Relationships between seismic attenuation and rock properties

- Analysis from the Ross Lake heavy oilfield, Sask.

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Outline – Attenuation & rock properties

- Introduction
  - Attenuation as a lithology & fluid indicator
  - Q for processing
- Well log analysis and Q estimation
- Q vs. rock properties
- Many observations & conclusions

Introduction

- Seismic attenuation:
  - attribute of waves propagating in the earth.
  - Quality factor Q: ratio of stored energy to dissipated energy

$$\frac{1}{Q} = \frac{\Delta W}{2 \pi W}$$

- Rock properties:
  - rock type, mineralogy
  - porosity, pore fluid, saturation, …

Purpose of this study

Find relationships between attenuation & rock properties

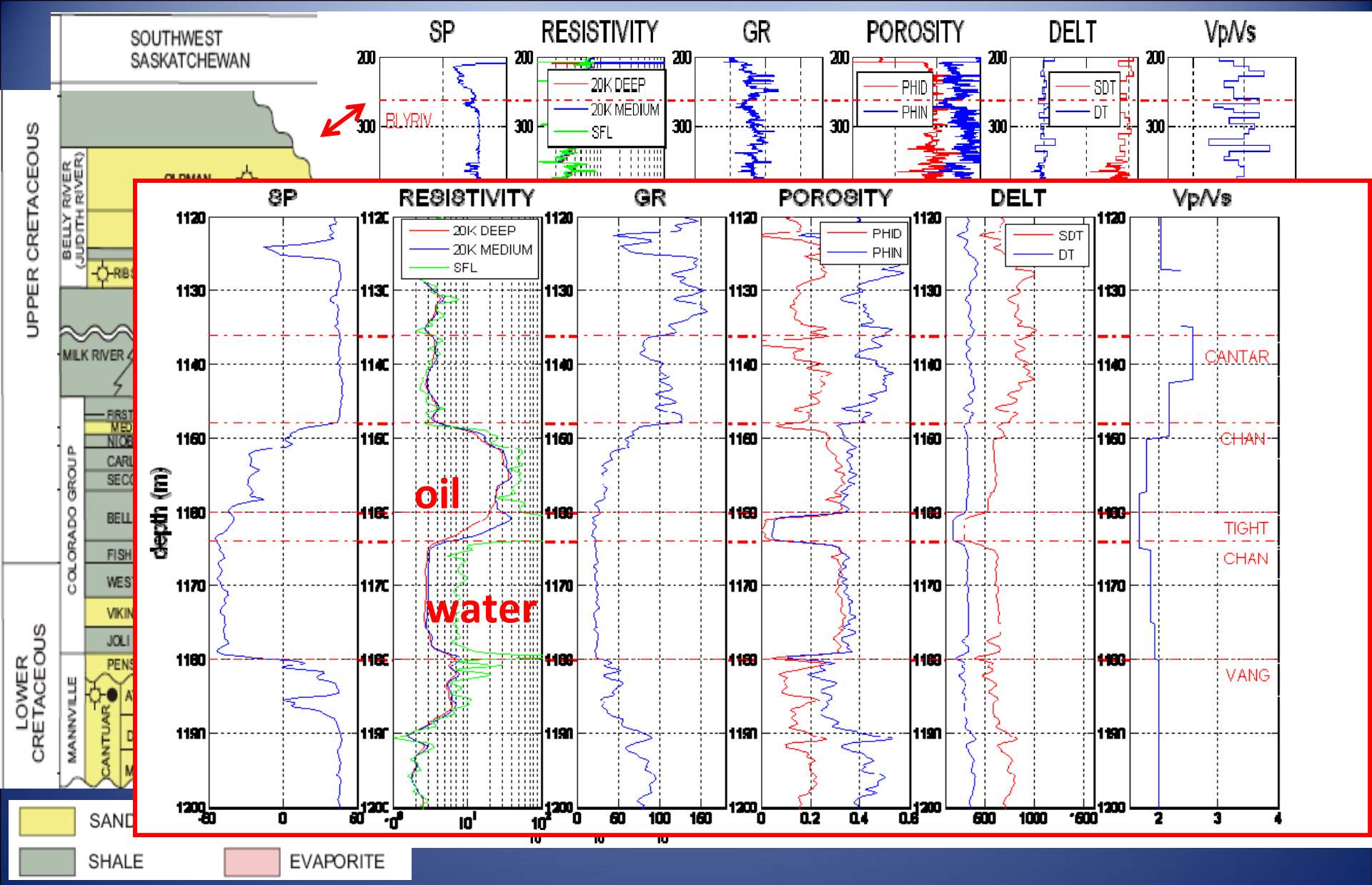
Introduction

Data used:

- well 11-25-13-17W3 from the Ross Lake heavy oilfield, Saskatchewan
- well log data & near-offset (54m) VSP data

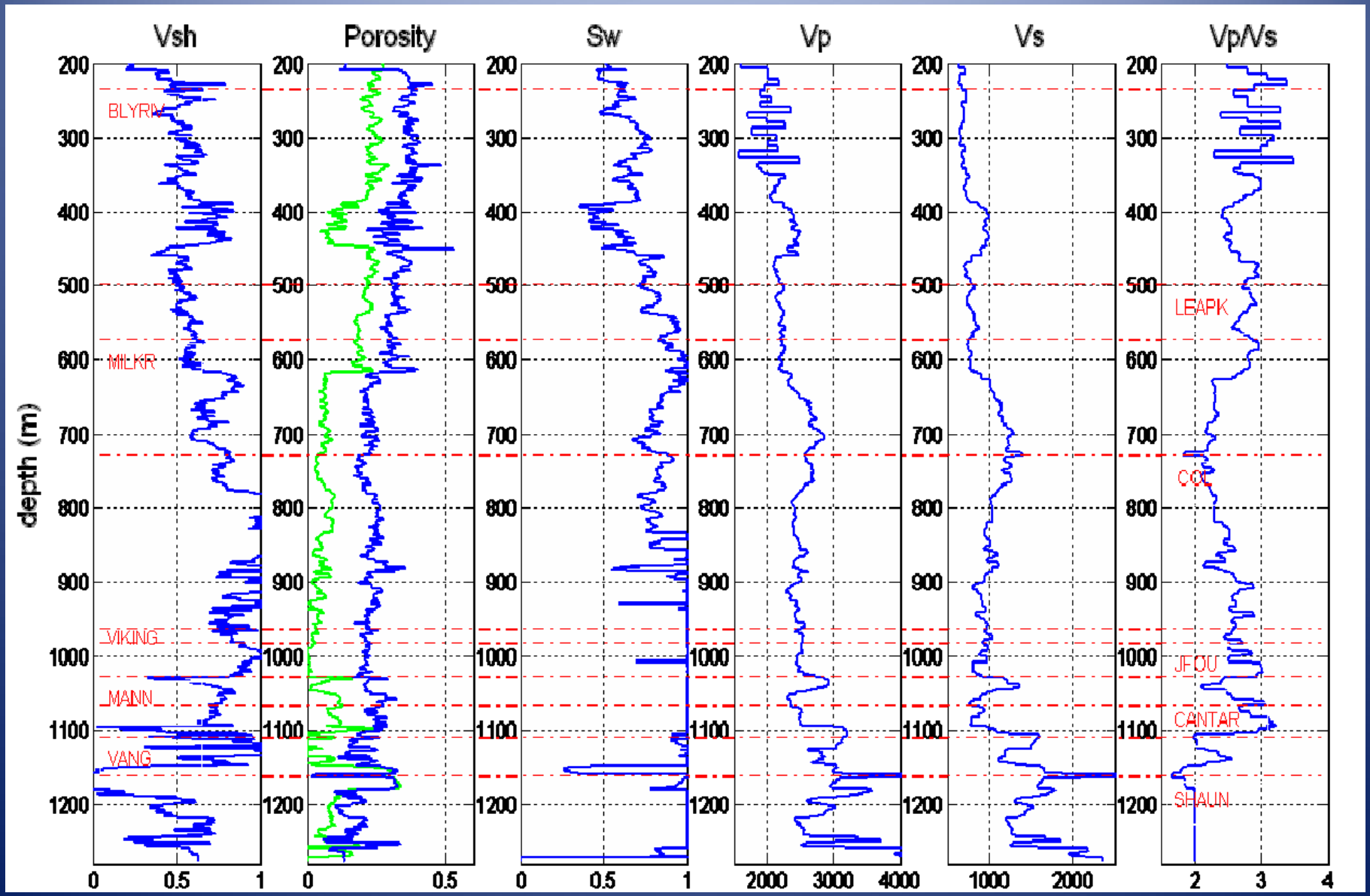
VSP source:

- ❖ Vertical vibrator, 8-180Hz
- ❖ Horizontal vibe, 5-100Hz



Regional table of formations and well log curves for the Well 11-25-13-17W3

Rock properties from well logs



Q from VSP data

Spectral ratio method

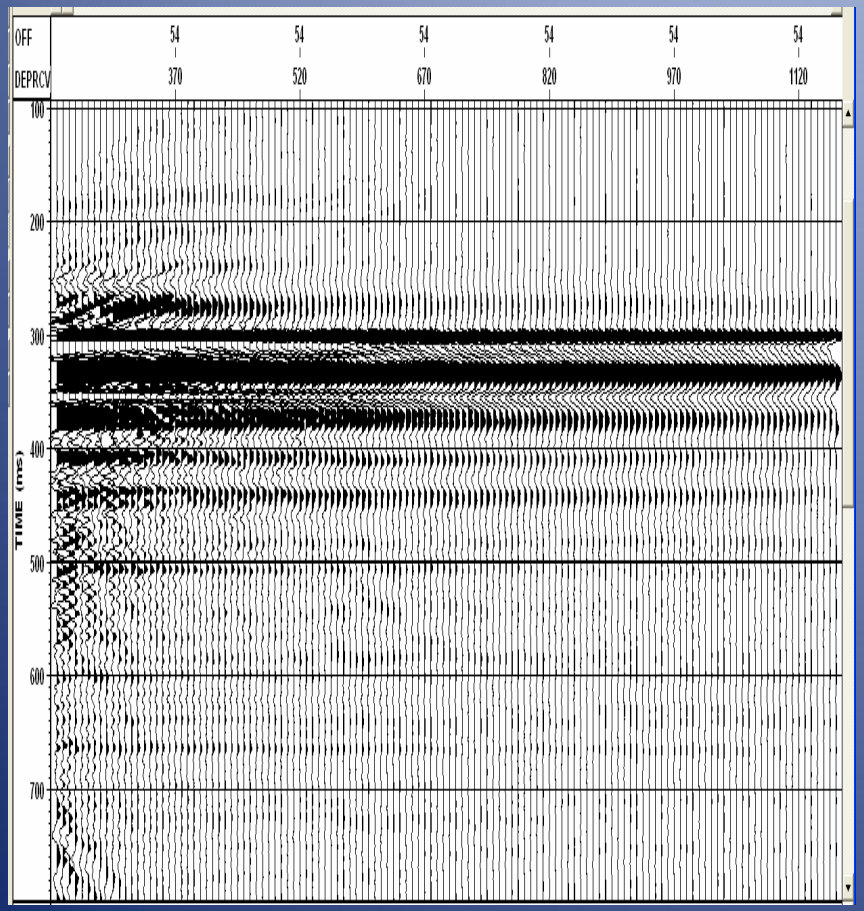
$$\ln\left[\left|\frac{A_2(\omega)}{A_1(\omega)}\right|\right] = -\frac{|\omega|}{2Q}(t_2 - t_1) + \ln(K)$$

