



# Density estimations from seismic inversion and density-velocity relations

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# Outline

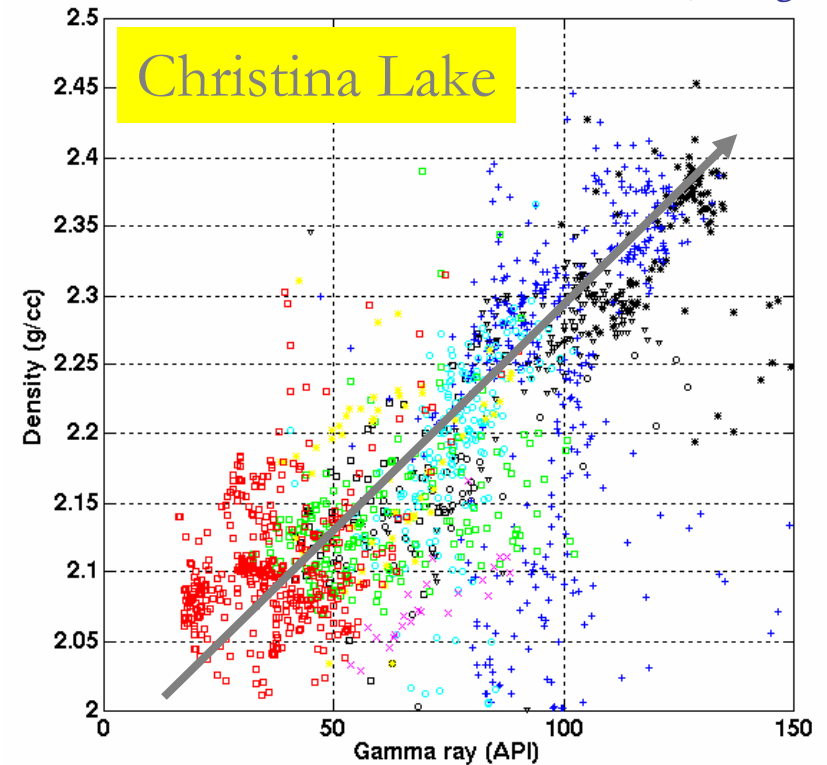
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- Introduction
- Area of study
- Log analysis and crossplots
- Density-velocity relations
- Band-limited inversion
- Summary

# Introduction

- Bulk density of a rock
  - Mineral composition
  - Porosity
  - Fluid type
  - Water saturation
- Estimating density from seismic data
  - Limitations
  - Constraints

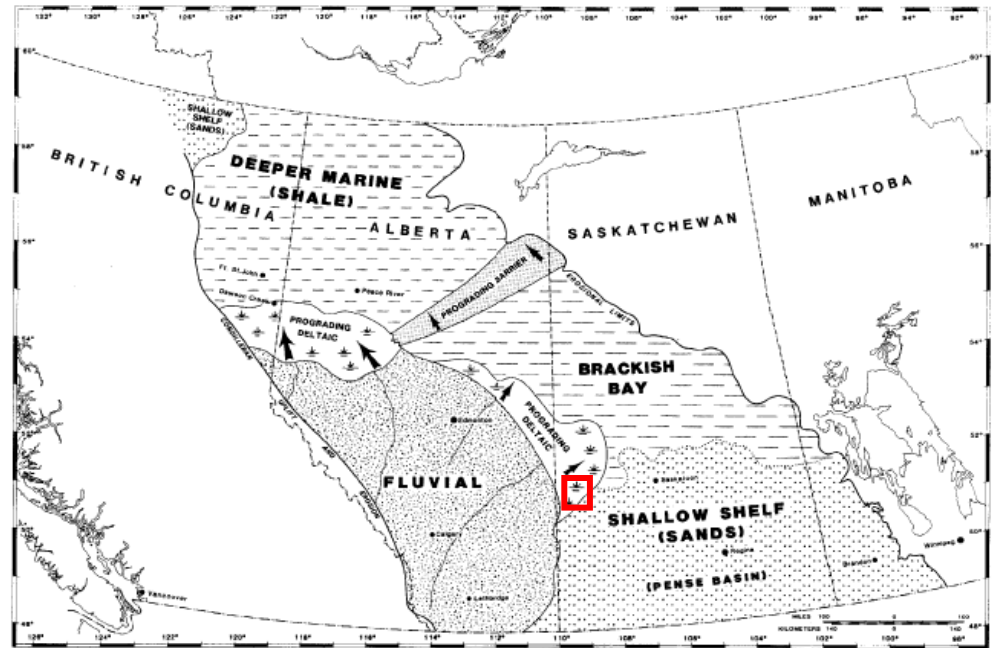
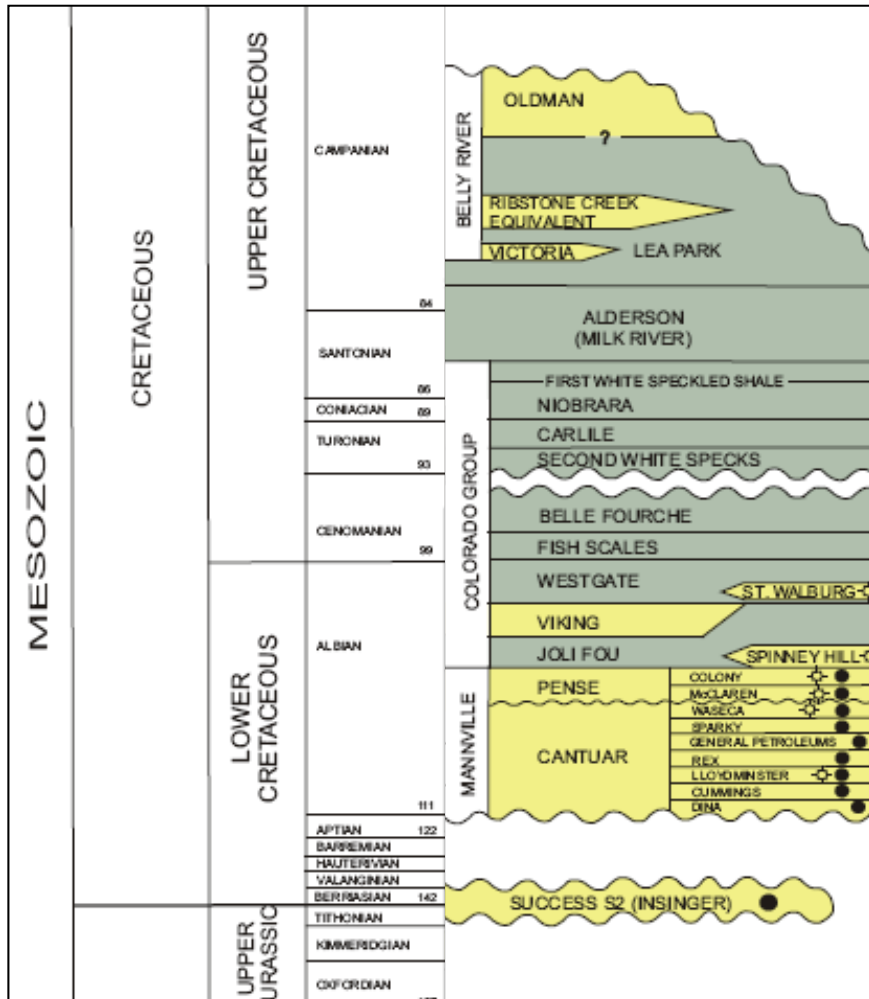
From Xu, Yong



- Best quality sand
- Good quality sand
- Bad quality sand
- Marine sand
- Marine mud

