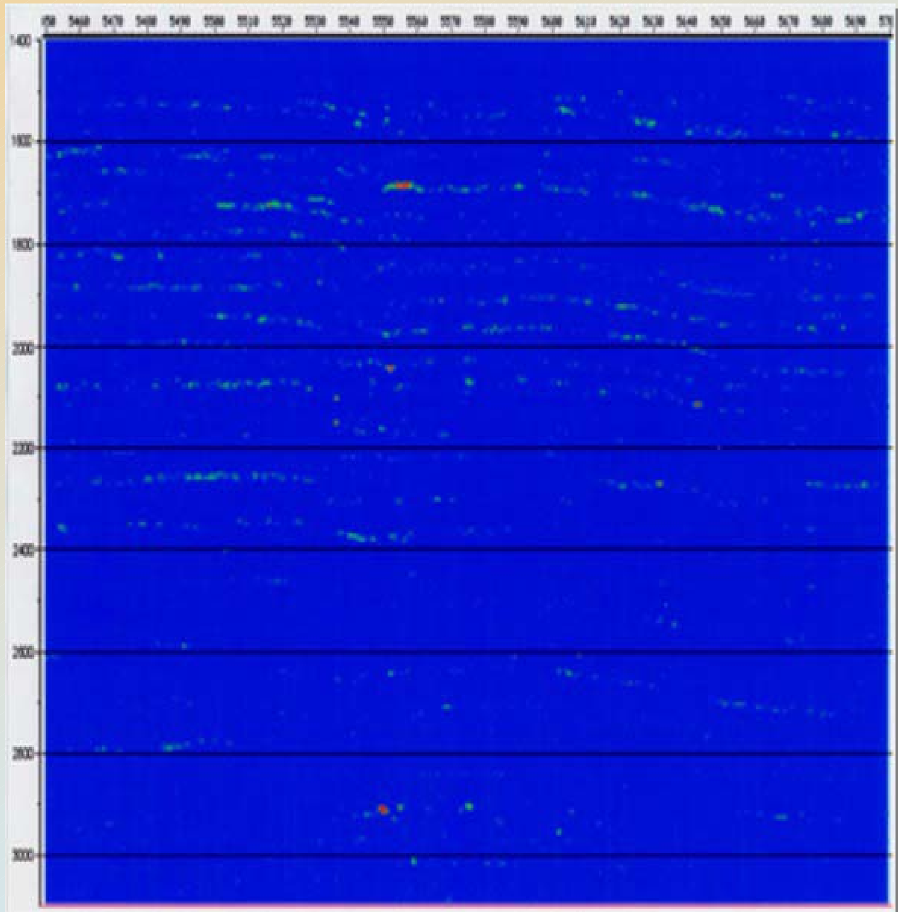
Oil-Saturated Reservoir Zone
Gulf of Mexico



Low Frequency AVO



Conventional AVO

Data for processing are courtesy of Fairfield Industries

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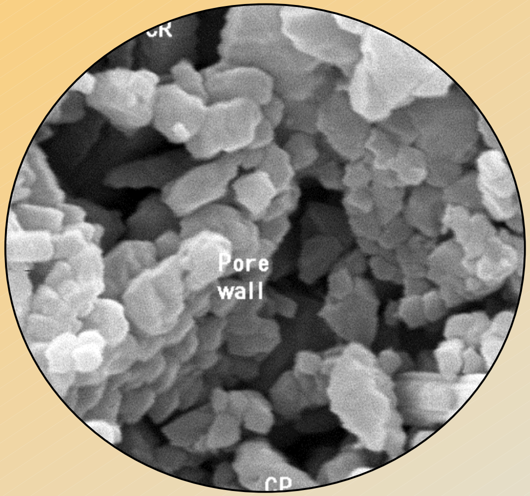
Assumptions

- The volume of highly-conductive medium (connected fractures) is small with respect to that of the “storage” medium (matrix)
- Both media are present in every representative volume. The fluid pressure in fractures may be different from that in matrix
- Darcy flow in the system of fractures; the fluid locked in the matrix blocks can be transported only through local exchange with the surrounding fractures; global Darcy flow in the matrix is negligible
- The deformation and porosity variation are due rearrangements of the grains and to compressibility of the bonds between the grains.

