Interpretation of a multicomponent walkaway VSP experiment

CREWES Project

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Outline

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  - Post-stack and pre-stack inversion of P-wave data
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  - PP-PS joint inversion and comparison to P-wave inversion
- **Summary**
- **Acknowledgements**

Objective

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Apply multicomponent VSP data to characterize the target reservoir

- Obtain rock properties and fluid information by inversion and AVO analysis on the P-wave data
- Conduct PP-PS joint inversion, add details to P-wave interpretation

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Why 3C walkaway VSP data?

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- Converted-wave data enhance traditional P-wave exploration
- Accurate time-depth conversion of geological features
- High S/N, broad-band data
- Deterministic deconvolution
- Can obtain robust reflection coefficients
- Walkaway VSP geometry is ideal for AVO analysis

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3C walkaway VSP acquisition

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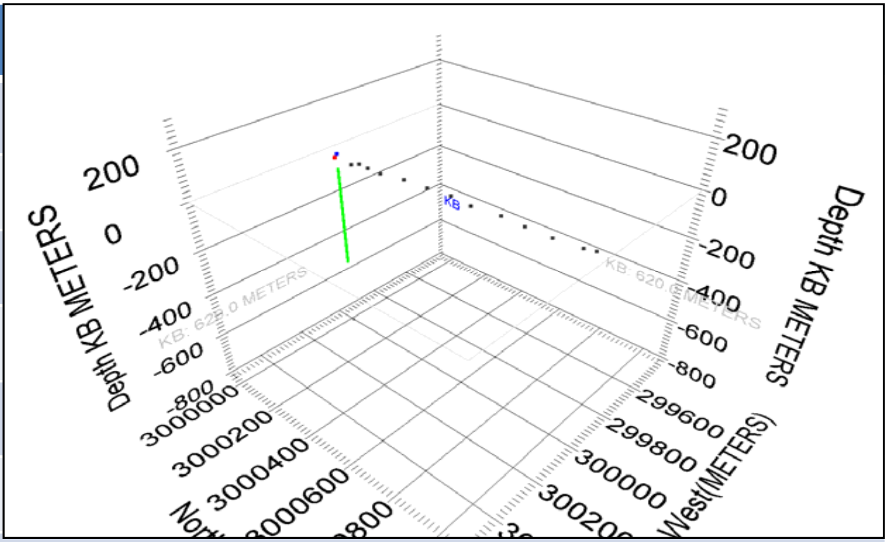
Acquisition parameters & geometry

	Dynamite	Vibroseis
Receiver type	VectorSeis	VectorSeis
Number of receivers/spacing	220/2m	220/2m
Receiver depth (m)	55-507	55-507
Sample rate (ms)	1	1
Record length (s)	3	3
Offset (m)	11.5-1031	11.5-1031
Charge (kg)/ Sweep	0.125	EnviroVibe, 10-300Hz, over 20s, linear, one sweep per vibe point, 100/1000ms taper
Borehole	562m TD, vertical, no fluids in borehole	



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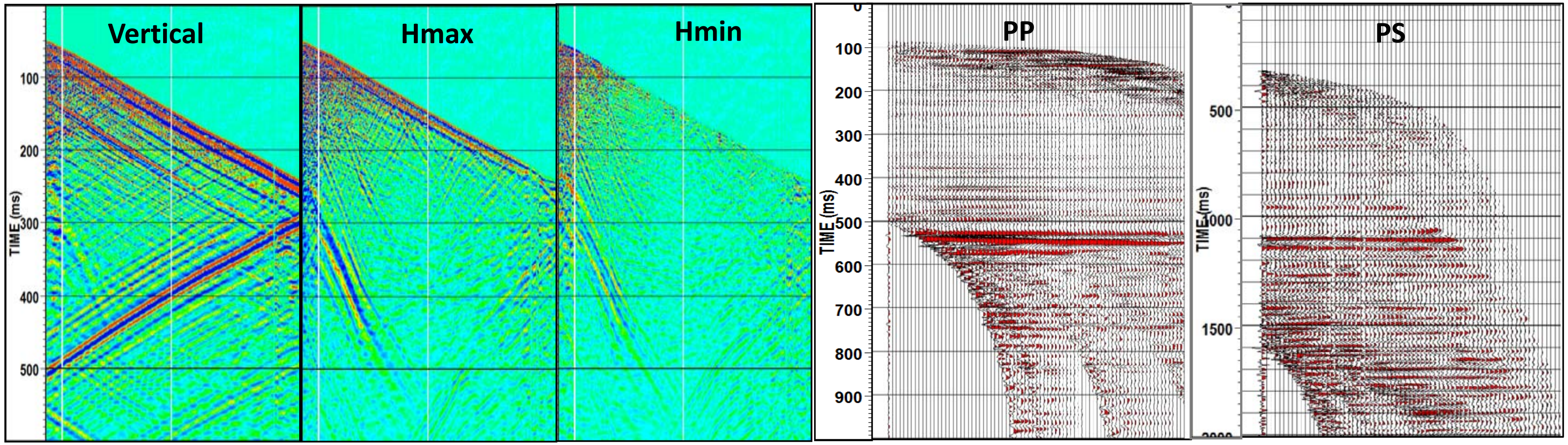
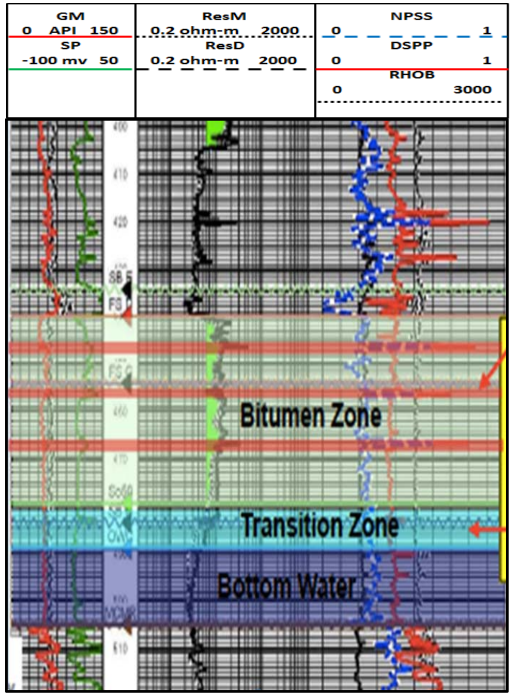
Shot record and processed image