# Area of study

- 3C-3D survey near Manitou Lake, Saskatchewan

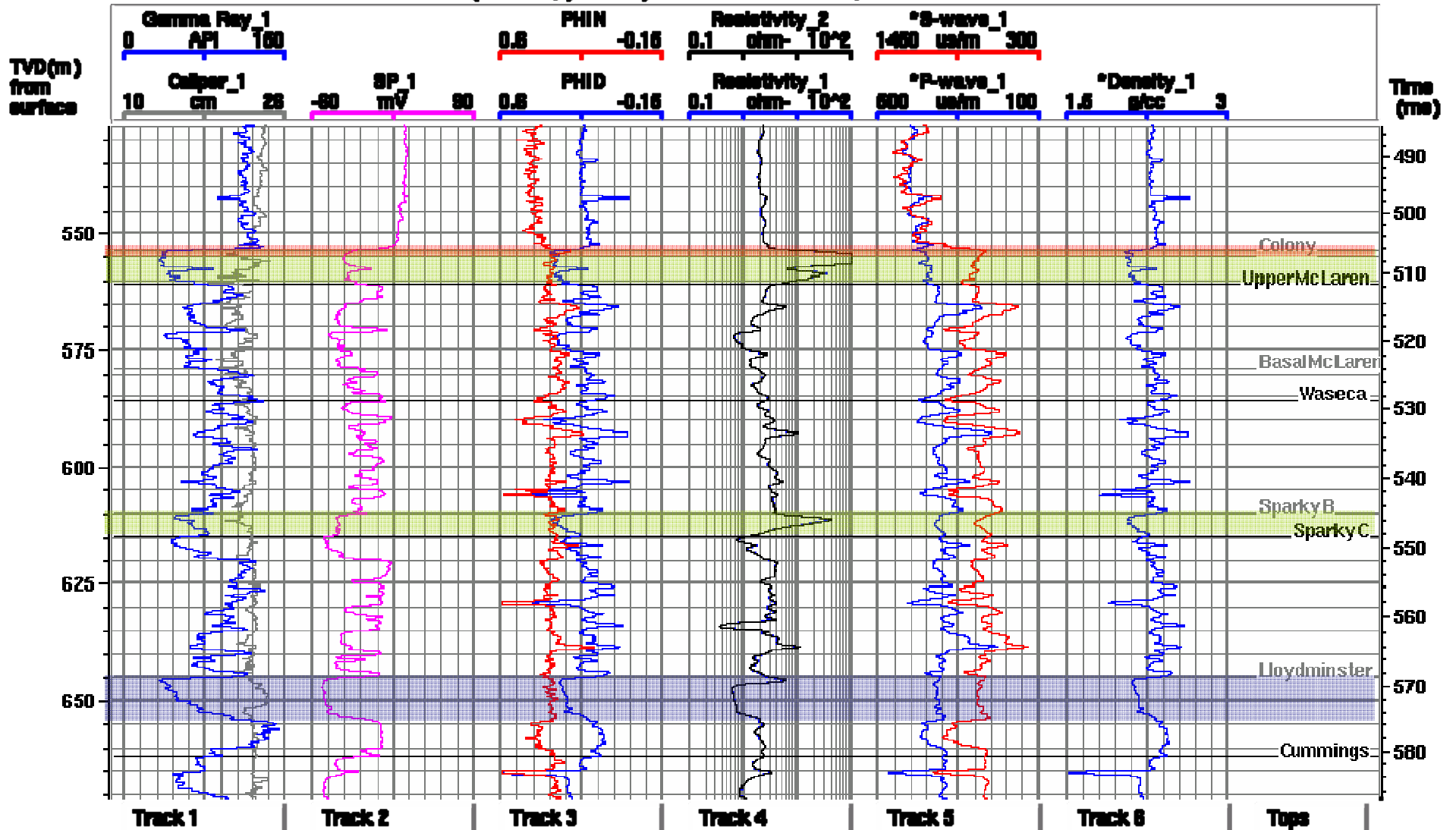


← Colony } Targets  
 ← Sparky }

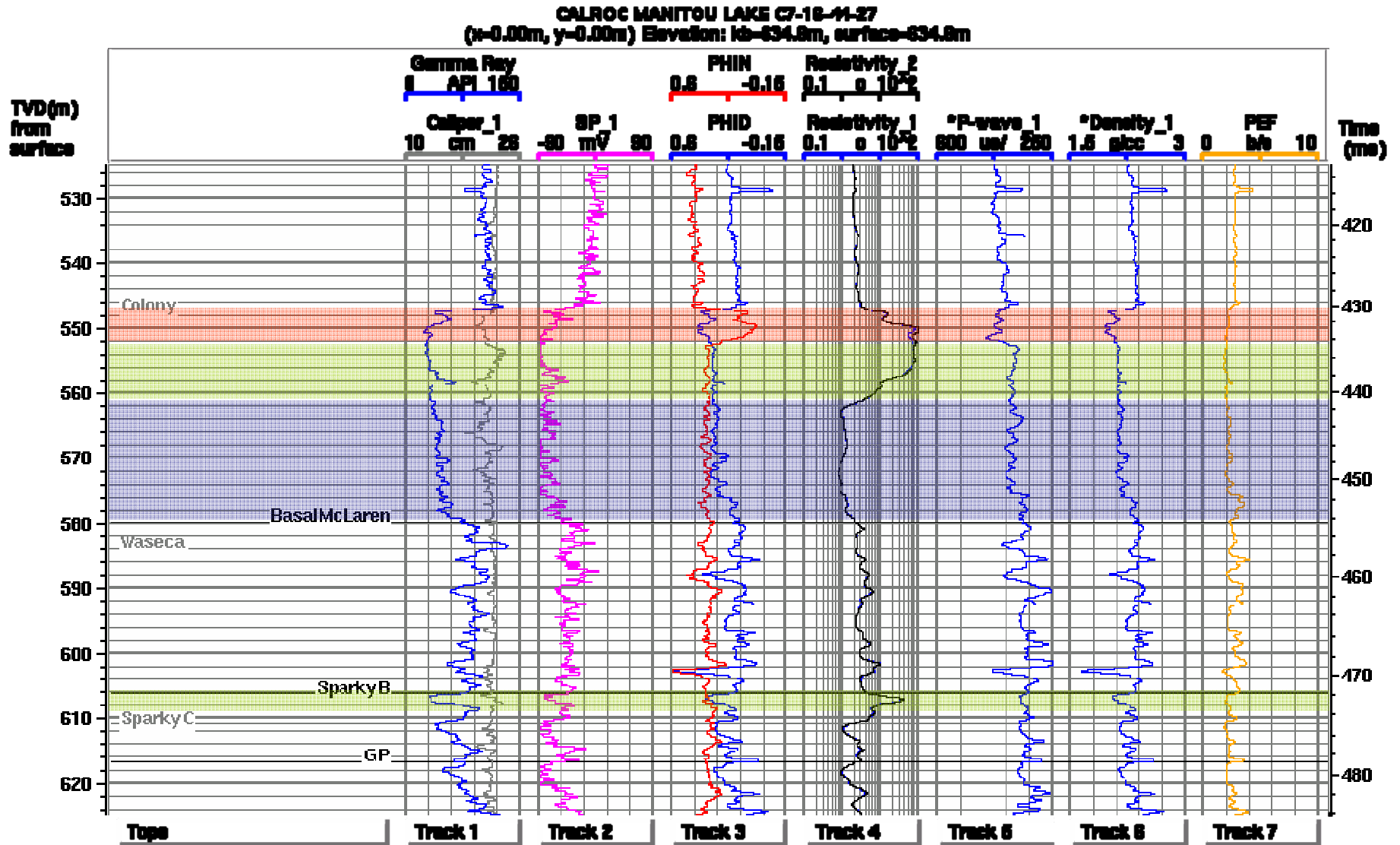
From Leckie and Smith, 1992

# Well A11-17

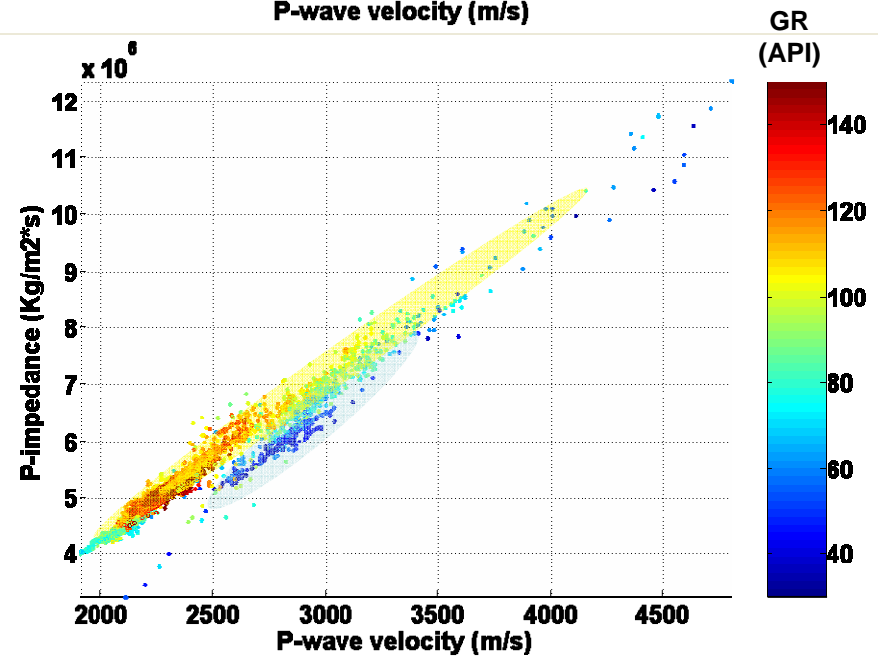