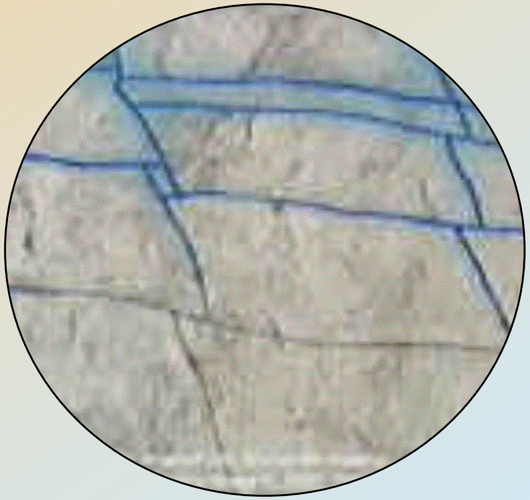
Dual Medium

Matrix porosity



Matrix porosity depends on deposition and provides ***fluid storage***

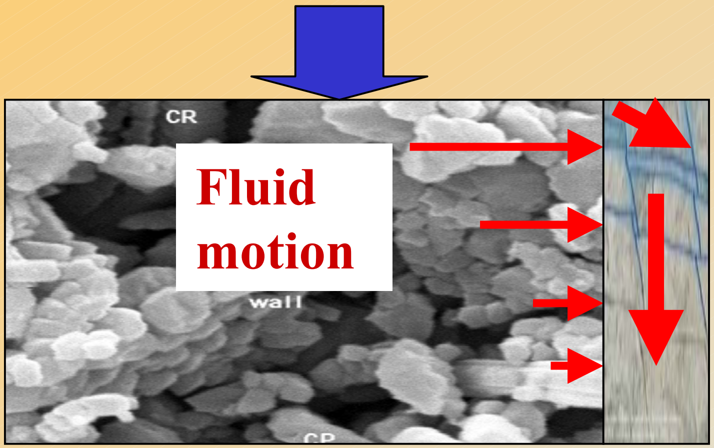
Fracture porosity



Fracture porosity is controlled by fracturing and provides ***fluid transport***

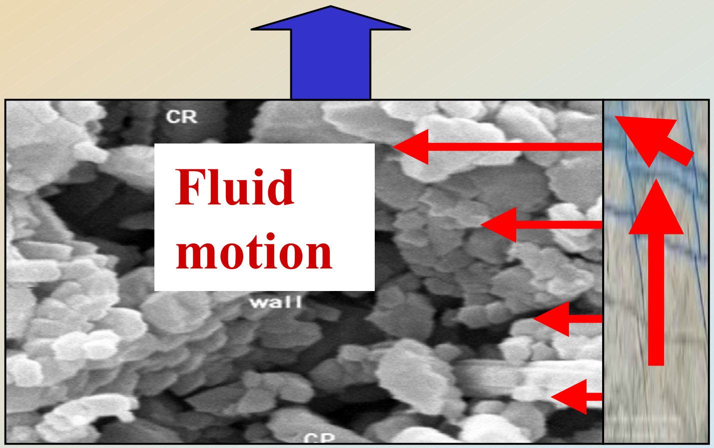