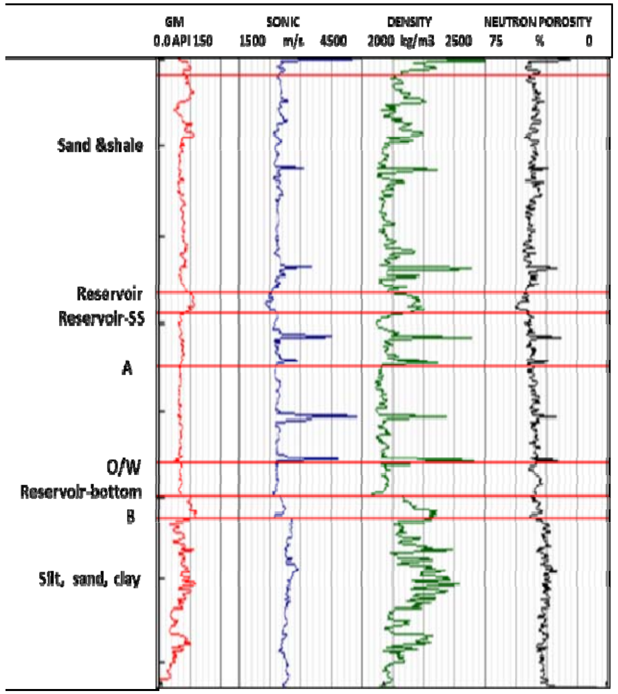
Shot record

Processed images

Geology and well log analysis



Typical logs in study area



Logs from well A

- a heavy oil reservoir
- deposited as incised valleys, encased within deltaic, shoreface sands and marine muds
- relatively shallow (500 m), with unconsolidated/partly consolidated sand/shale sequence
- thickly bedded sandstone reservoir (50-75 m)
- high porosity (20-30%)

P-wave post-stack inversion

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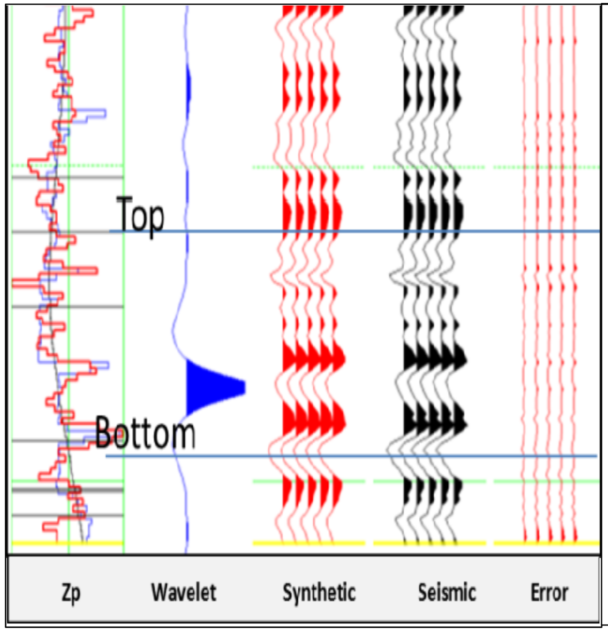
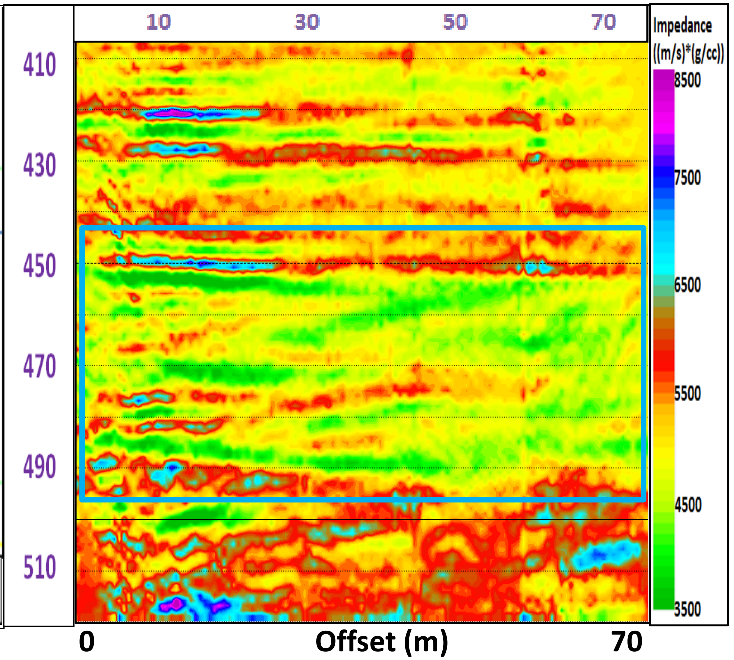
Inversion analysis



