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Prediction of reservoir parameters with seismic data

Xiucheng Wei* and Kristopher Innanen

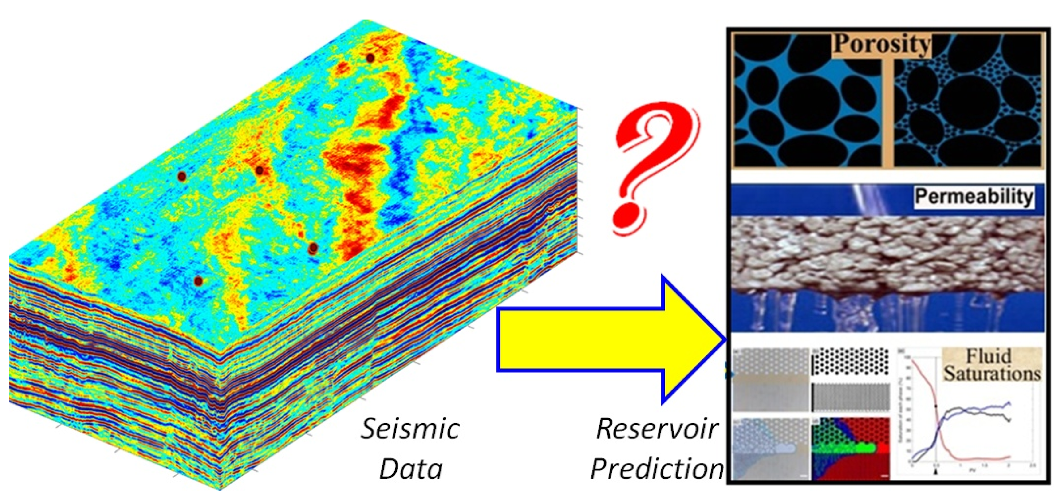
wei_xiucheng@hotmail.com

Introduction

The seismic response carries information of the oil and gas reservoir parameters. The conventional seismic inversion is only the inversion of the elastic parameters, or some seismic attributes. These results did not provide the porosity, permeability and fluid saturation parameters that directly affect the development of the oil reservoir. Some researchers proposed methods of predicting reservoir parameters using seismic data, but not at the same time for the above three reservoir parameters. The seismic response is a comprehensive result of reservoir parameters. The results of our study are shown here: The porosity, permeability and fluid saturation of oil and gas reservoir are predicted with seismic data at the same time under the unified rock physical model.

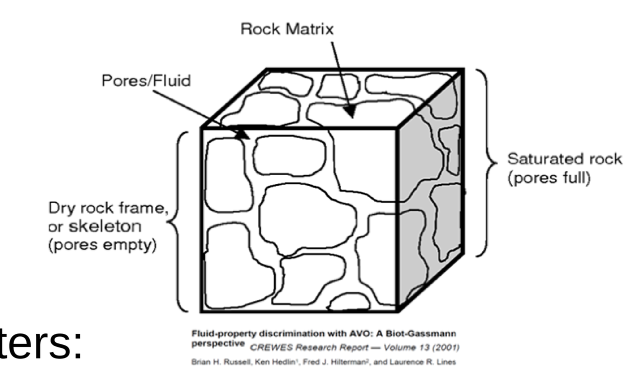
Objective

Under the condition of logging interpretation results and seismic horizon, the reservoir porosity, permeability and fluid saturation parameters, which are interested to reservoir engineers, are predicted with seismic data by using a unified petrophysical model.



Methods

Model：



Parameters:

	Bulk Modulus	shear modulus	Density	porosity	pore structure	Permeability	Saturation
Rock Matrix	K_m	μ_m	ρ_m	0			
Pores/Fluid	K_f	0	ρ_f				$S_g - S_o - S_w$
Skeleton	K_d	μ_d	ρ_d	φ	γ_s Size	K	
Saturated Rock	K_s	$\mu_s = \mu_d$	ρ_s		γ_c Roundness		$S_g - S_o - S_w$

Relations:

Rock Matrix:

$$K_m = \left[\sum_i P_i K_i + 1/(\sum_i \frac{1}{P_i K_i})\right]/2 \qquad \mu_m = \left[\sum_i P_i \mu_i + 1/(\sum_i \frac{1}{P_i \mu_i})\right]/2 \qquad \rho_m = \sum_i P_i \rho_i$$

Skeleton:

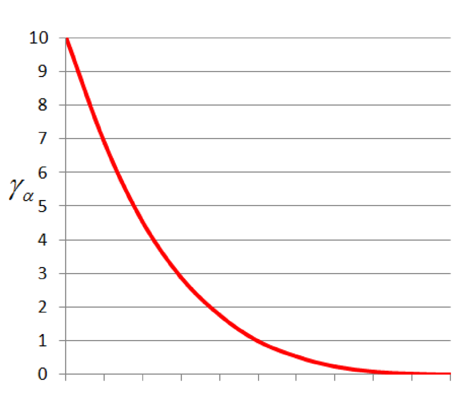
$$K_d = K_m \frac{1-\varphi}{1+\gamma_a \alpha\varphi} \qquad \mu_d = \mu_m \frac{1-\varphi}{1+\gamma_a \gamma\alpha\varphi} \qquad \rho_d = \rho_m(1-\varphi)$$

$$\alpha = 2\frac{1-\varphi_c}{\varphi_c} \qquad \gamma = \frac{1+2\alpha}{1+\alpha} \qquad \varphi_c - \text{Critical porosity}$$

$$\gamma_\alpha = a(1-\gamma_v)^2 + b(1-\gamma_v)^4 \qquad a=2, \quad b=8$$

$$\gamma_\alpha = \begin{cases} 10 & \gamma_v = 0 \\ 1 & \gamma_v = 0.5 \\ 0 & \gamma_v = 1 \end{cases}$$

$$\gamma_v = f(\gamma_s, \gamma_c)$$



Pores/Fluid:

$$\rho_f = \varphi(\rho_g S_g + \rho_o S_o + \rho_w S_w)$$

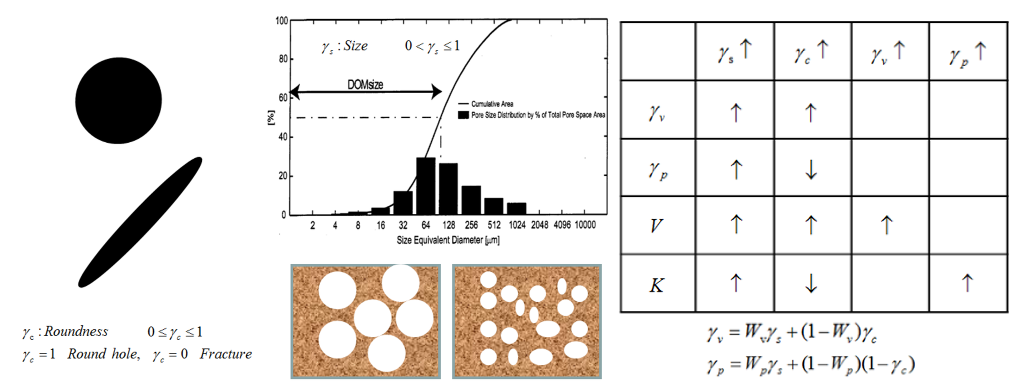
$$K_f = \begin{cases} K_f^{(1)}(0.15-\varphi)/0.15 + K_f^{(2)}\varphi/0.15 & 0 \le \varphi \le 0.15 \\ K_f^{(2)}(0.3-\varphi)/0.15 + K_f^{(3)}(\varphi-0.15)/0.15 & 0.15 \le \varphi \le 0.3 \\ K_f^{(3)} & \varphi > 0.3 \end{cases}$$

$$K_f^{(1)} = S_g K_g + S_o K_o + S_w K_w \qquad K_f^{(2)} = \rho_f V_f^2 = \rho_f / \left(\frac{S_g}{V_g} + \frac{S_o}{V_o} + \frac{S_w}{V_w}\right)^2 \qquad K_f^{(3)} = 1/\left(\frac{S_g}{K_g} + \frac{S_o}{K_o} + \frac{S_w}{K_w}\right)$$

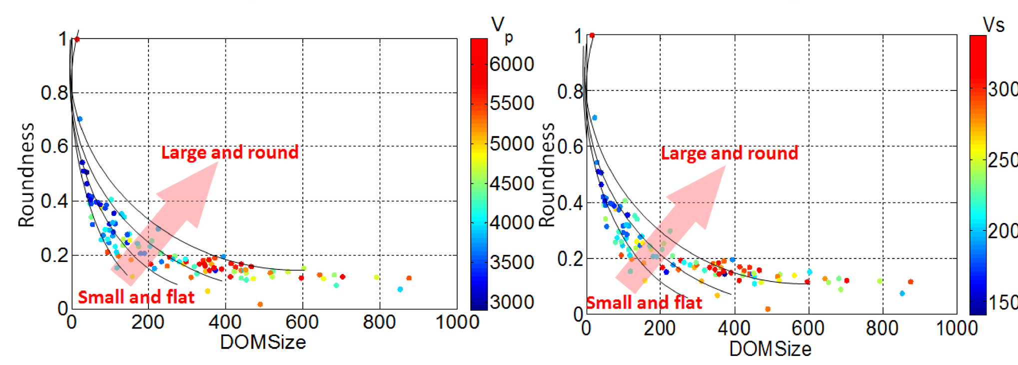
Saturated Rock:

$$K_s = K_d + \frac{\left(1-\frac{K_d}{K_m}\right)^2}{\frac{\varphi}{K_f} + \frac{1-\varphi}{K_m} - \frac{K_d}{K_m^2}} \qquad \mu_s = \mu_d \qquad \rho_s = \rho_m(1-\varphi) + \varphi(\rho_g S_g + \rho_o S_o + \rho_w S_w)$$