Biot-Barenblatt Model

Compression



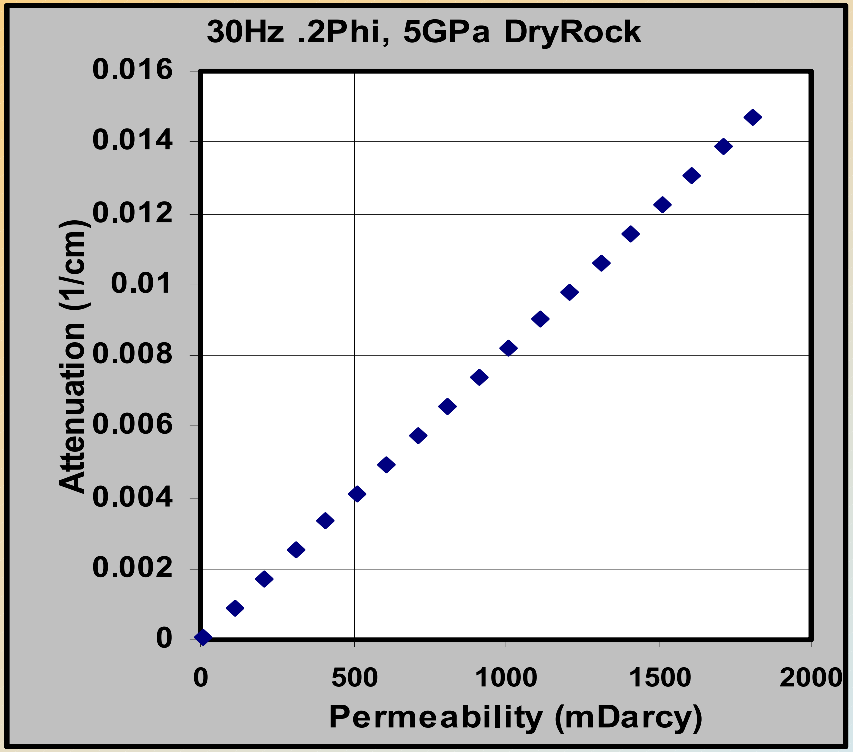
Increased pressure

Dilation



Decreased pressure

Seismic Attenuation



Attenuation is proportional to reservoir permeability

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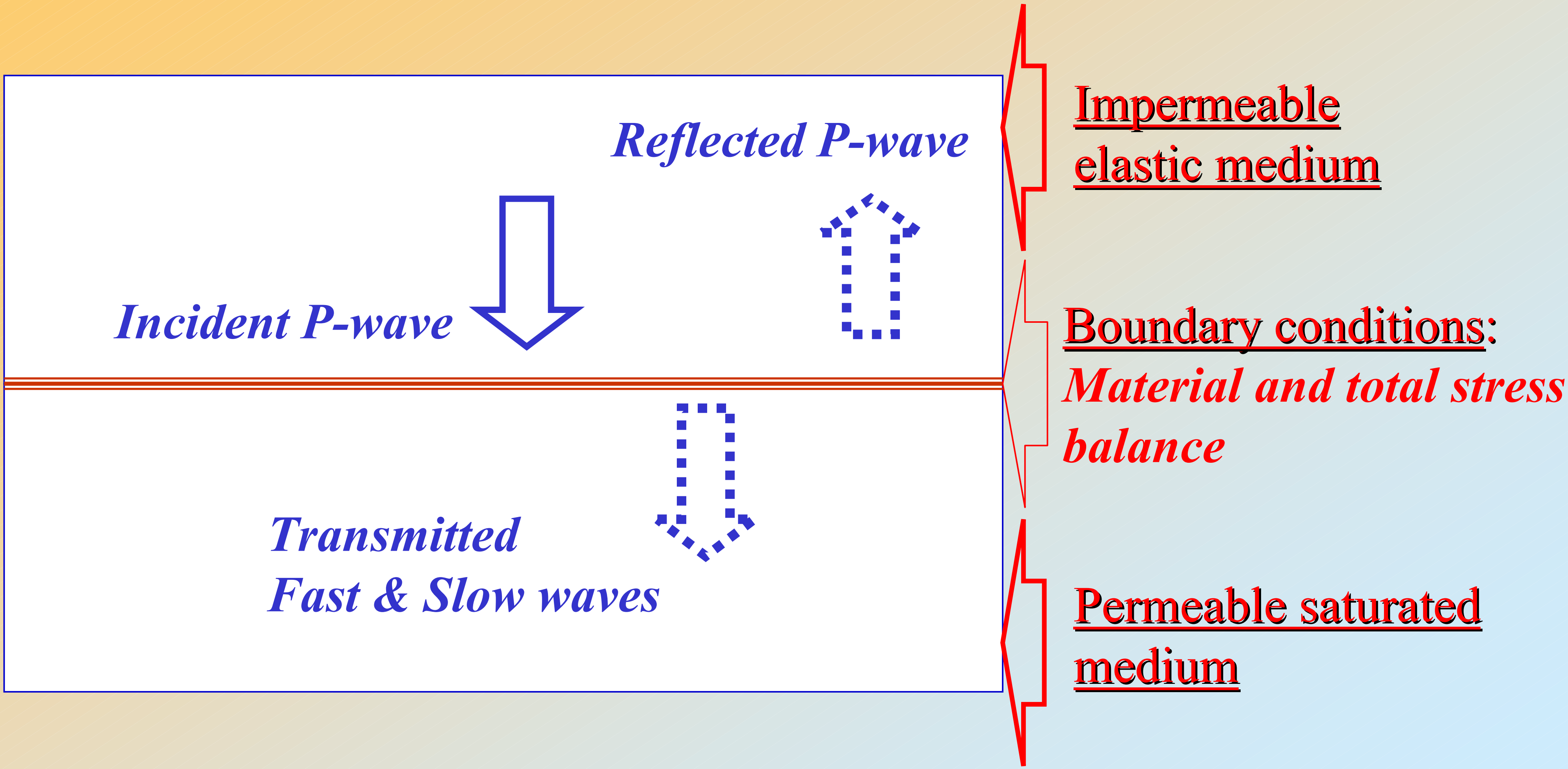
Reflection Model