Interval Q value for layered earth

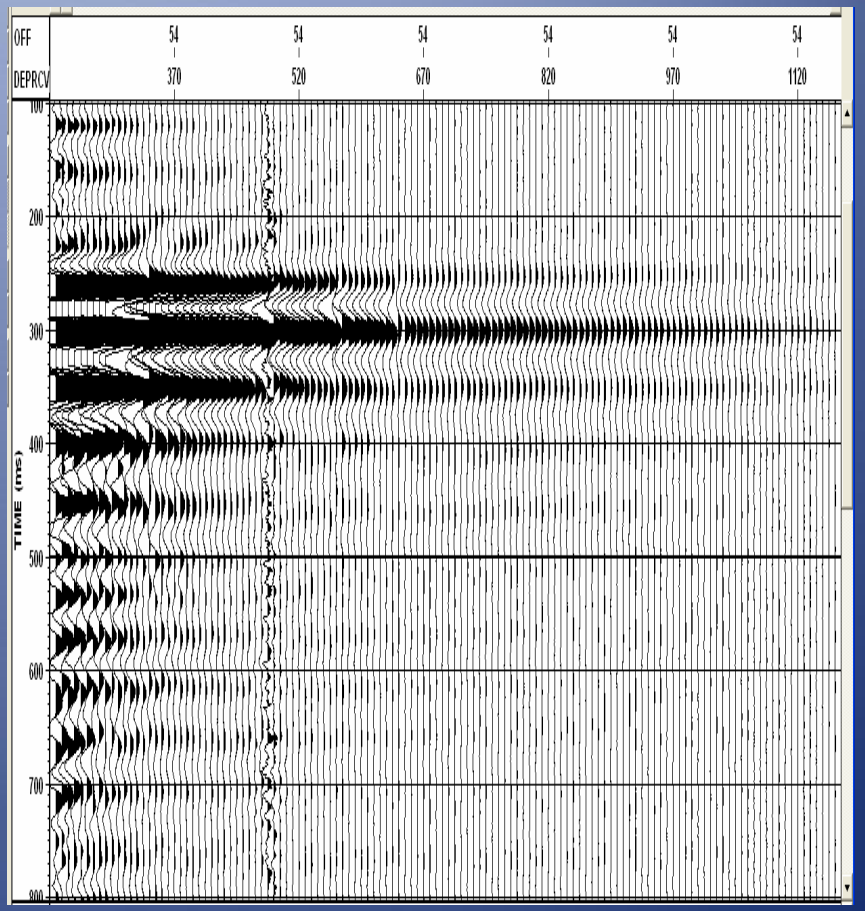
$$\frac{t(n+1) - t(n)}{Q_{\text{int}erval}(n+1)} = \frac{t(n+1)}{Q_{ave}(n+1)} - \frac{t(n)}{Q_{ave}(n)}$$

(from Bale et al., 2002)