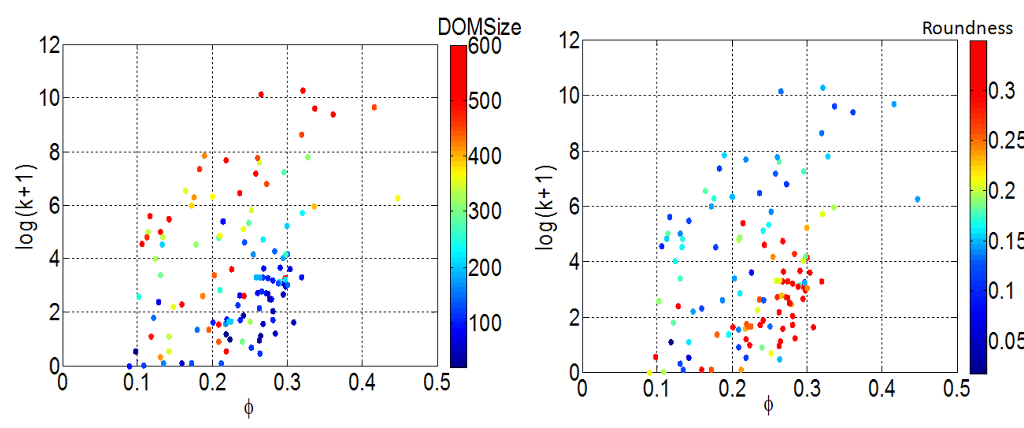
Pore structure



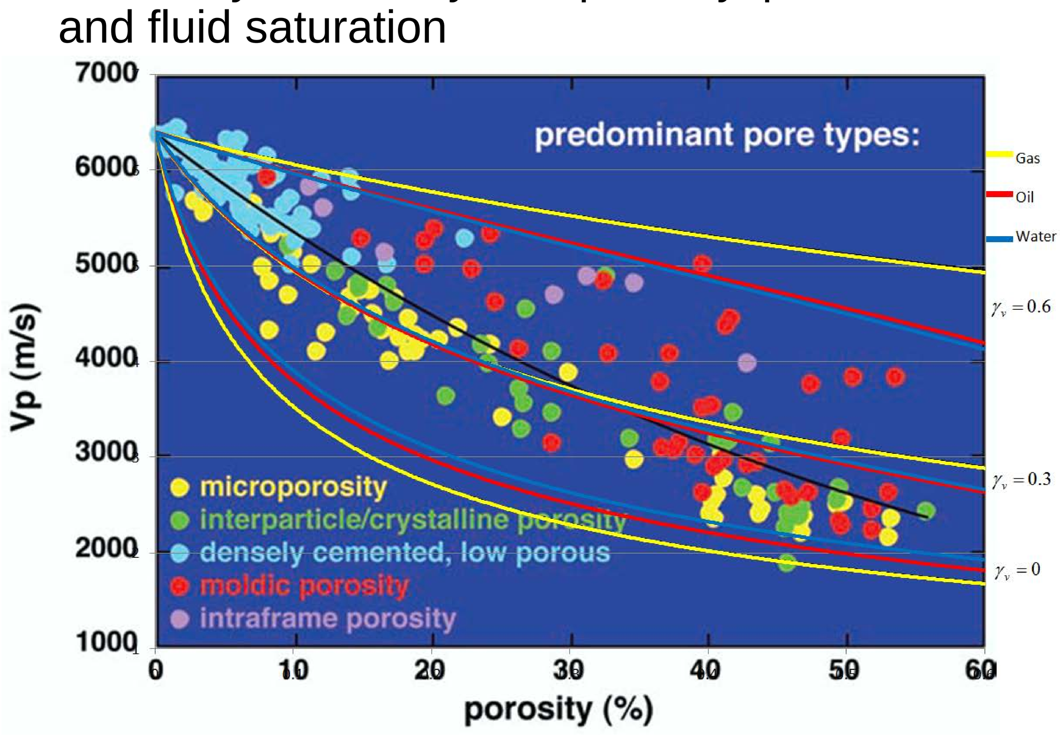
Effect of pore structure on Velocity



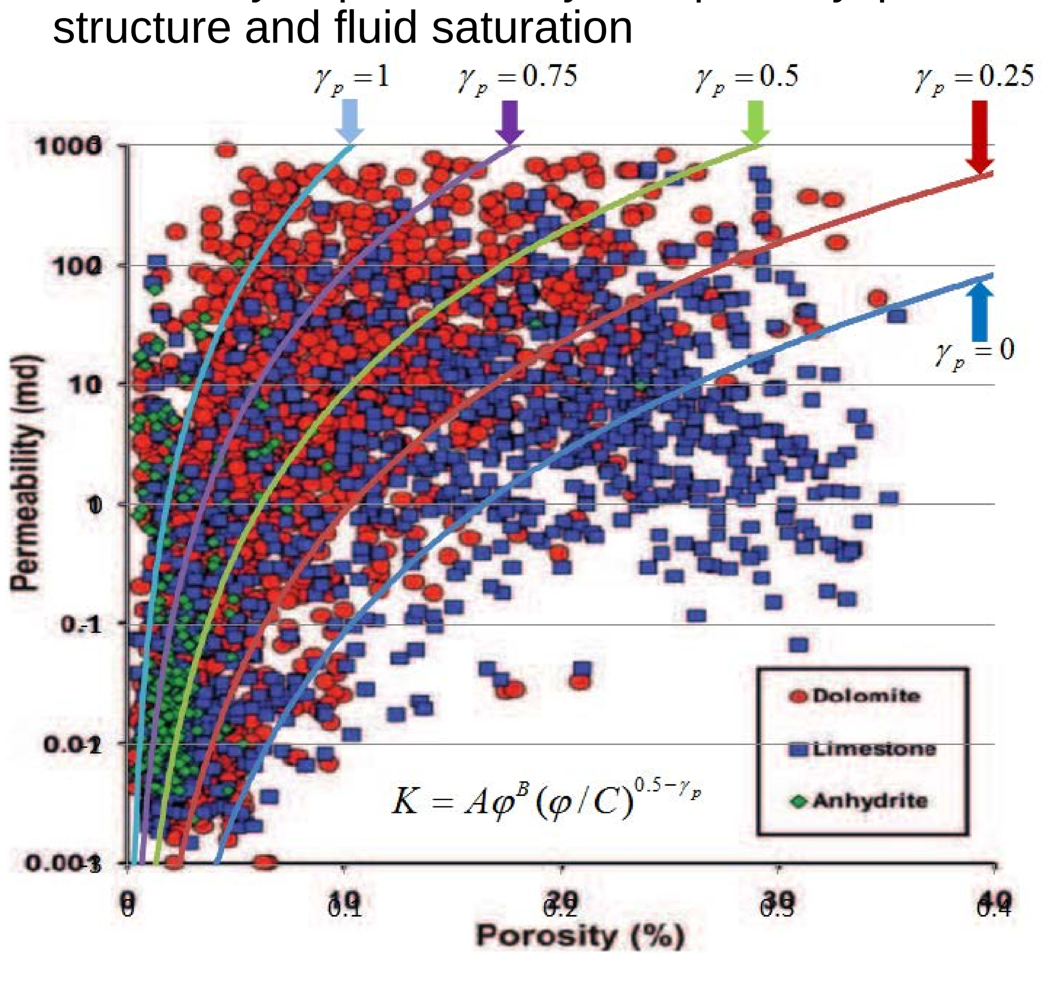
Effect of pore structure on permeability



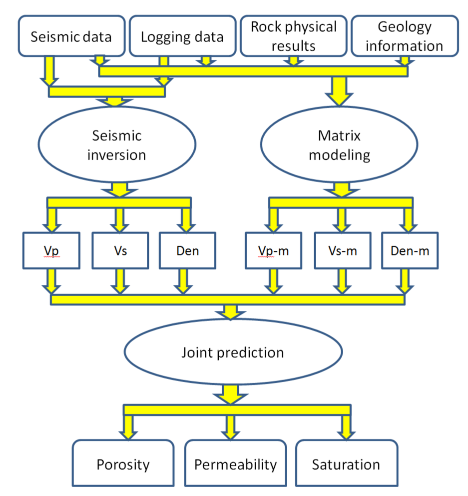
The variety of velocity with porosity, pore structure and fluid saturation