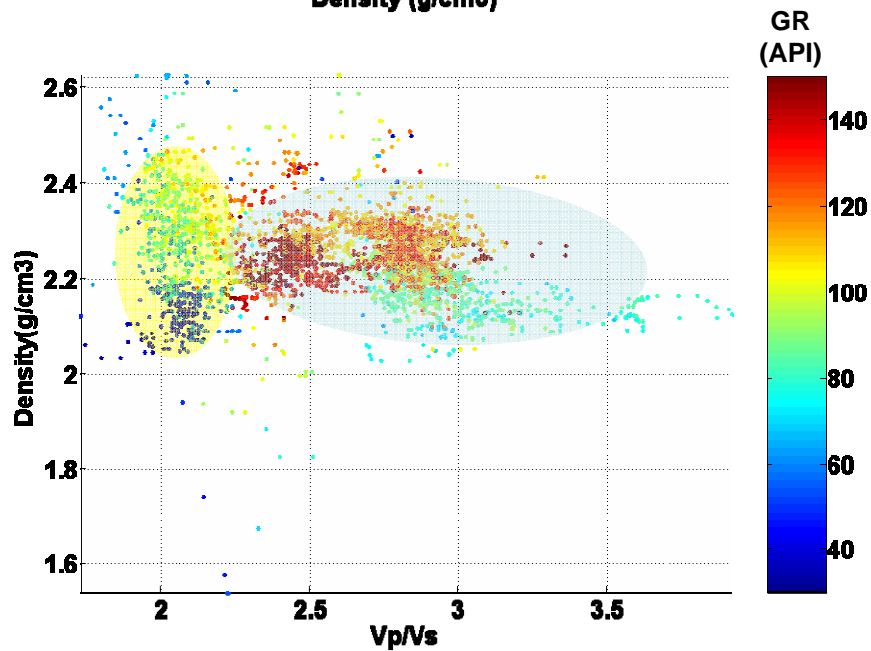
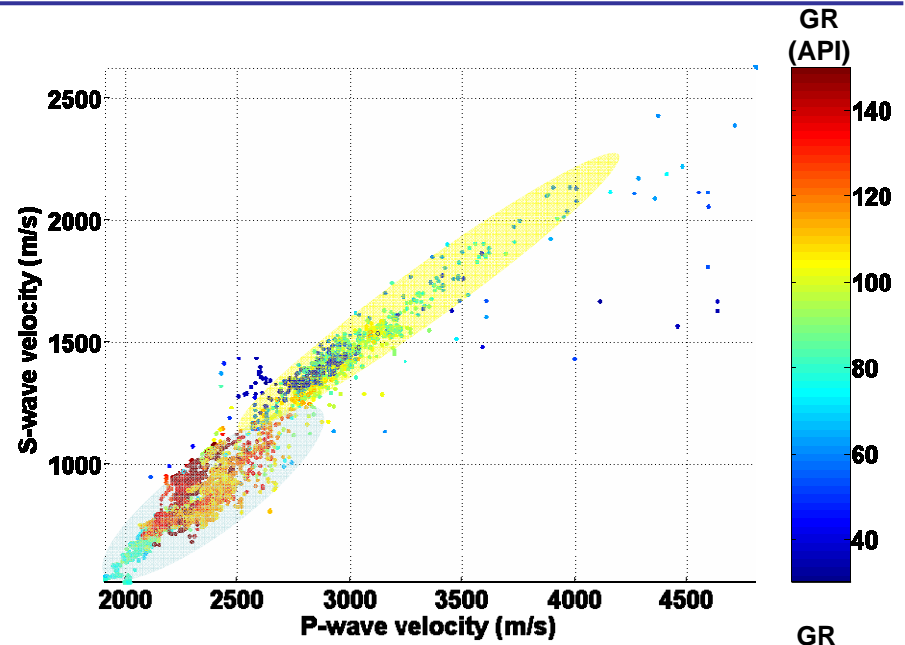
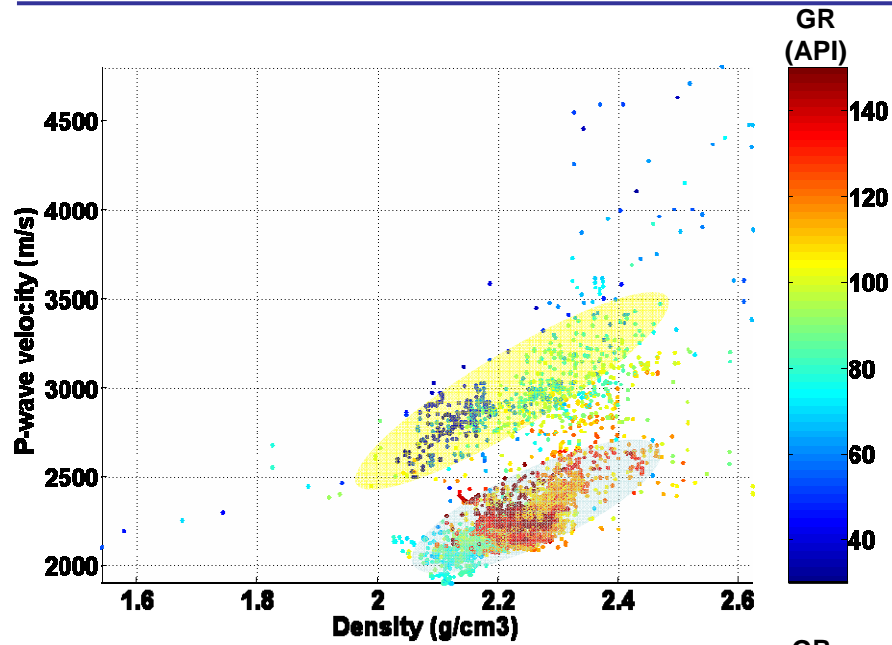
CALROC MANITOU LAKE A11-17-44-27  
 (x=0.00m, y=0.00m) Elevation: kb=637.72m, surface=637.72m