P-impedance



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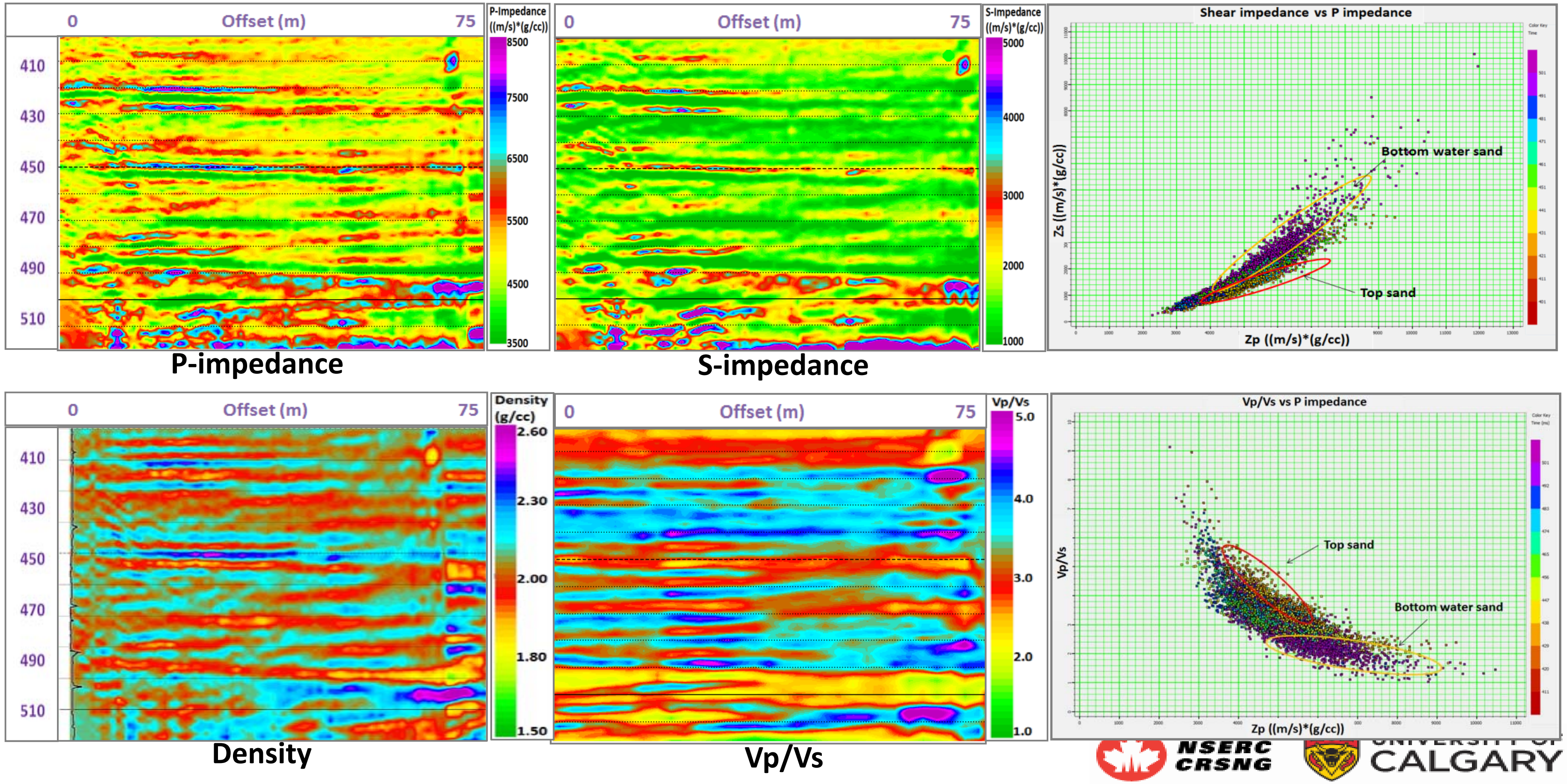
P-wave pre-stack inversion