Q from VSP data

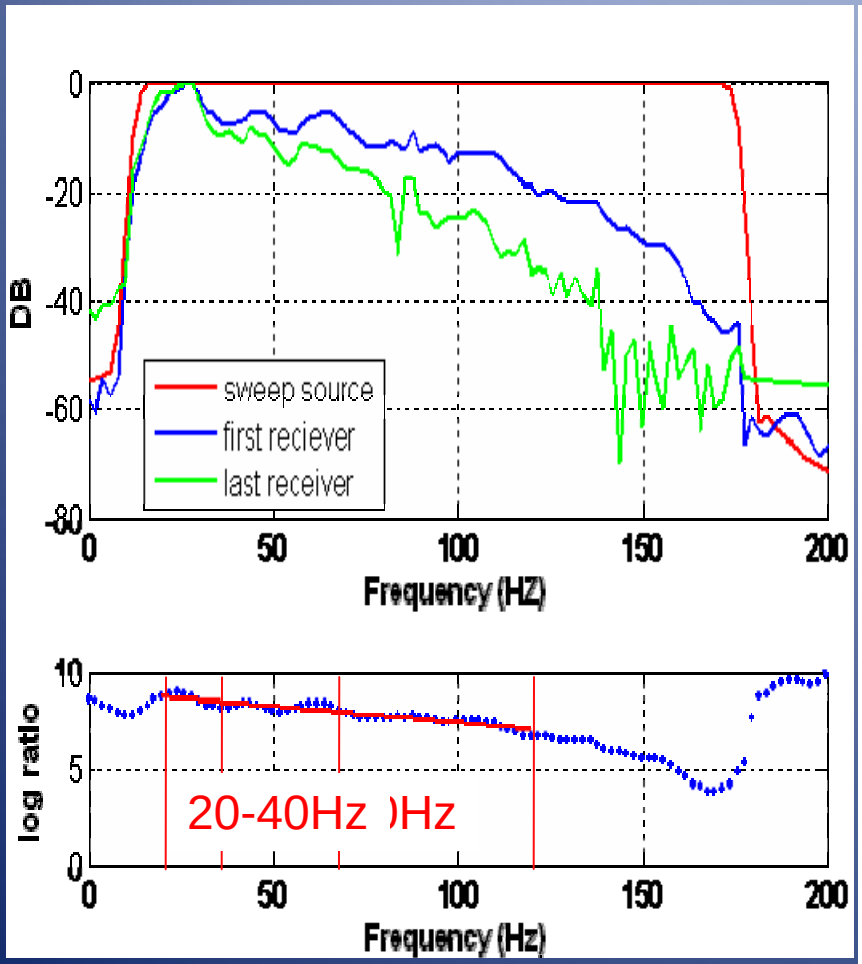


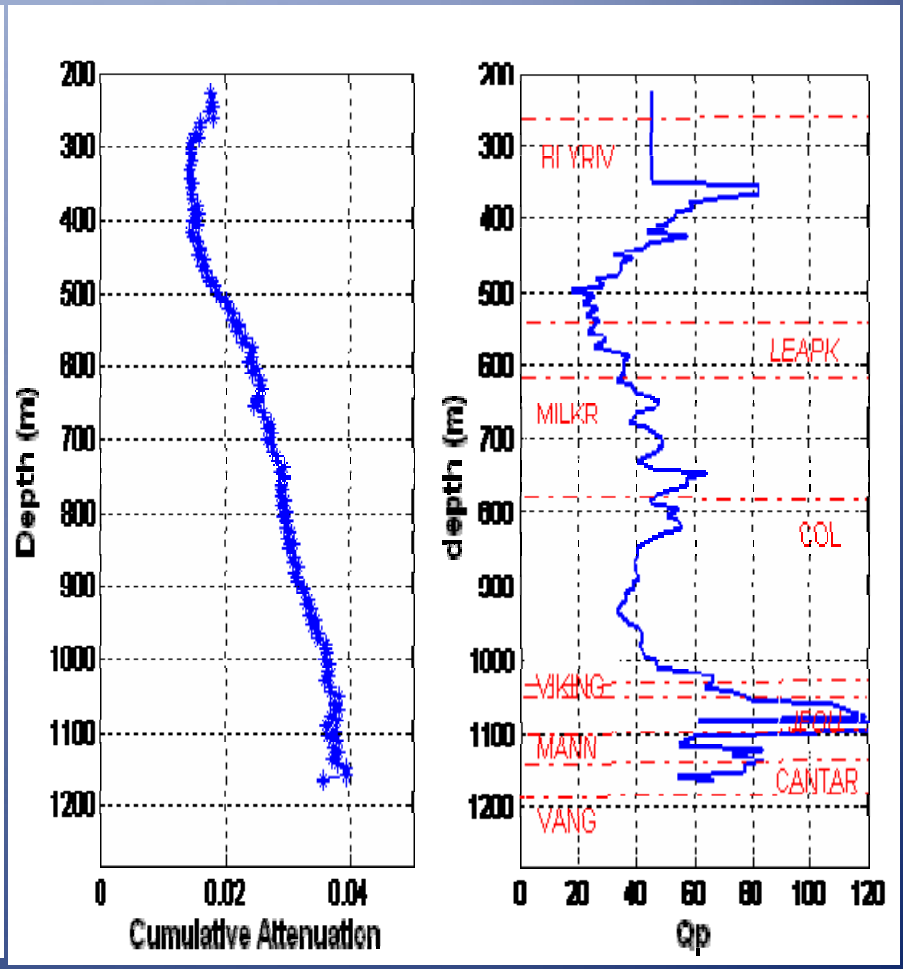
Flattened down-going P wave



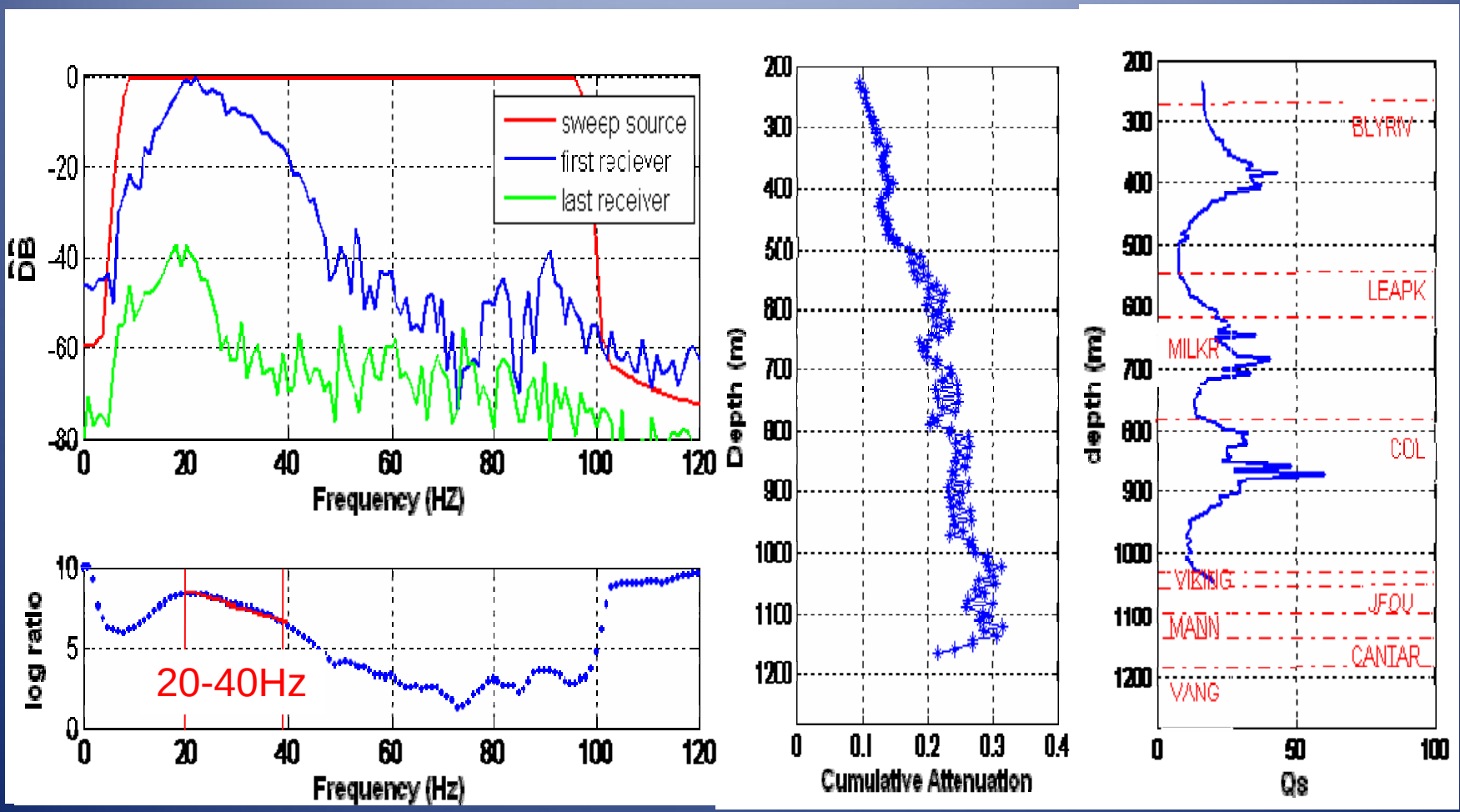