Reflection Coefficient

$$R = R_0 + R_1(i\,\omega\rho_f\,\kappa/\eta)^{1/2}$$

$$R_0 = (Z_1 - Z_2)/(Z_1 + Z_2)$$

$$R_1 = C(Z_1 Z_{S2})/(Z_1+Z_2)^2$$

Z_i – impedances

C – function of rock & fluid compressibility

R_0 and R_1 are not dependent on hydraulic diffusivity or frequency

i – imaginary

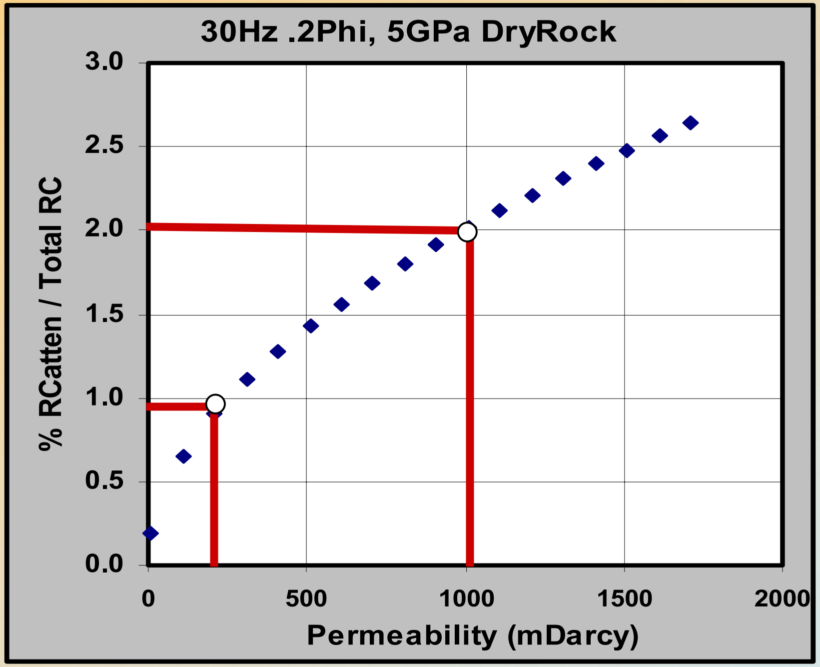
ω – frequency

ρ_f – fluid density

κ – medium permeability

η – fluid viscosity

Reflection vs. Permeability



Frequency-dependent part of reflection reveals dependence on permeability

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Attributes

Amplitude analysis

$$R = R_0 + R_1(i\,\omega\rho_f\,\kappa/\eta)^{1/2}$$

↓

$$K(A - A_0)^2/\omega_0 = \rho_f\,\kappa/\eta$$

К – calibration constant

A – observed amplitude

Ao – synthetic amplitude

ω_0 – observed frequency

Spectral analysis

$$\partial R / \partial \omega = (R_1/2)\,(i\,\rho_f\,\kappa/\eta\omega)^{1/2}$$

↓

$$C(\partial S / \partial \omega)^2\omega = \rho_f\,\kappa/\eta$$

C – calibration constant

ω – frequency

$\partial S / \partial \omega$ – first derivative over frequency

ρ_f - fluid density κ/η - fluid mobility

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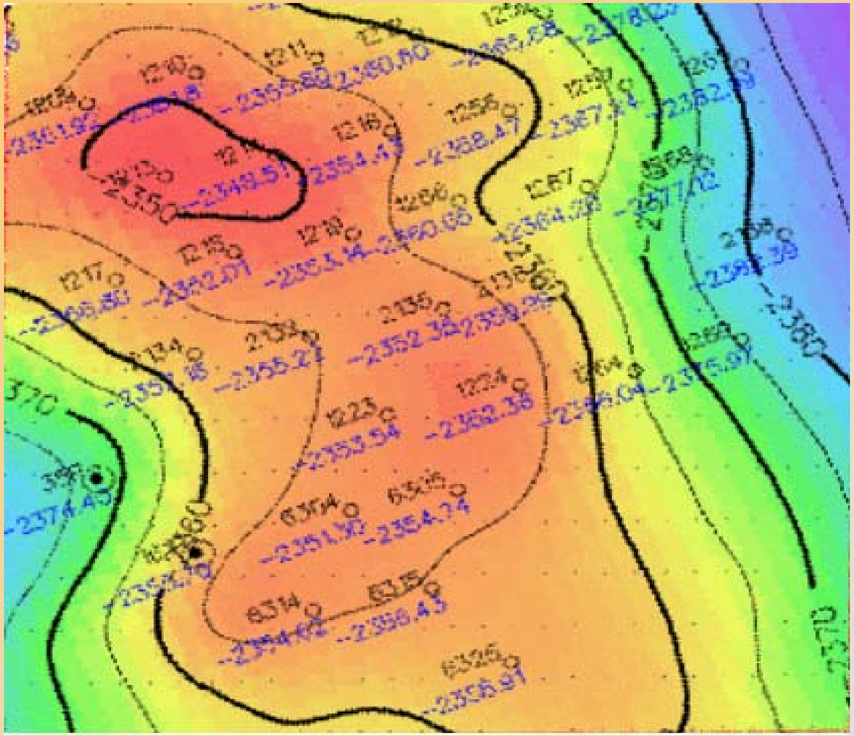
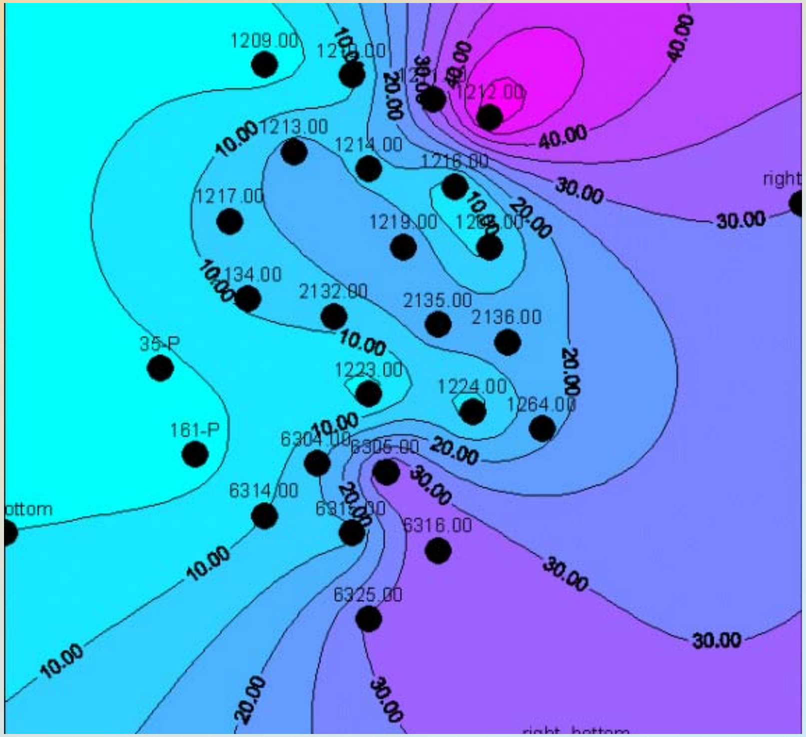
Reservoir Characterization