The variety of permeability with porosity, pore structure and fluid saturation



Workflow

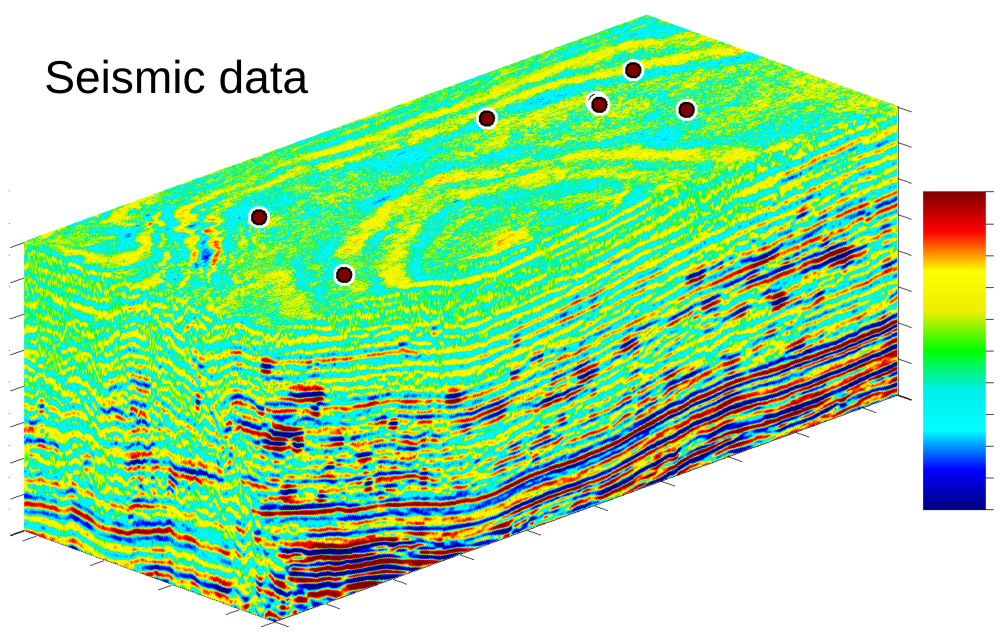


Results

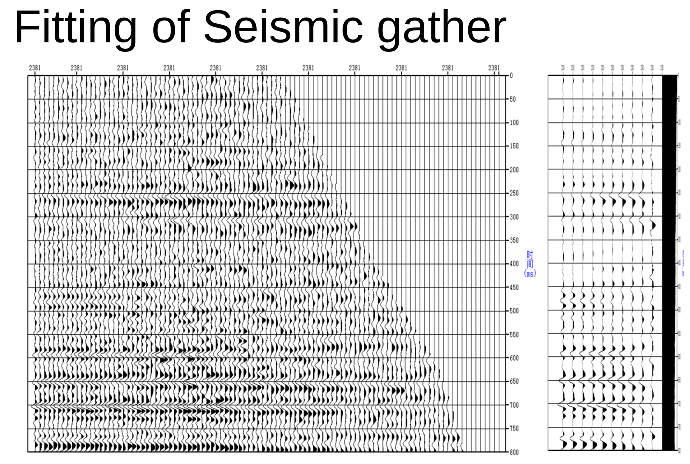
Data range:12.5*17=212.5 square kilometer.

7 wells with logging interpretation.