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P-wave AVO responses

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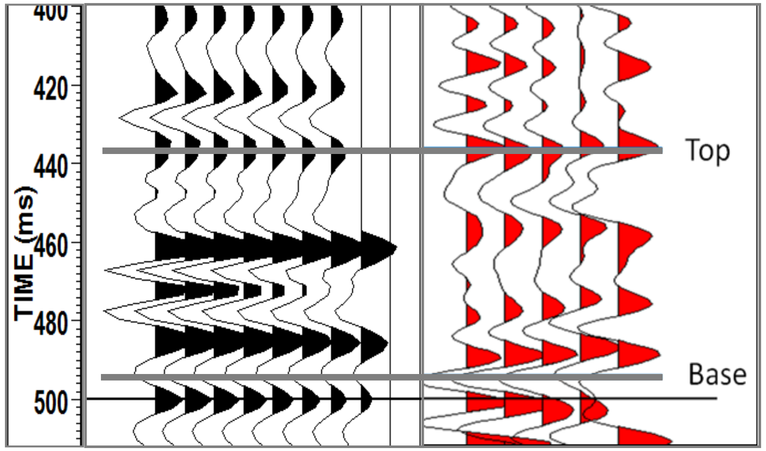

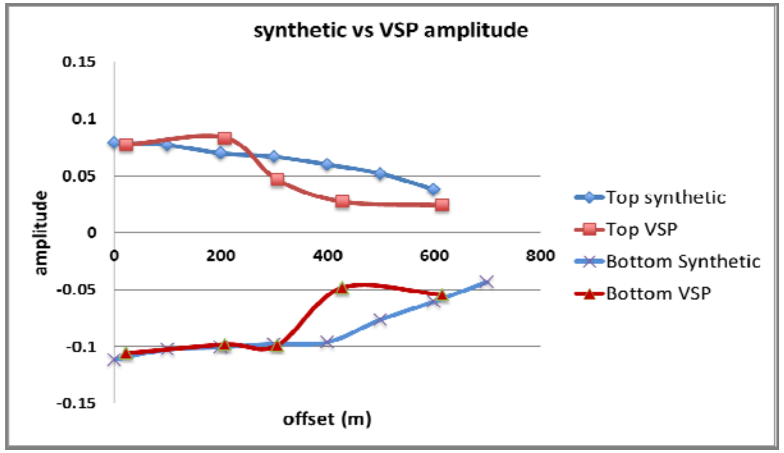

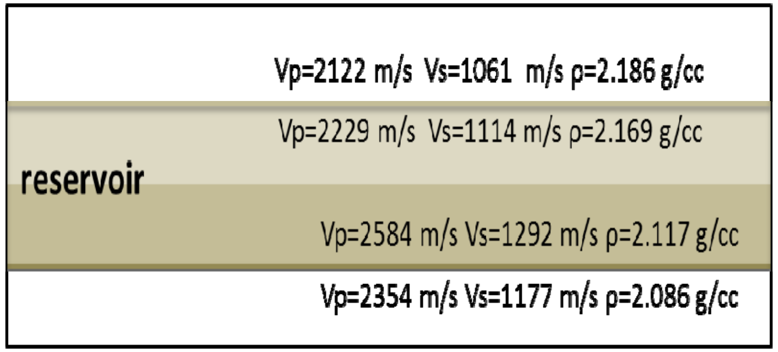

Reservoir	Top	Base
Interface	shale-sand	sand-shale
Impedance change	+ve	-ve
Amplitude	+ve	-ve
Amplitude change	Decreases with offset	Decreases with offset
Poisson's ratio	Decrease	Increase
AVO classification	I	IV
	Wet sand, no gas response	

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AVO attributes

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	Two-term Aki-Richard	Two-term Fatti method
Attributes	Intercept A	Rp0
	Gradient B	Rs0
Derived attributes	AVO product: A*B	Zp
	Poisson’s ratio change : A+B	Zs
	Shear wave reflectivity: A-B	Lambda-Mu-Rho

Wiggins’ form (1986) of Aki-Richard equation is:

$$R_\theta = A + B\sin^2\theta$$

where:

$$A = \left[\frac{\Delta V_p}{2V_p} + \frac{\Delta\rho}{2\rho}\right] \text{ and } B = \frac{\Delta V_p}{2V_p} - 4\left[\frac{V_s}{V_p}\right]^2\frac{\Delta V_s}{V_s} - 2\left[\frac{V_s}{V_p}\right]^2\frac{\Delta\rho}{\rho}$$

A is called the intercept, B the gradient, and the A*B called AVO product.

Fatti et al.(1994) rewritten Aki-Richards equation as:

$$R_p(\theta) = c_1 R_p(0^0) + c_2 R_s(0^0)$$

Where $R_p(0^0) = \frac{1}{2}\left[\frac{\Delta V_p}{V_p} + \frac{\Delta\rho}{\rho}\right]$ *and* $R_s(0^0) = \frac{1}{2}\left[\frac{\Delta V_s}{V_s} + \frac{\Delta\rho}{\rho}\right]$