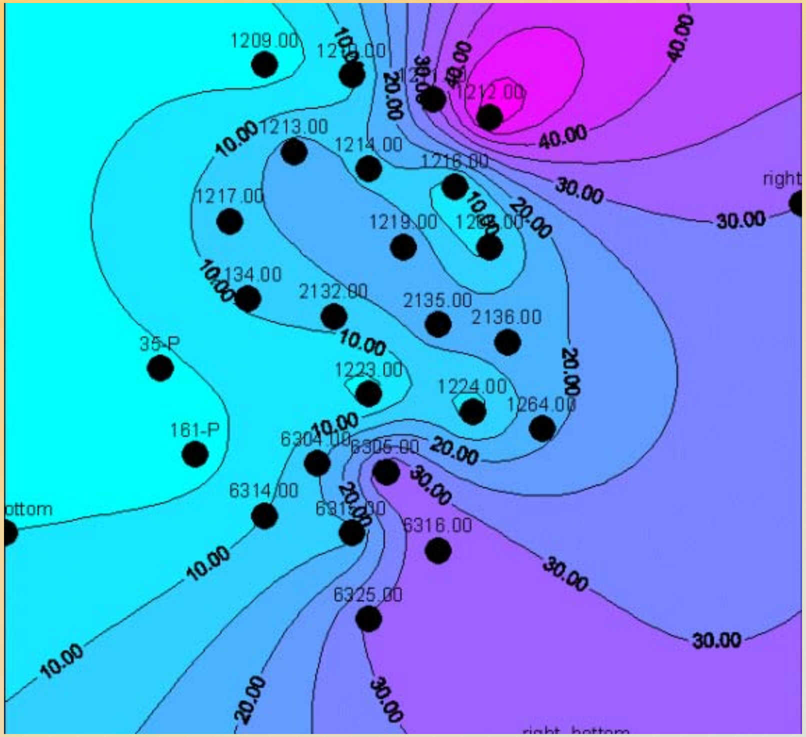
Structural map



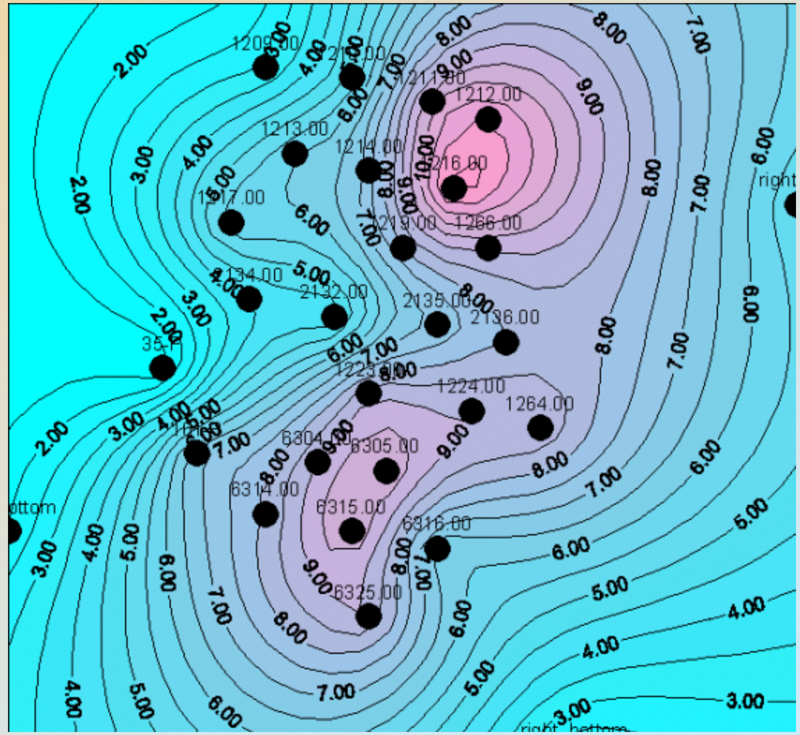
Permeability map

Data of Lukoil-AIK

Reservoir Characterization

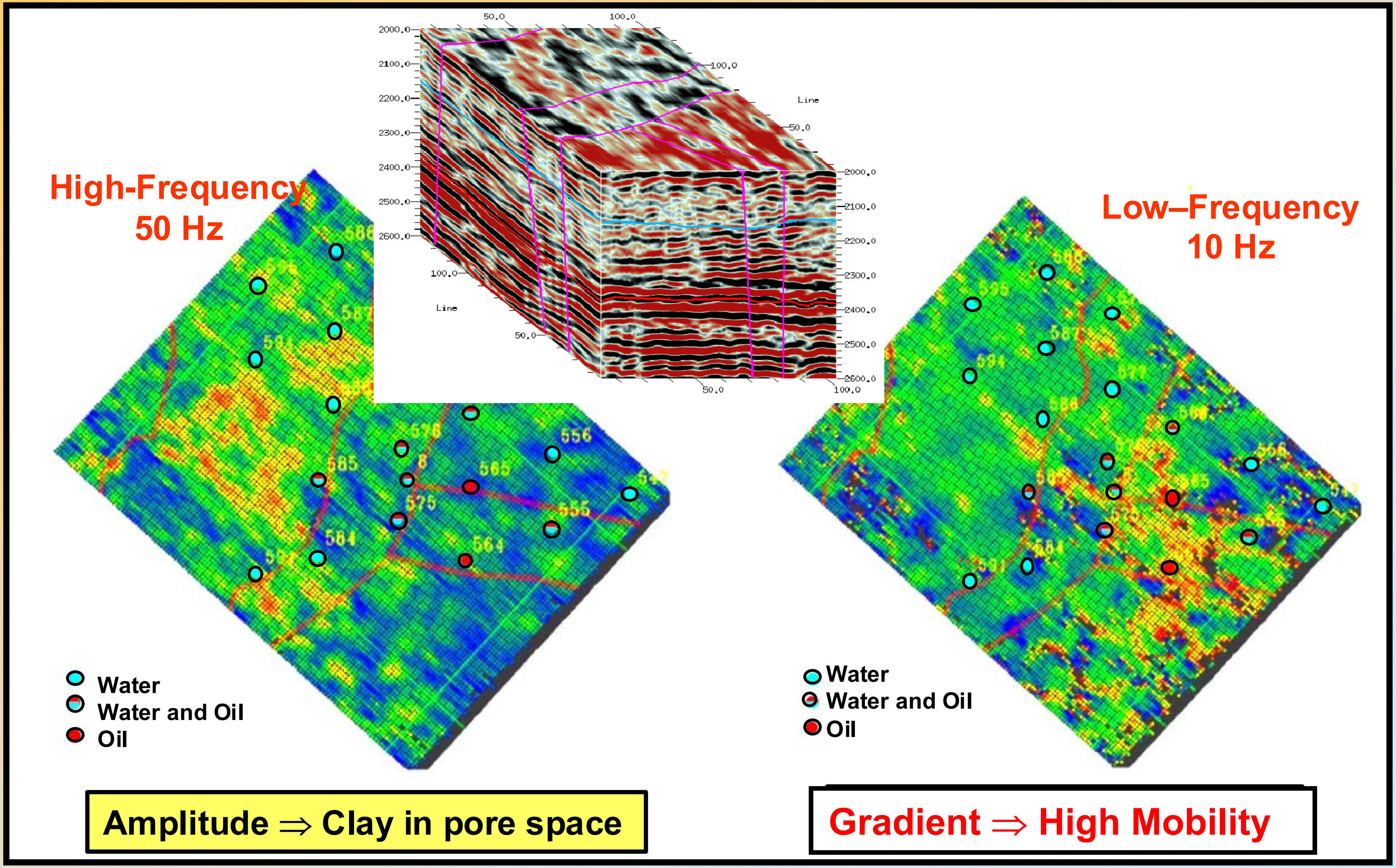


Permeability map



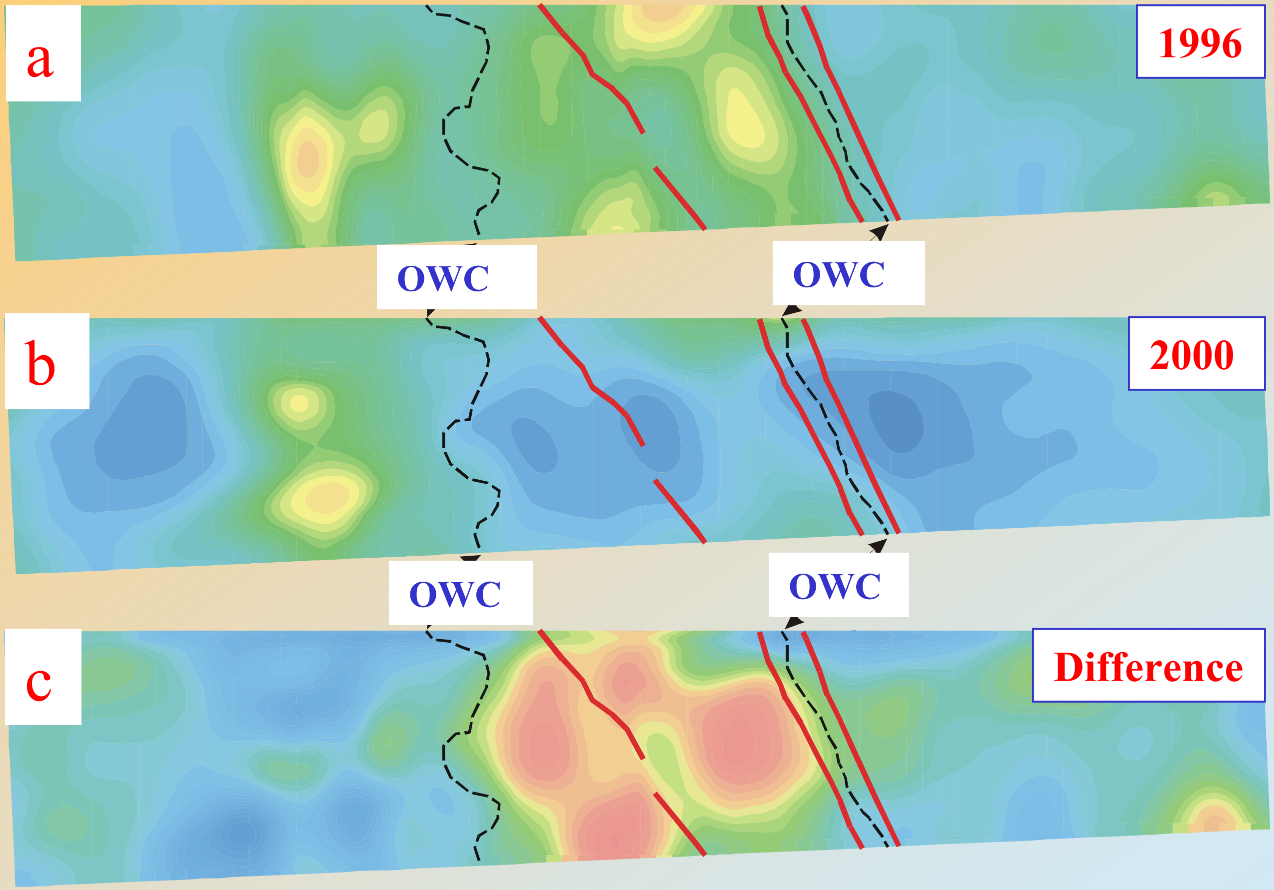
Low-frequency seismic attribute map