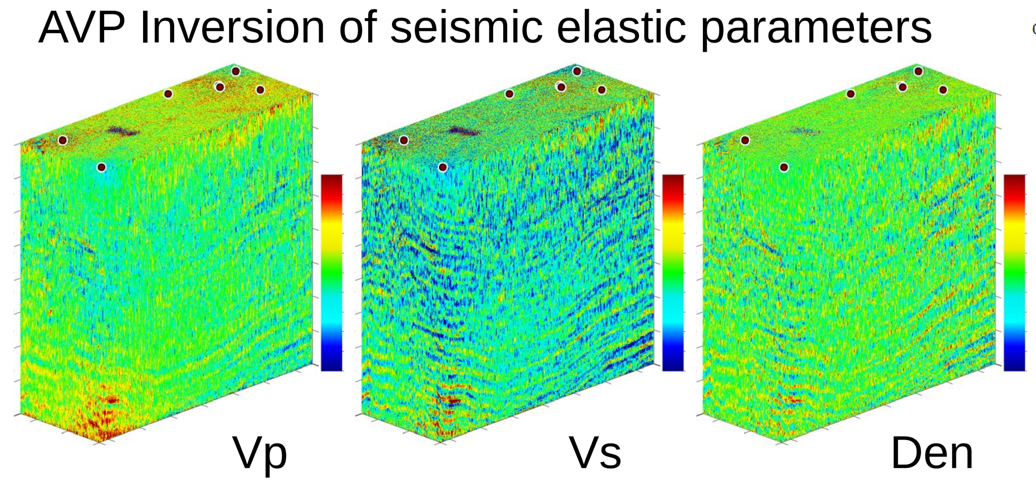
Seismic data



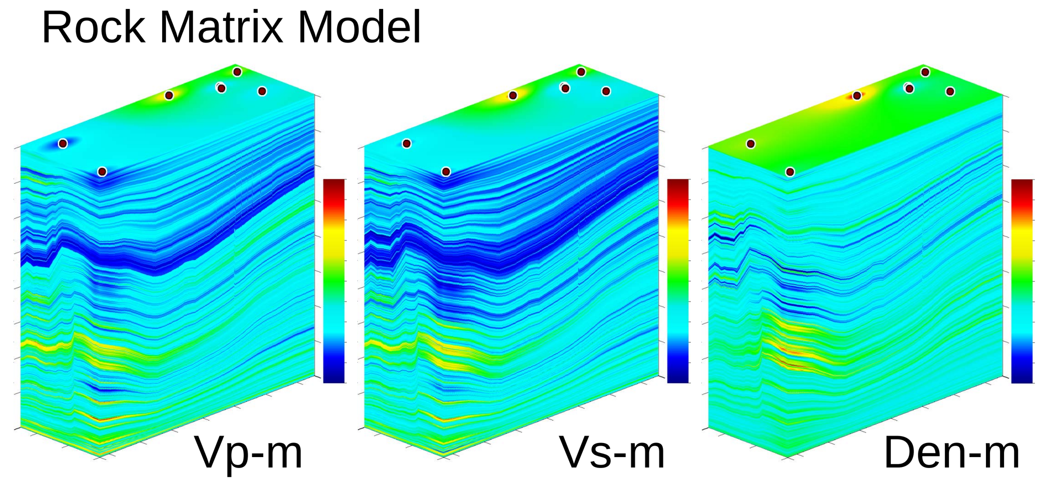
AVP Fitting of Seismic gather



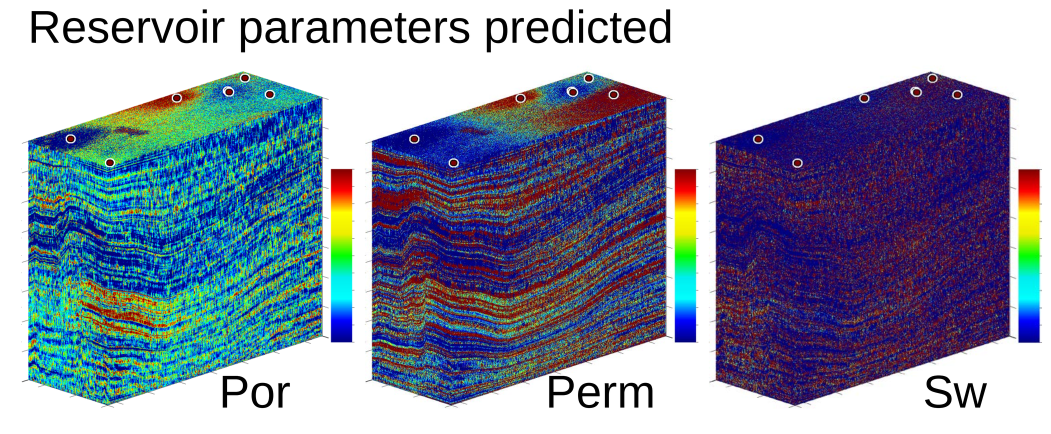
AVP Inversion of seismic elastic parameters