$$c_1 = 1 + \tan^2\theta,\ c_2 = -8\left(\frac{V_s}{V_p}\right)^2\sin^2\theta$$

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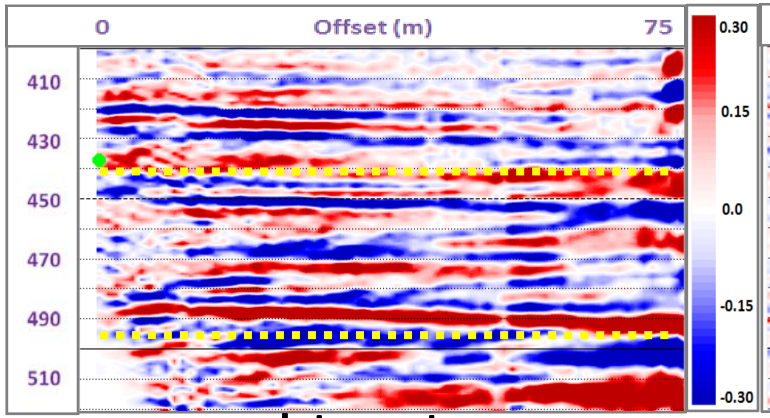
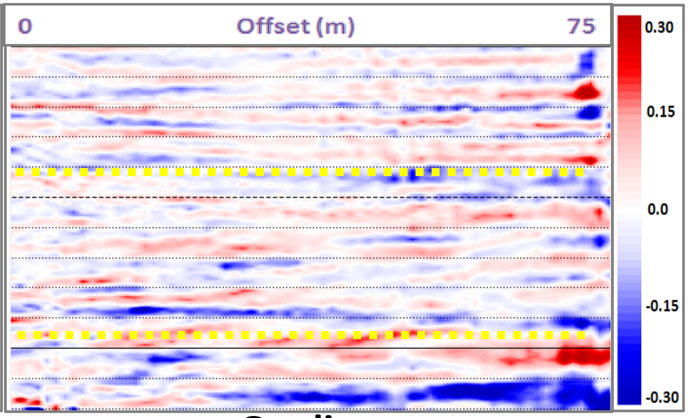
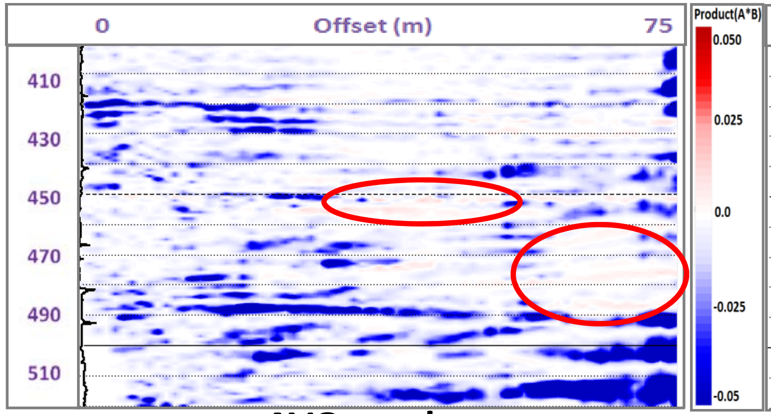
AVO attributes analysis