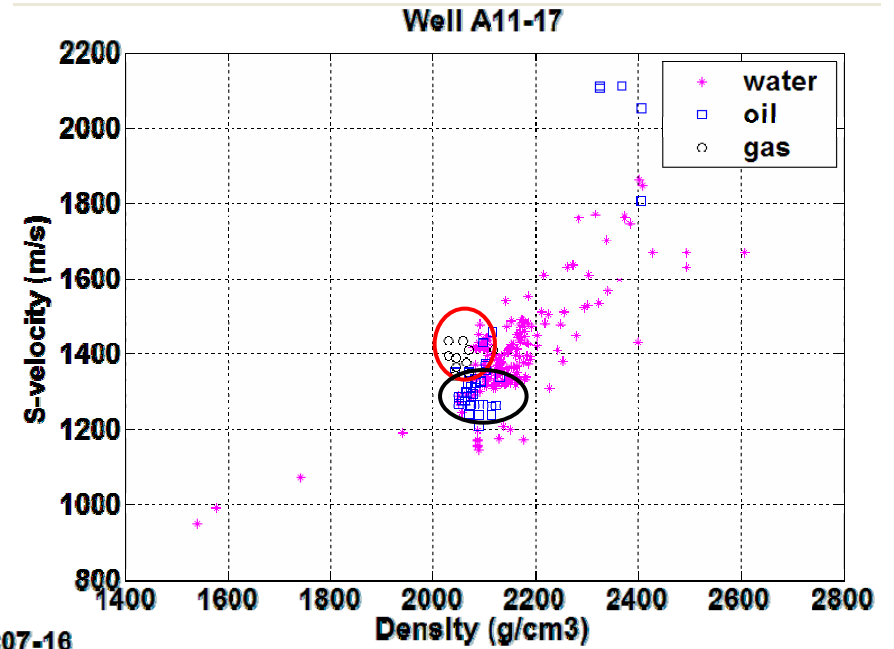
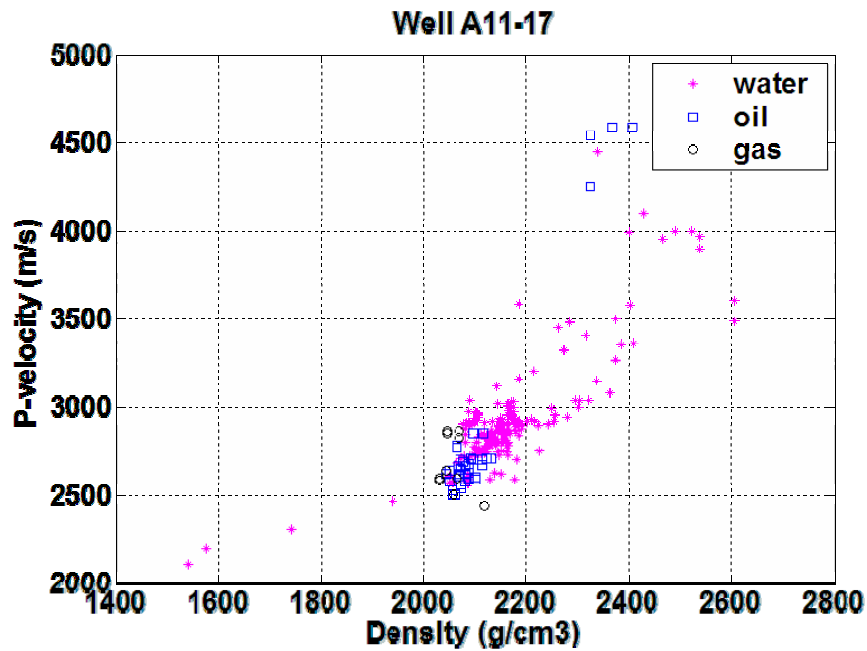
# Well C07-16



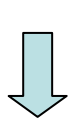
# Crossplots for A11-17



# Fluid effect on density



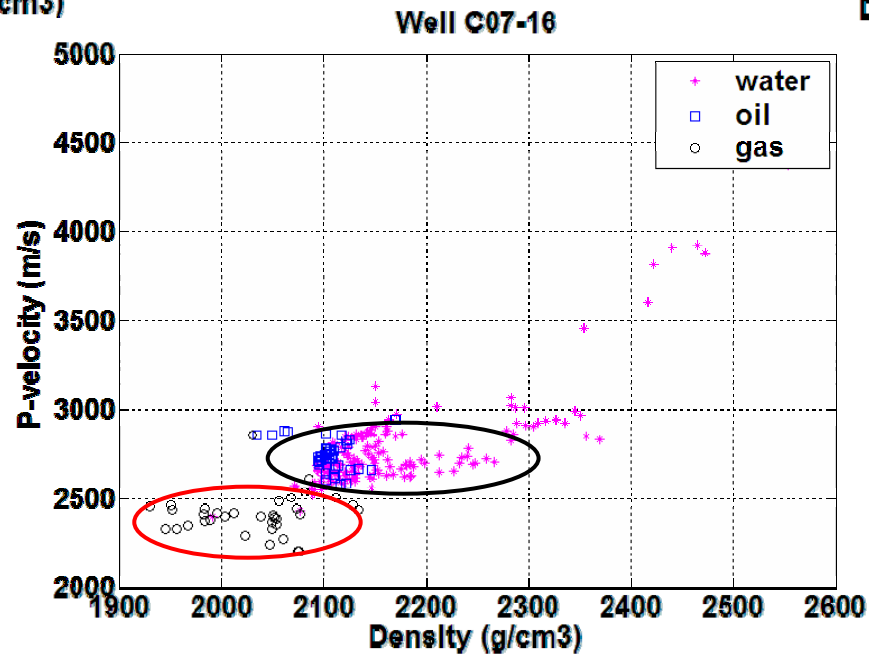
**GAS**



Density and  
P-wave  
velocity



S-wave  
velocity





# Density-velocity relations

- Gardner's Relation  
(Gardner et al., 1974)

$$\rho = aV^m$$

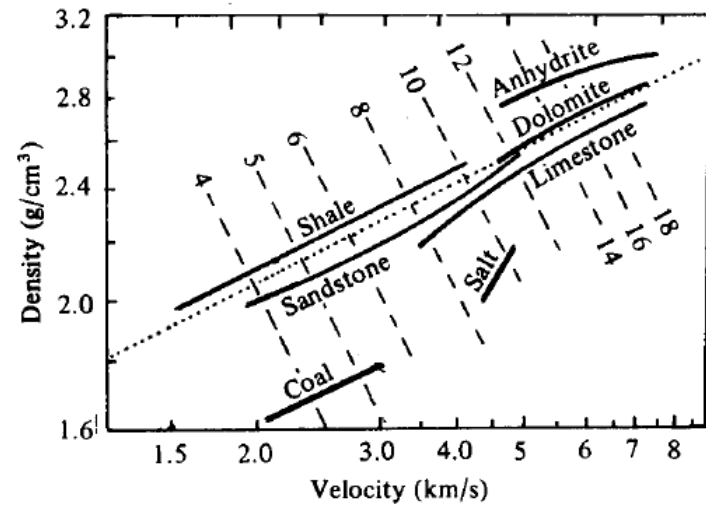
$$\log(\rho) = \log(a) + m\log(V)$$

- Lindseth's relation  
(Lindseth, 1979)