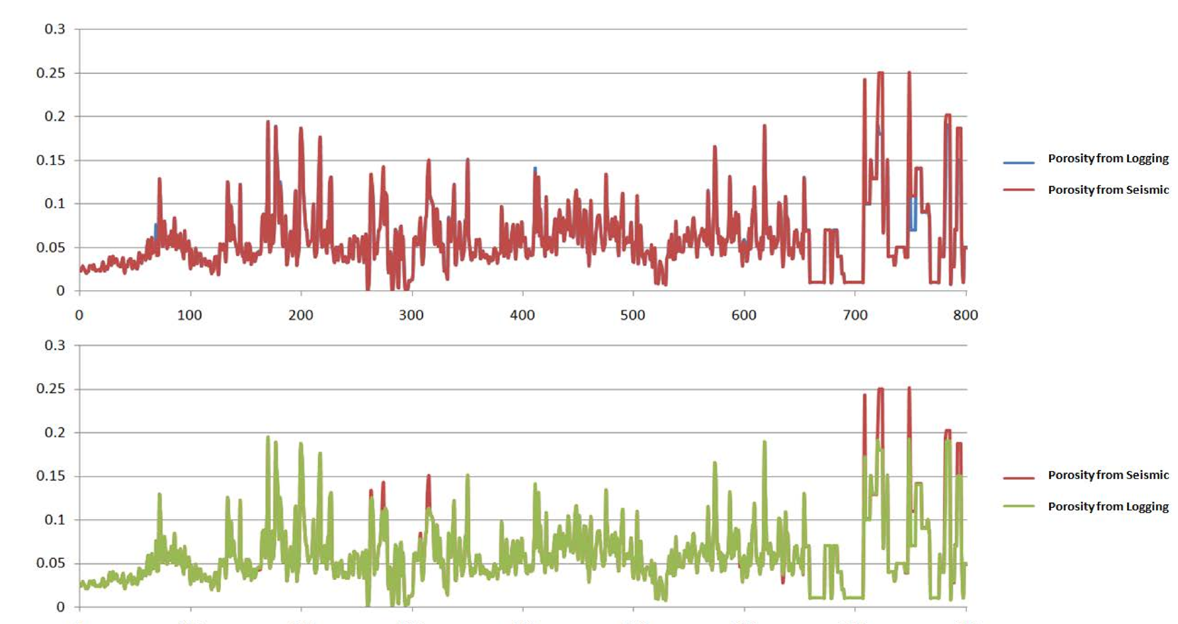


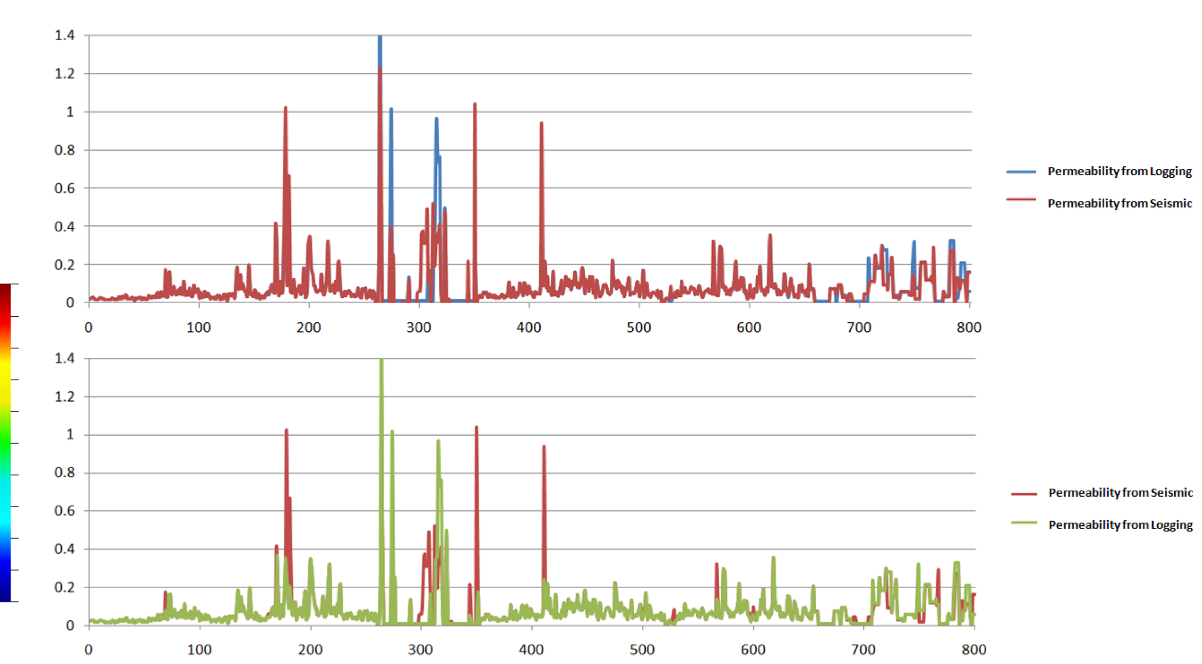
Rock Matrix Model

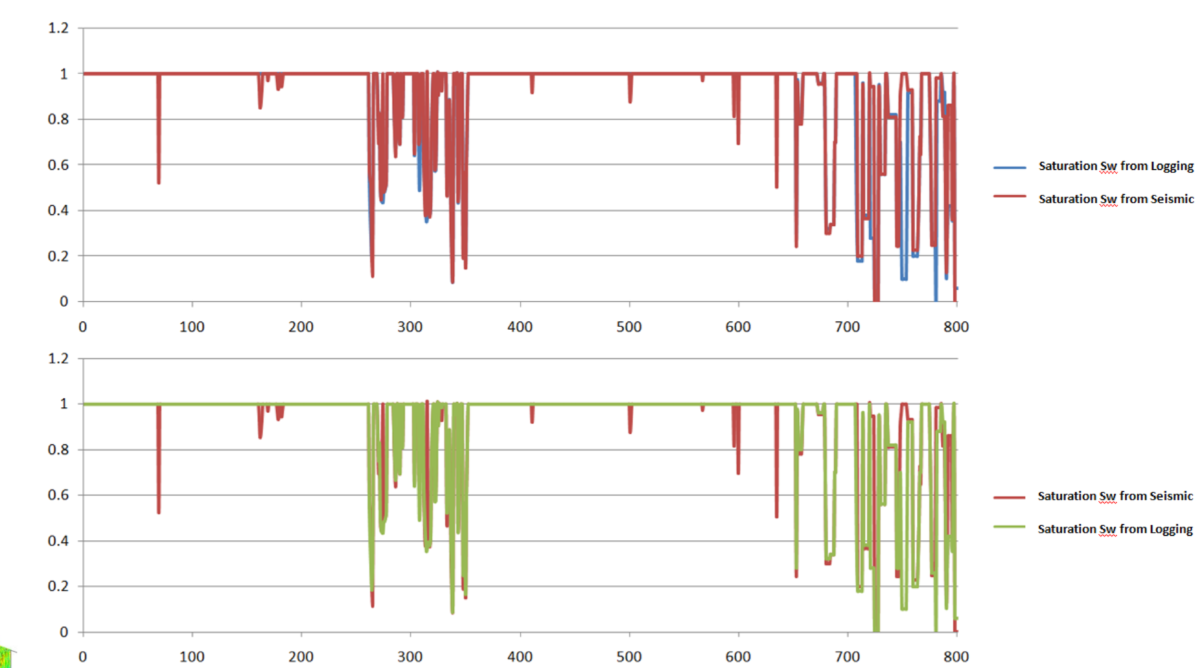


Reservoir parameters predicted



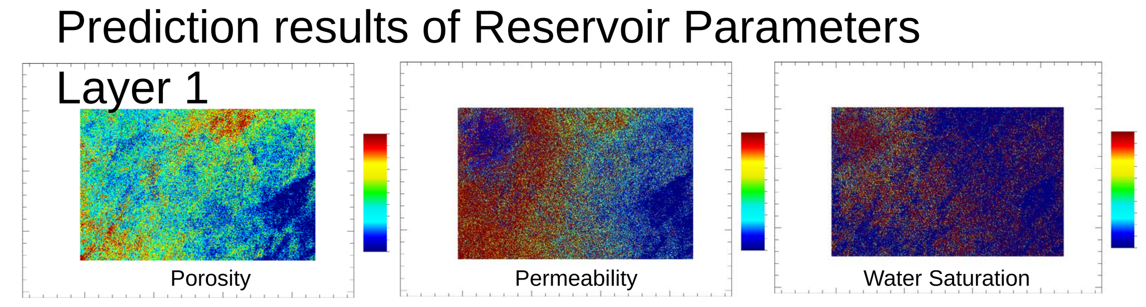




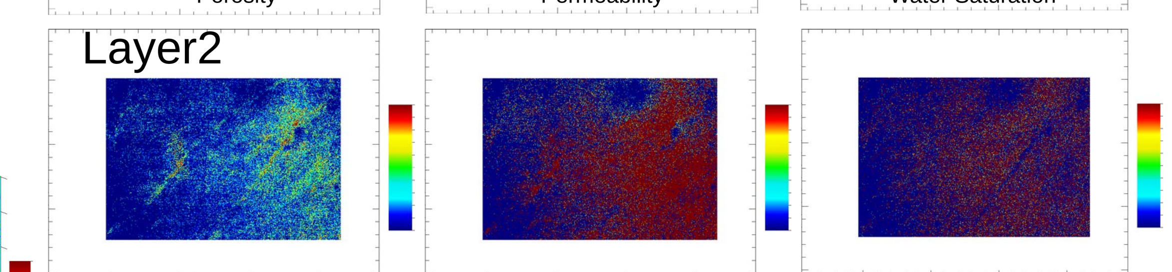


Prediction results of Reservoir Parameters

Layer 1



Layer2



Conclusion

1. It is very important to establish a petrophysical model that contains rock matrix, dry rock frame, pore structure characteristics and different fluid saturation.
2. The inversion results of seismic elastic parameters directly affect the accuracy of reservoir parameter prediction, and the seismic AVP inversion, which is superior to AVO inversion, has been effectively applied.
3. Rock matrix model with zero porosity established in space is the key step of reservoir parameters prediction. The result of sedimentary facies will be applied to the modeling of rock matrix, which should improve the prediction precision.

References

1. Brian H. Russell, etc. Fluid-property discrimination with AVO: A Biot-Gassmann perspective, CREWES Research Report-Volume 13(2001).
2. Ralf J. Weger, etc. Quantification of pore structure and its effect on sonic velocity and permeability in carbonates, *AAPG Bulletin* 10(93):1297-1317, **October 2009.**
3. Yue Feng Sun, Pore structure effects on elastic wave propagation in rocks: AVO modeling, *Journal of Geophysics and Engineering*, Volume 1, Issue 4, December 2004, Pages 268–276.

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UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
Department of Geoscience