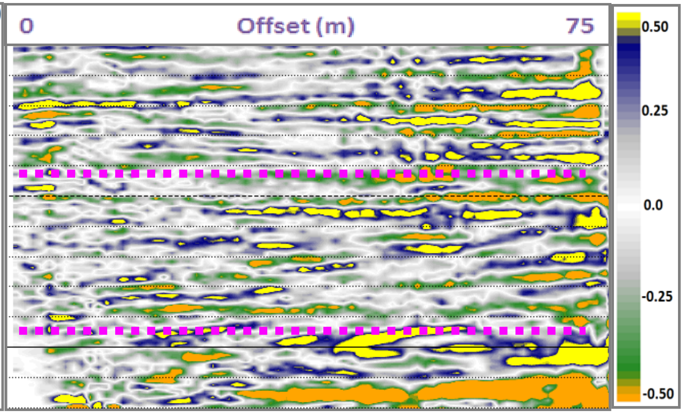
Intercept



Gradient

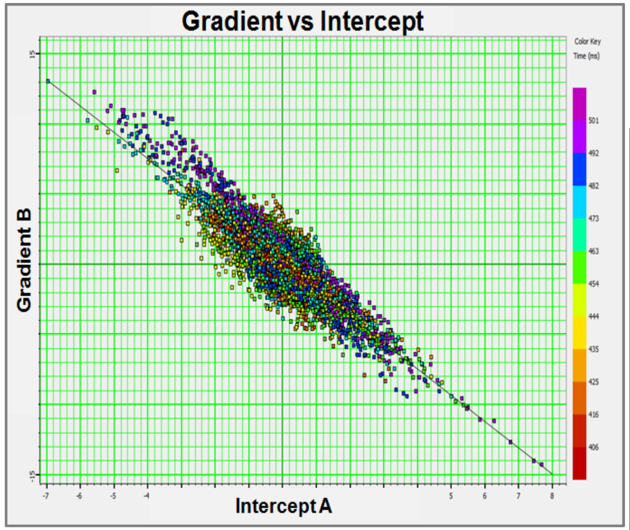


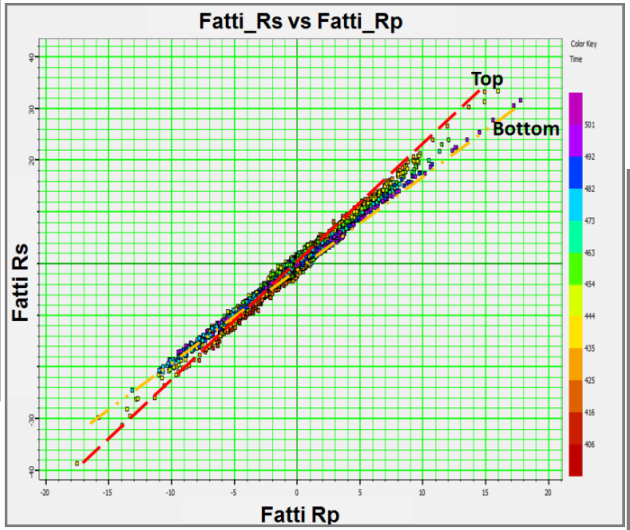
AVO product

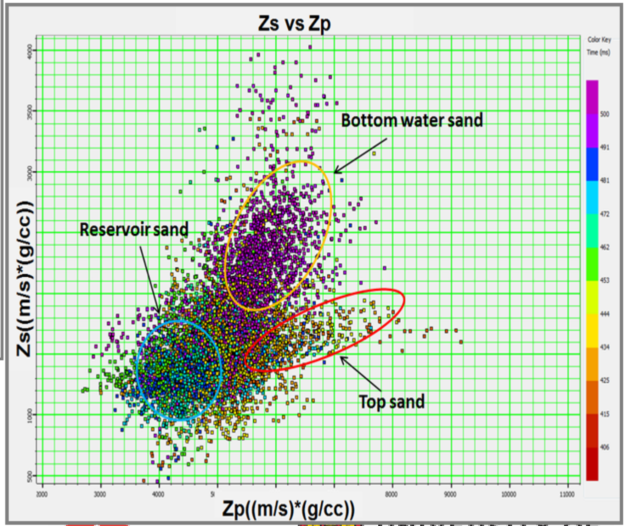


Scaled Poisson’s ratio change

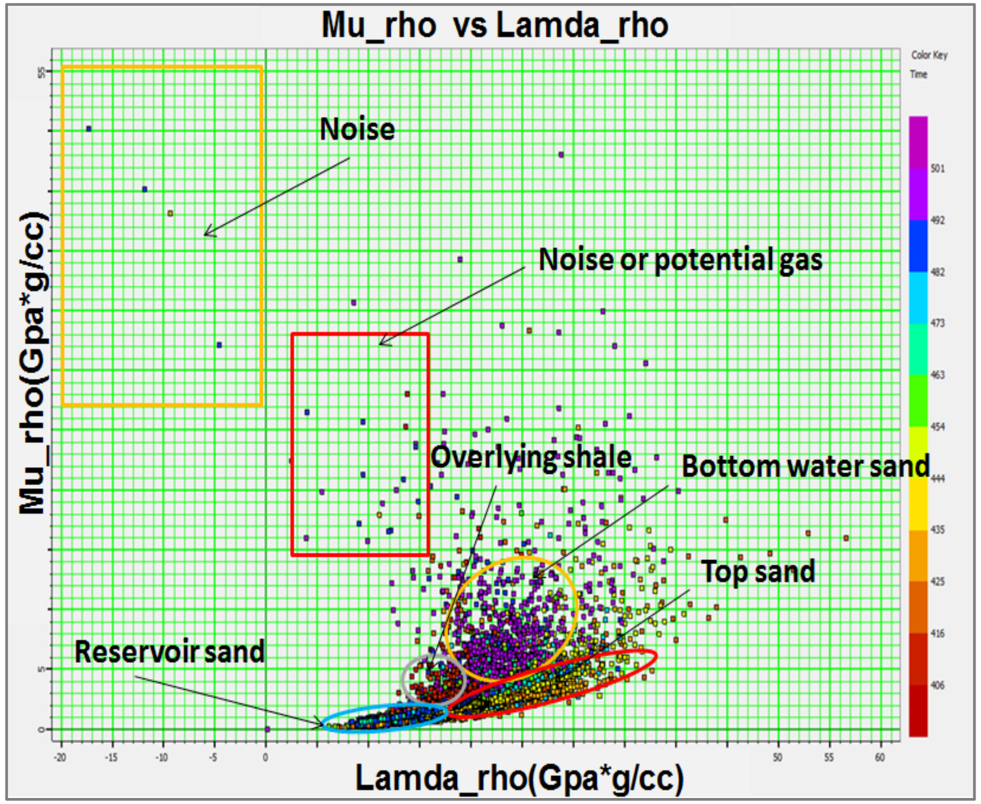
AVO attribute crossplots





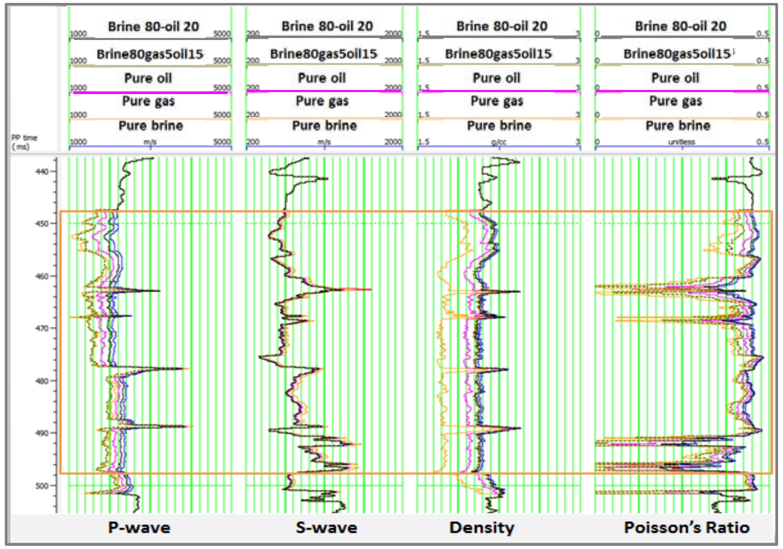


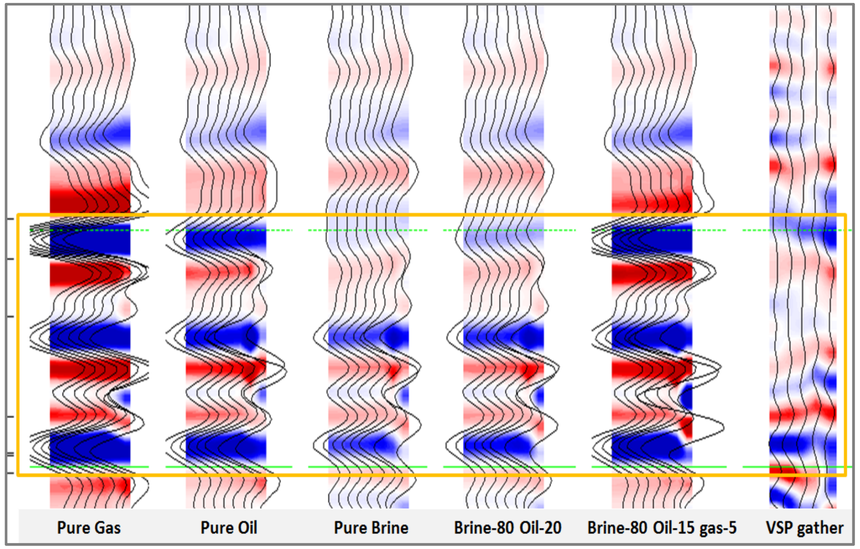
AVO Lamda-Mu- Rho analysis



- Crossplot minimizes the effects of density