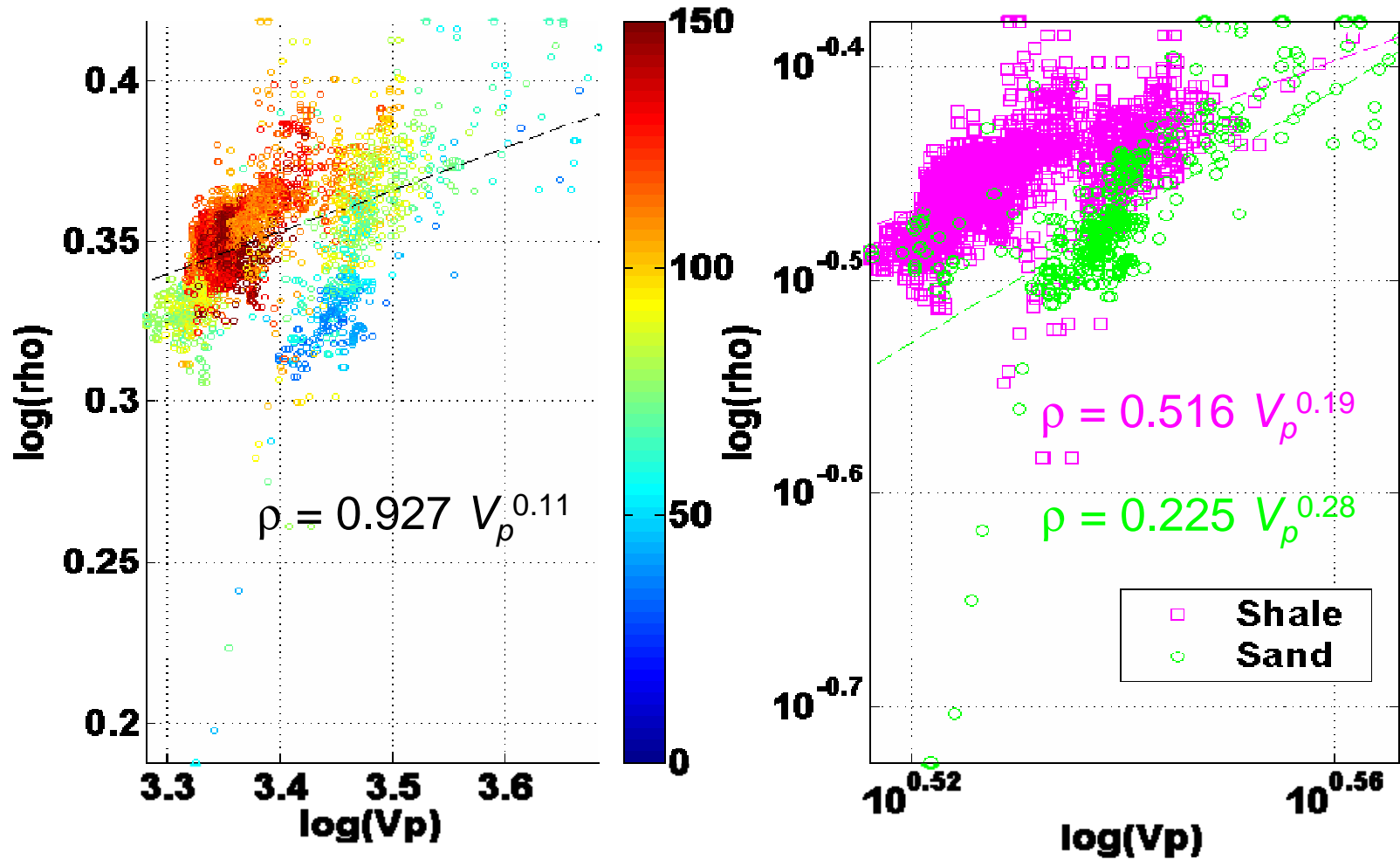
$$V = 0.308\rho V + 3460$$

$$\rho = \frac{V - d}{cV}$$

From Sheriff and Geldart, 1995

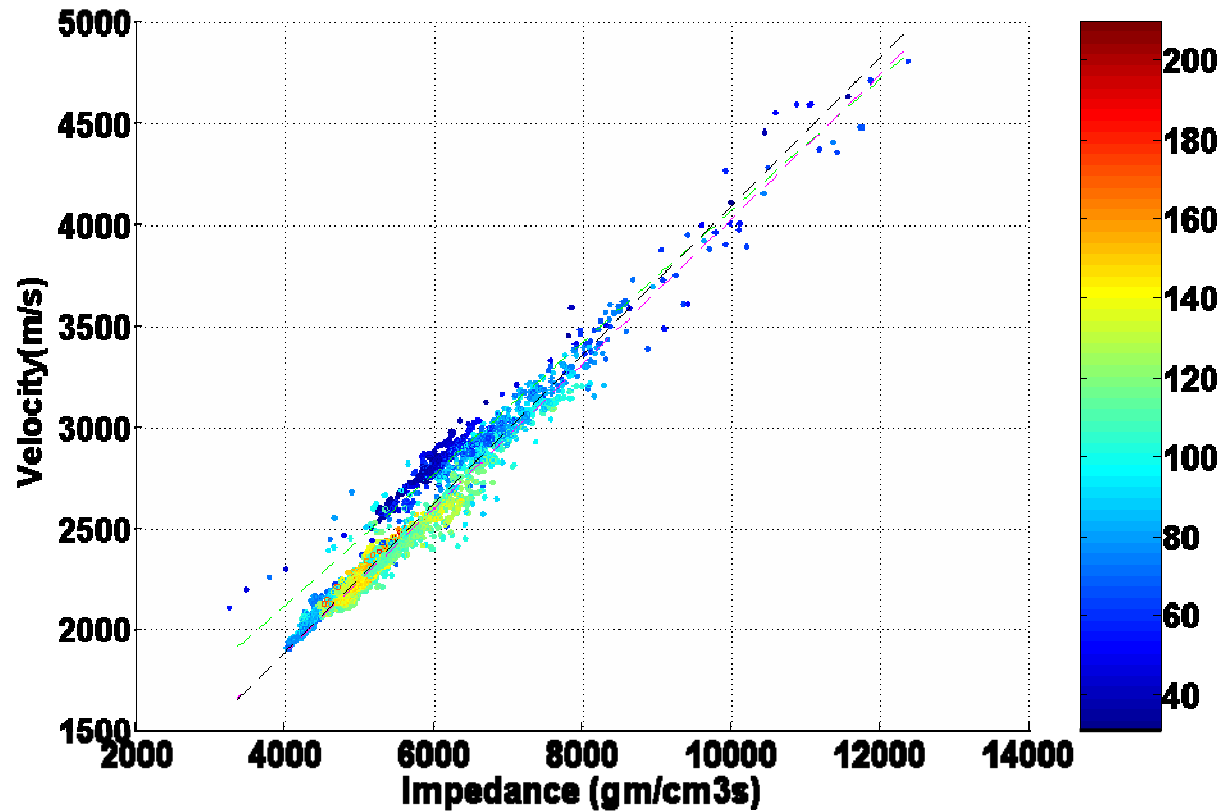


# Gardner's crossplot



Original Gardner  $\longrightarrow \rho = 0.31V^{0.25}$