Reservoir Characterization



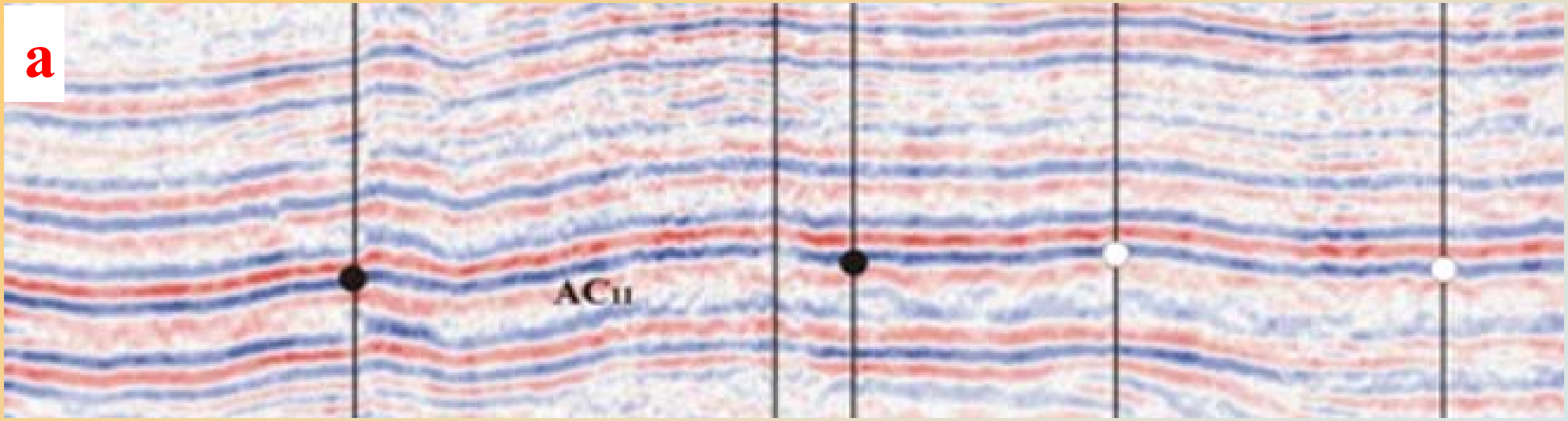
Data of Sibneft

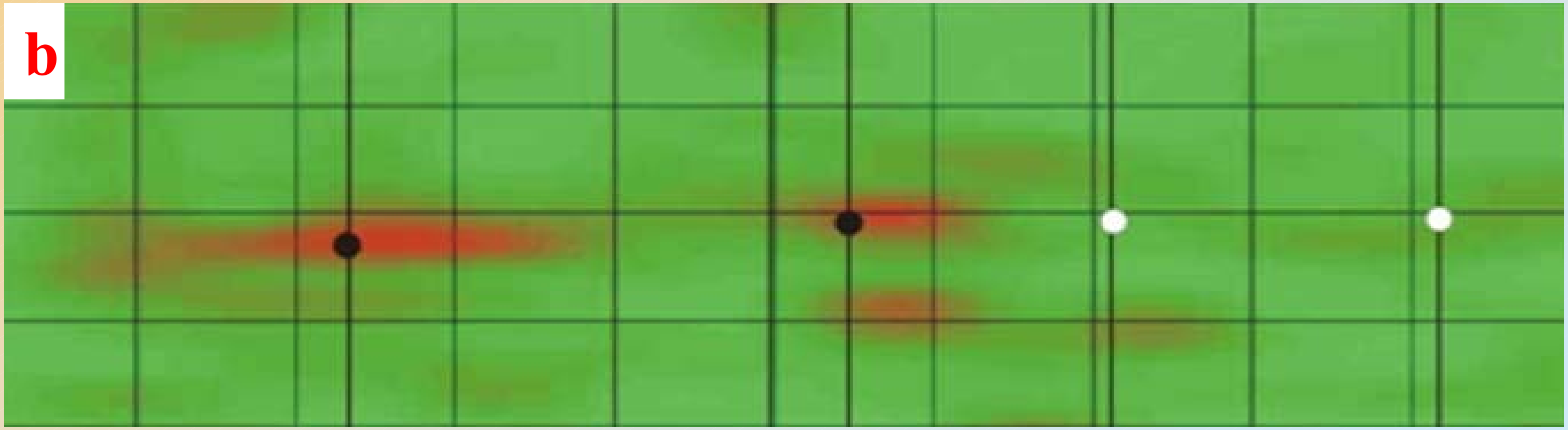
Seismic Monitoring



Frequency-Dependent Amplitude Analysis

Sandstone Reservoir



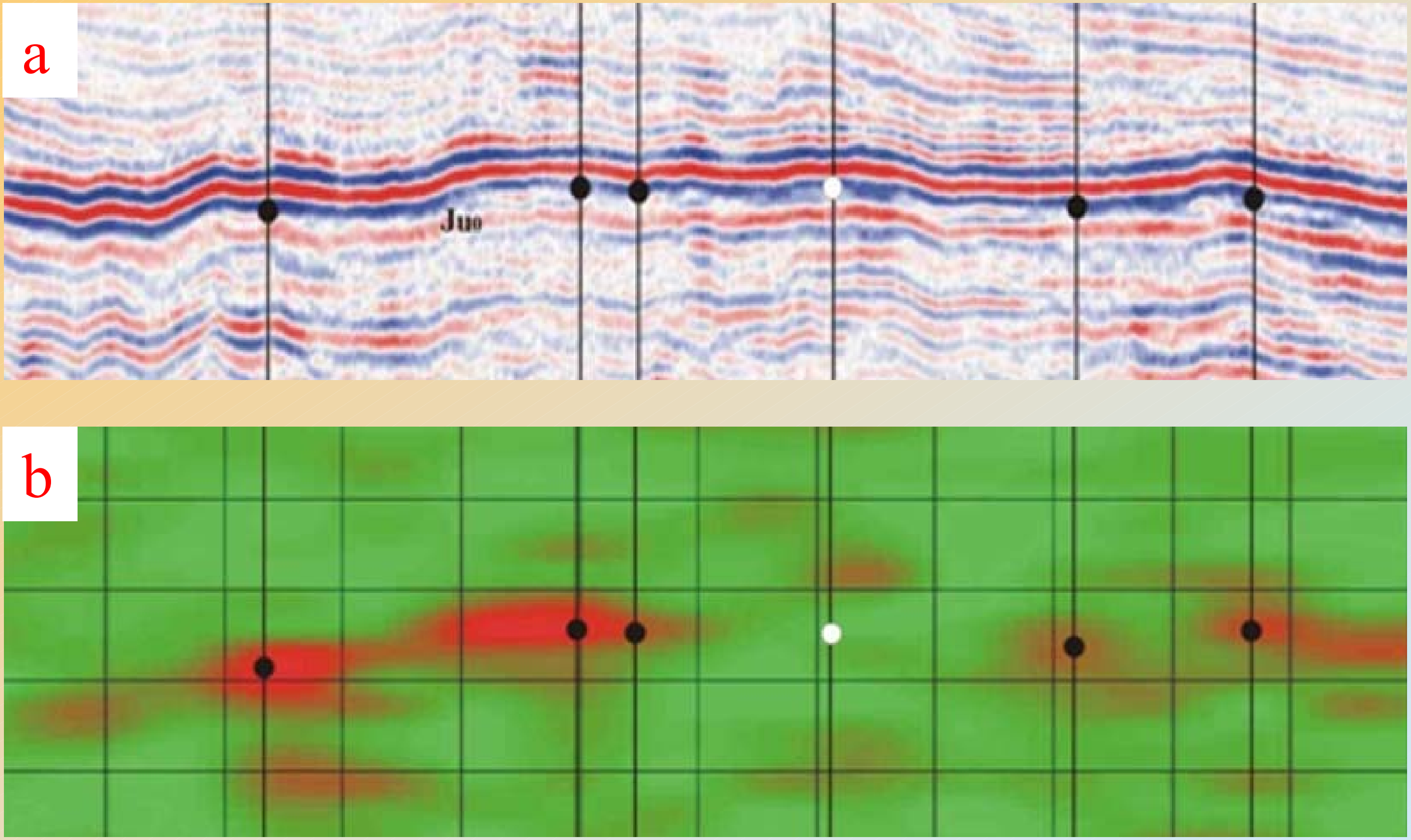


a – Conventional Processing **b – Frequency Decomposition & Analysis**

● - Oil ○ - No Oil

Data of Surgutneftegaz

Shale Reservoir



a – Conventional Processing; b – Frequency Decomposition & Analysis;

● - Oil ○ - No Oil

Data of Surgutneftegaz

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Development tasks

Theory Development

- Frequency-dependent AVO extension

Laboratory measurements

- Permeability and fluid dependencies

Field data analysis

- Existing 2D and 3D seismic data
- 4D data sets

Acknowledgments

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Thanks for your attention ...

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