- the λ (incompressibility) is sensitive to pore fluid - an indicator of water vs gas
- the μ (rigidity) is sensitive to rock matrix - pure rock fabric or lithology

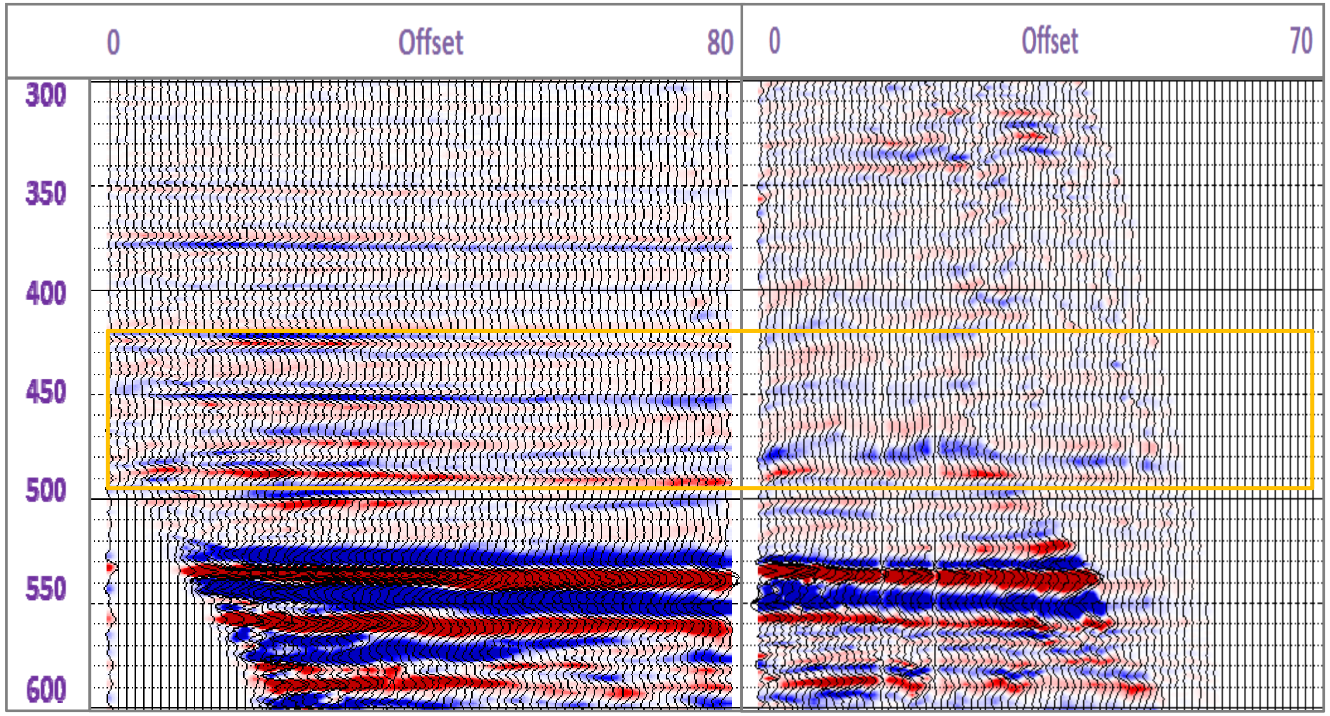
AVO modeling and production data





	Gas (c^3m^3)	Oil(m^3)	Water (m^3)	Gas%	Oil%	Water%
F12 Mo Prod	0	434	7443	0%	5.5%	94.5%
L12 Mo Prod	8	641	7267	0.1%	8.1%	91.8%
Cumulative Prod	8	1075	14710	0.05%	6.81%	93.14%