# Lindseth's crossplot



$$V = 0.927 \rho V_p + 411$$

$$V = 0.322 \rho V_p + 855$$

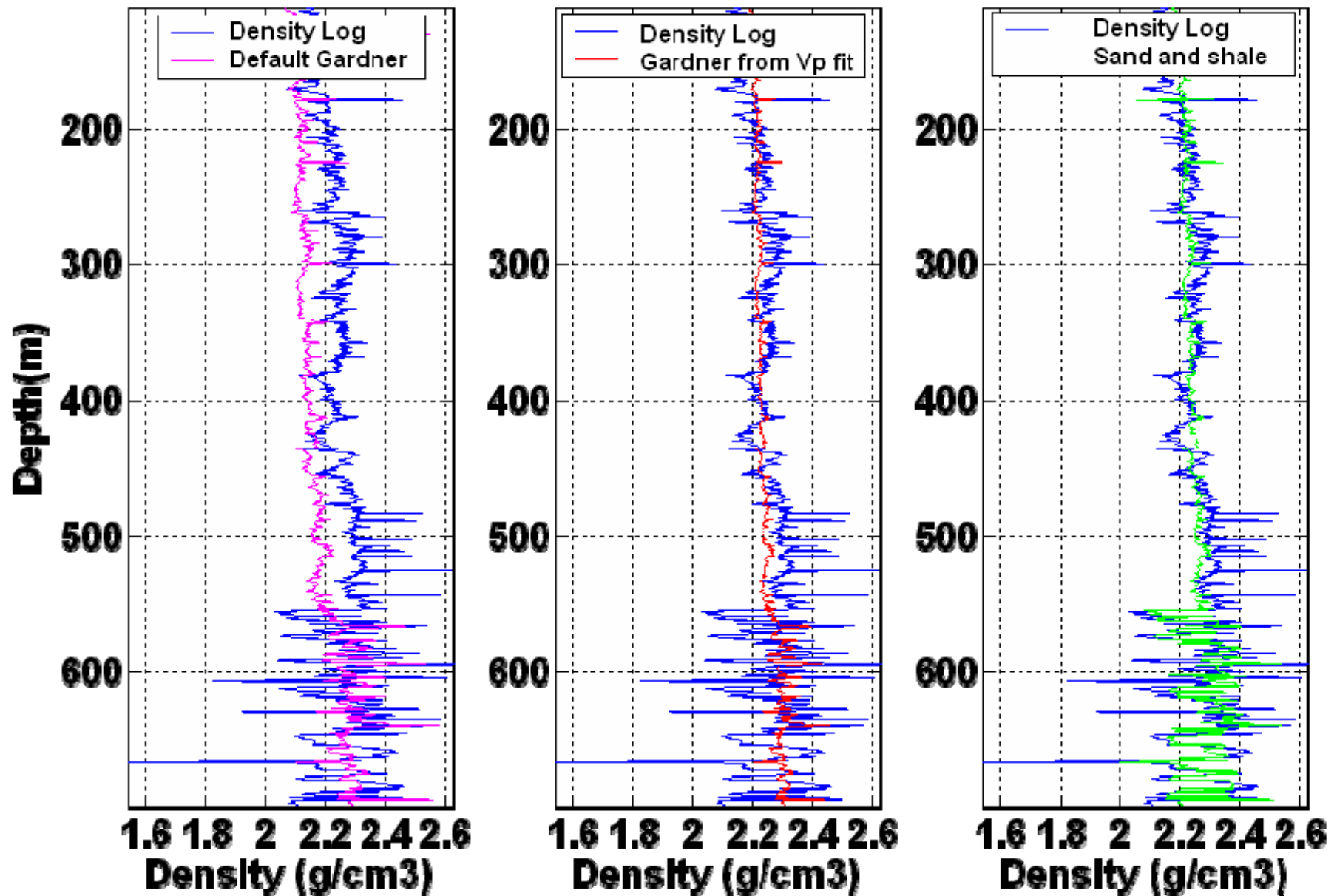
$$V = 0.357 \rho V_p + 459$$

Original Lindseth

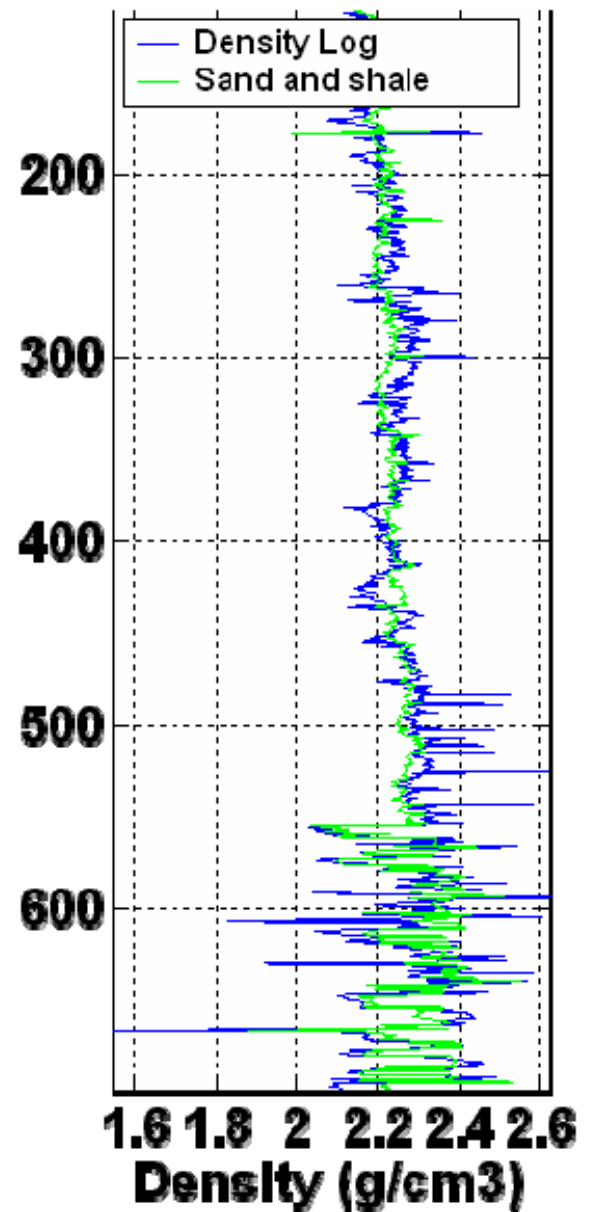
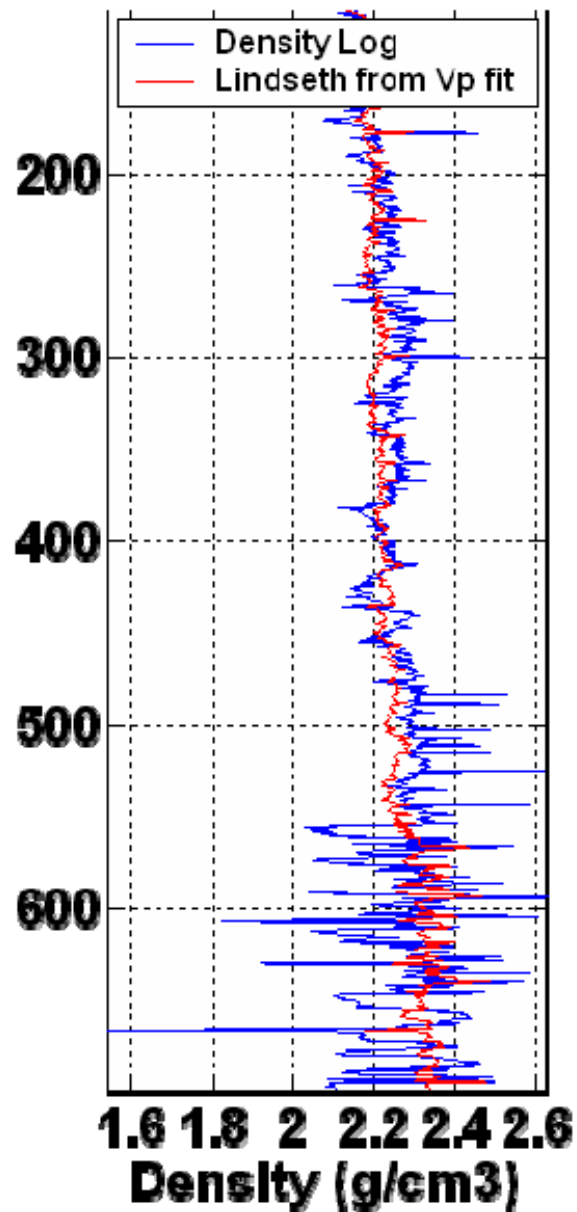
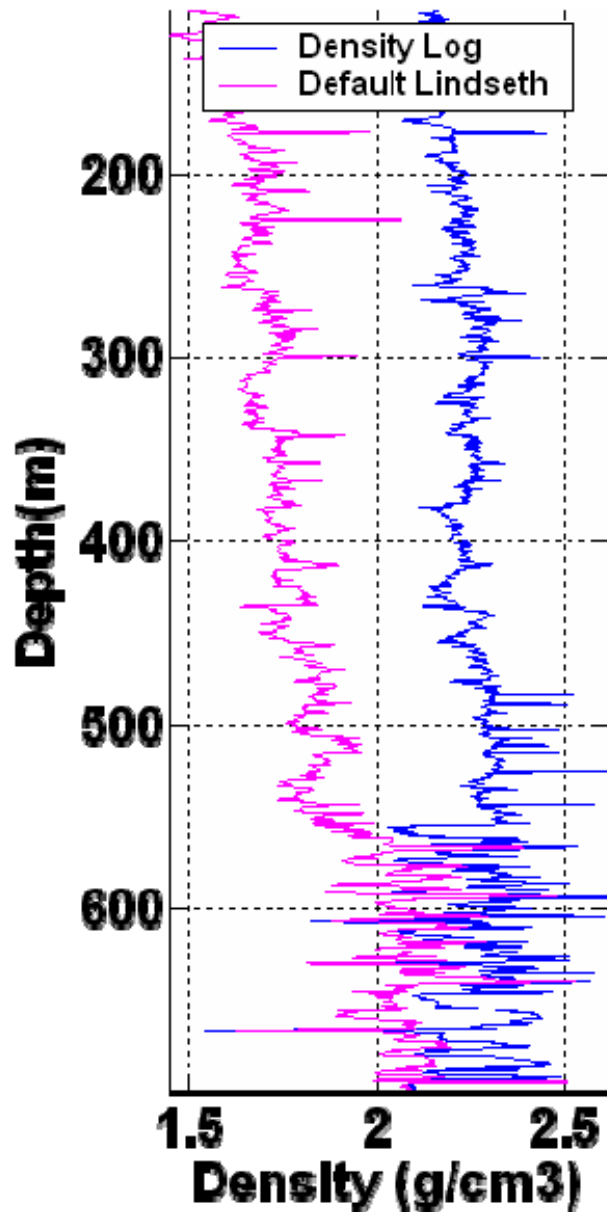