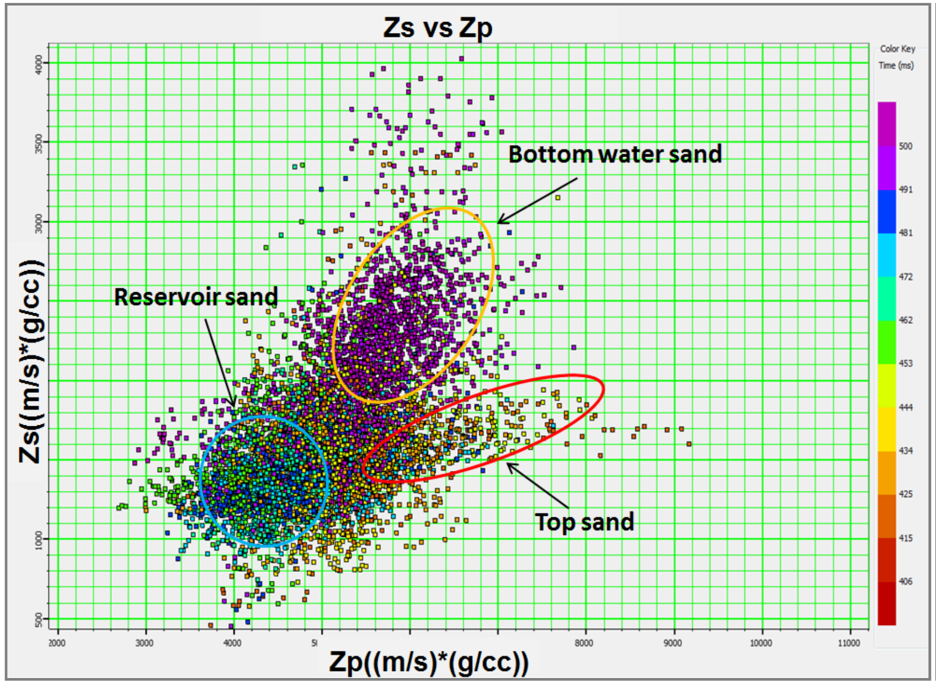
PP-PS registration



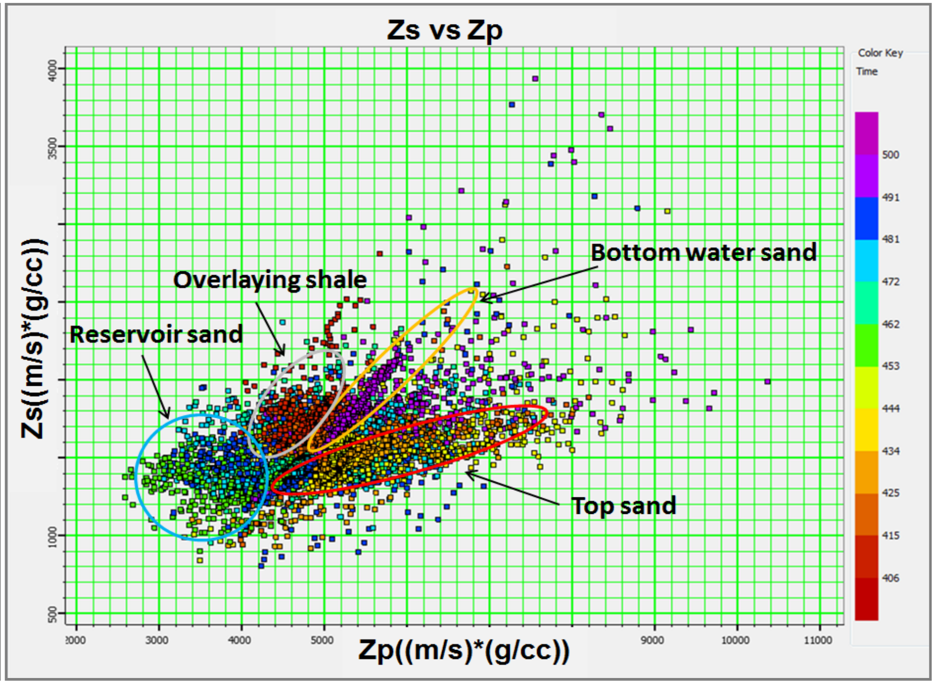
PP image

PS image

Comparison of P-wave and PP-PS joint inversion



P-wave inversion



PP-PS joint inversion

Summary

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- ☑ Hydrocarbon signatures may be more visible on VSP than surface seismic data
- ☑ Inverted rock properties and crossplots, AVO Lambda-mu-rho analysis are effective tools to predict lithologies and fluids in the reservoir studied.
- ☑ AVO analysis and modeling show no gas effects in the study interval which was validated by production data.
- ☑ Converted-wave data improve the accuracy of prediction of lithology and fluid discrimination
- ☑ The limitation of S-wave data, the distance of well and VSP borehole as well as absence of S-wave log may degrade the reliability of the detailed interpretations.

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