$$V = 0.308 \rho V + 1054$$

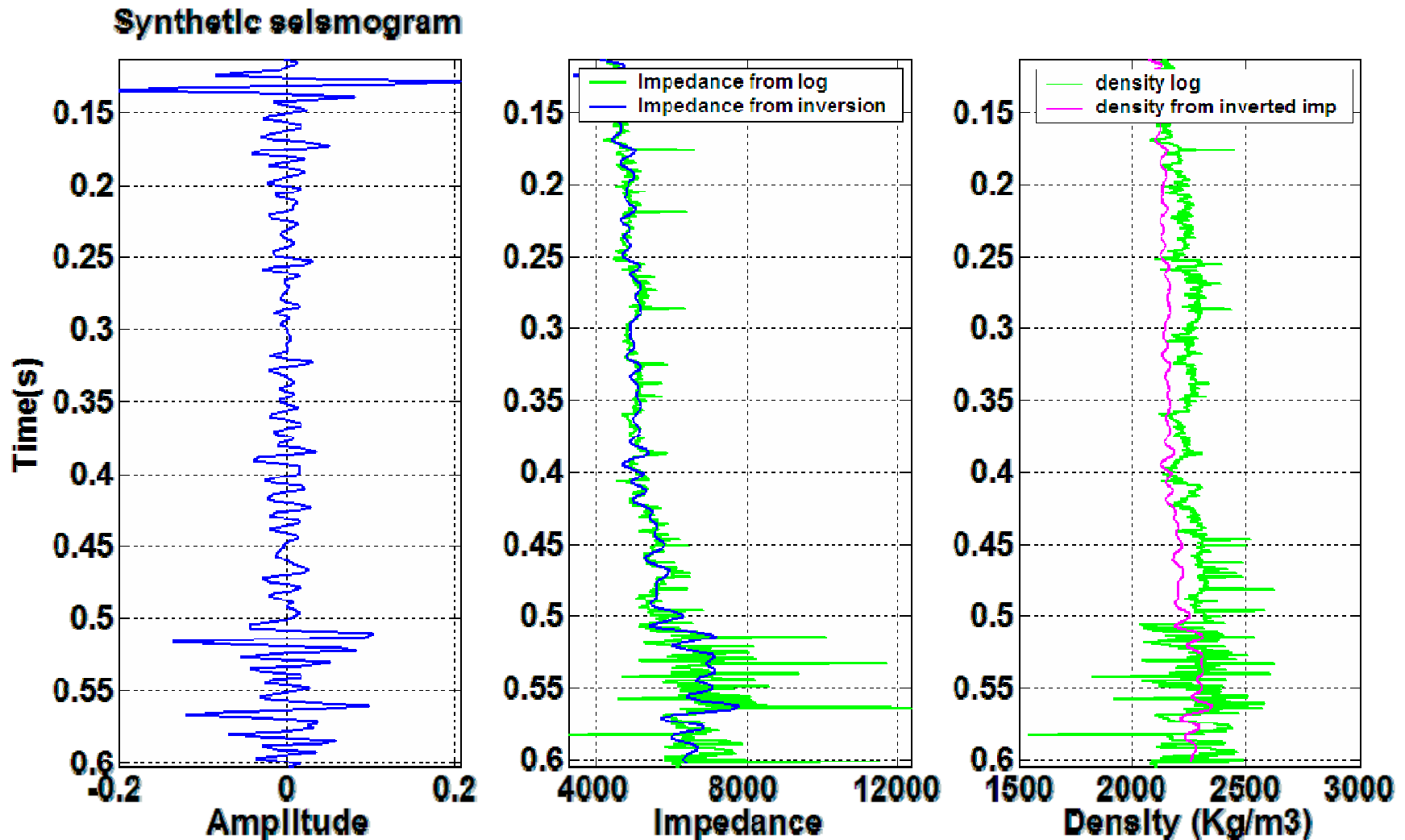
# Gardner's relation



# Lindseth's relation

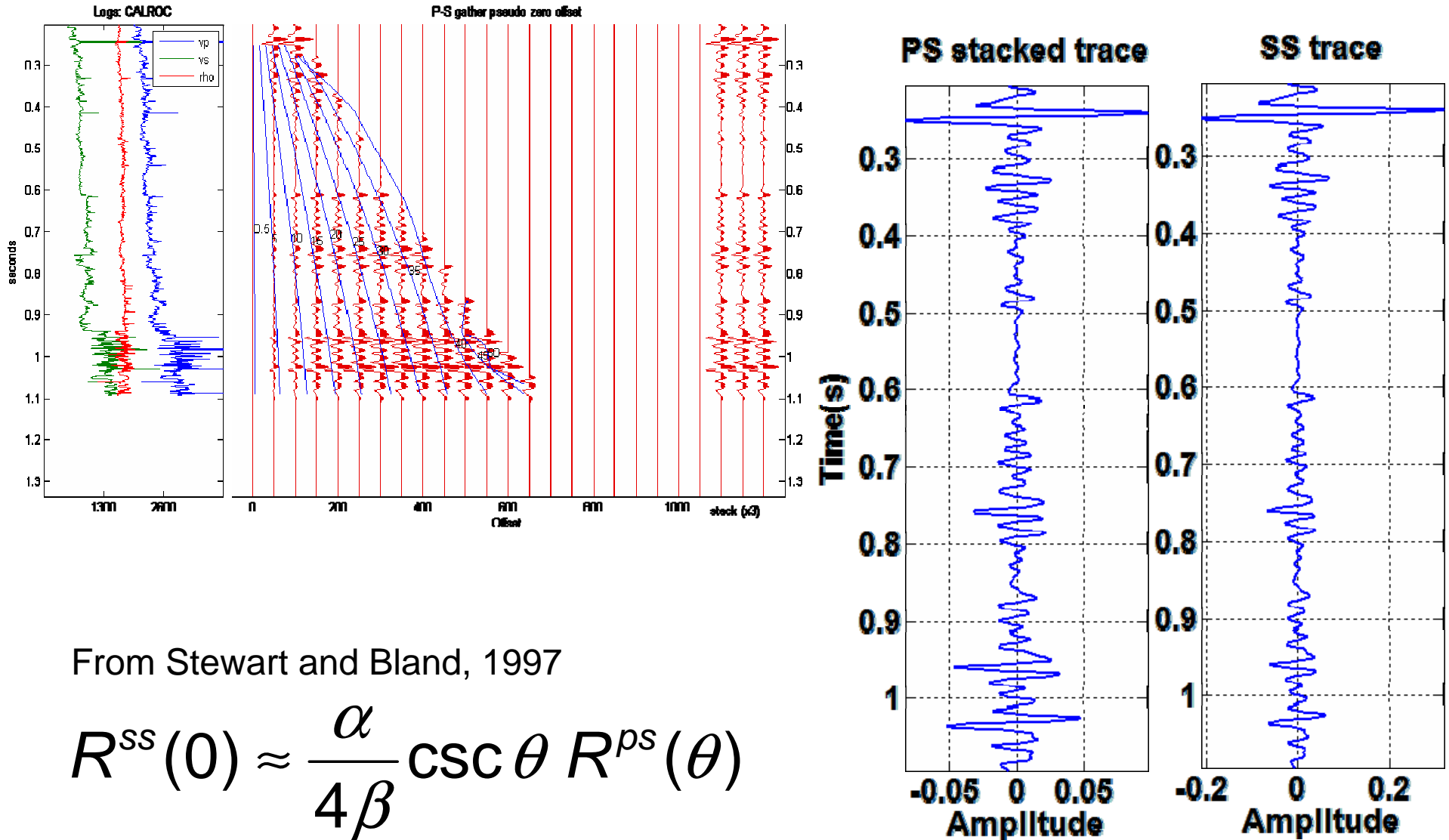


# Inversion results



# PS inversion

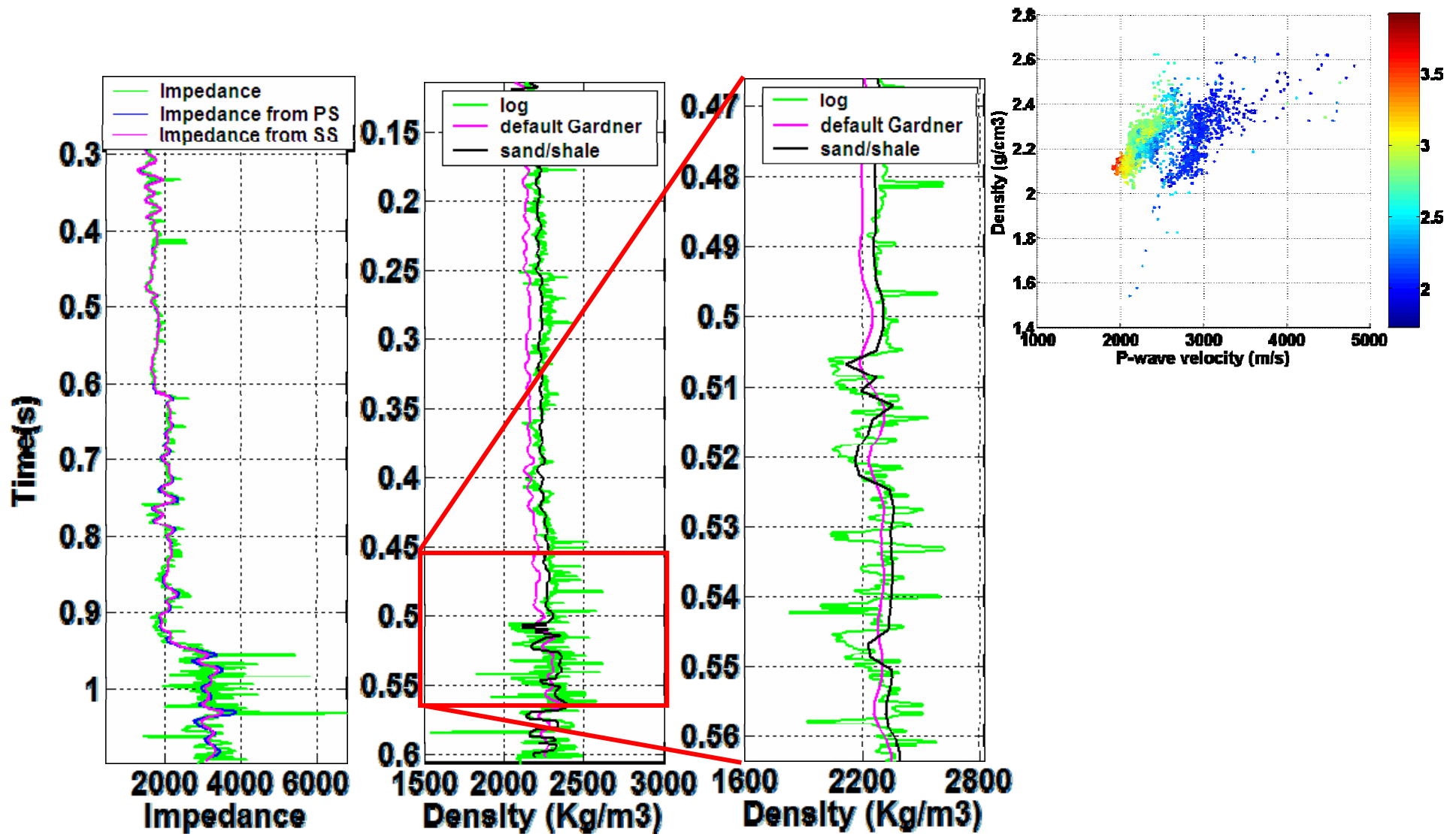
SYNGRAM P-P and P-S synthetic seismogram facility



From Stewart and Bland, 1997

$$R^{SS}(0) \approx \frac{\alpha}{4\beta} \csc \theta R^{PS}(\theta)$$

# Inversion with constraints





# Summary

<b>Fit</b>	<b>A</b>	<b>M</b>	<b>RMS error (g/cm<sup>3</sup>)</b>
Gardner's coefficients	0.310	0.25	0.1147
Gardner's single fit	0.9277	0.1131	0.0848
Gardner's fit for shale	0.5162	0.1896	0.0583
Gardner's fit for sand	0.2249	0.2847	0.0678
<b>Fit</b>	<b>C</b>	<b>D</b>	<b>RMS error (g/cm<sup>3</sup>)</b>
Lindseth's coefficients	0.308	1054.06.	0.4550
Lindseth's single fit	0.3702	411.09	0.0879
Lindseth for shale	0.3572	459.25	0.0579
Lindseth for sand	0.3224	855.37	0.0708
<b>Inversion</b>			<b>RMS error (g/cm<sup>3</sup>)</b>
Inversion with Gardner's coefficients			0.1032
Inversion with Gardner's single fit			0.0838
Inversion with Gardner's fit for shale and sand			0.0720

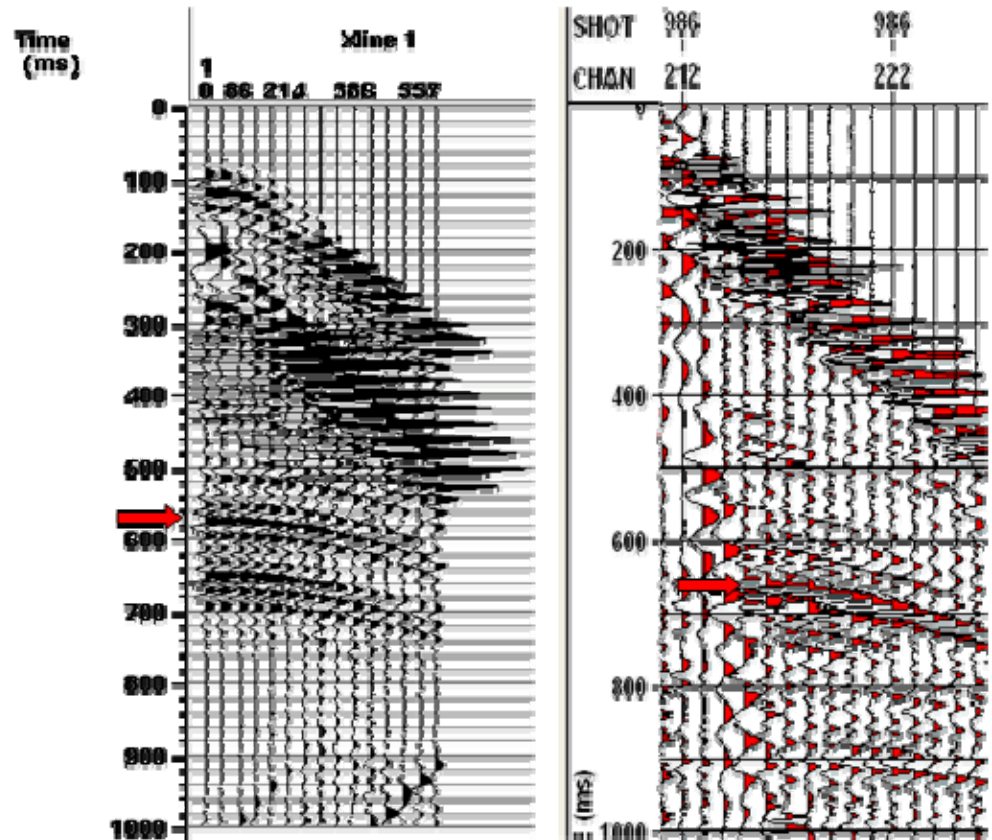
# Conclusions

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- Gamma-ray and  $V_p/V_s$  are the best lithological indicators in the area.
- Density variations related to porosity and/or fluid content.
- Use of density-velocity relations with local parameters.
- Results from P- and S-impedance inversions as constraint.
- Post-stack inversion of PS data very similar to SS inversion.

# Future Work

- Elastic inversion to directly estimate density
  - Nonlinear approach
  - Forward modeling: Syngam and reflectivity method
  - Optimization technique
  - Registration between PP and PS time
  - Constraints
- Fluid replacement modeling



# Acknowledgements

# Thank you!

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  - Calroc Energy Ltd and Aguila Consulting
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