Flattened down-going S-wave

Q from VSP data

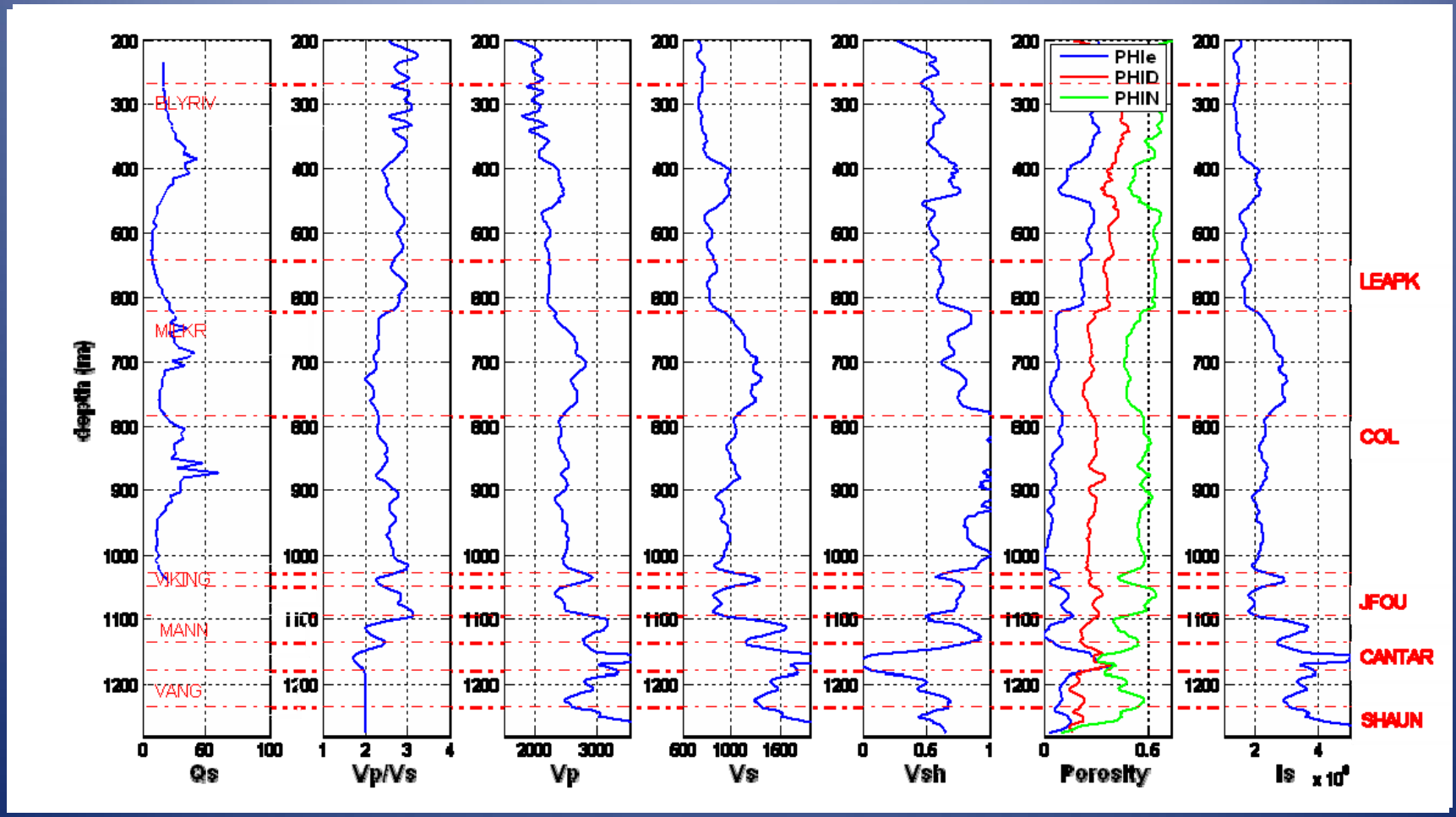




Q from VSP data

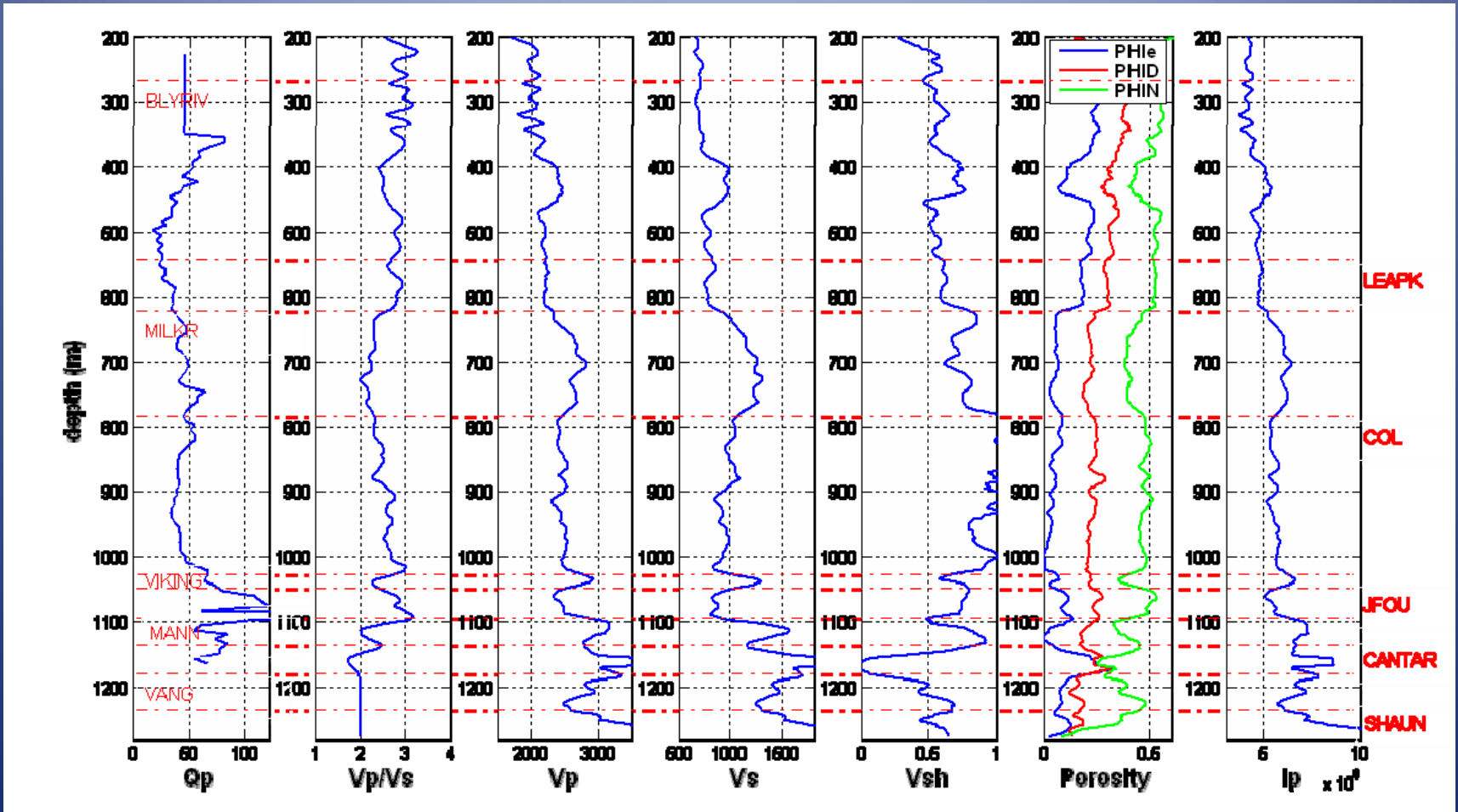


Q values and rock properties



High Q value: high velocity, high impedance, low Vp/Vs, low porosity;
Low Q value: low velocity, low impedance, high Vp/Vs, high porosity.

Q values and rock properties



High Q value: high velocity, high impedance, low Vp/Vs, low porosity;
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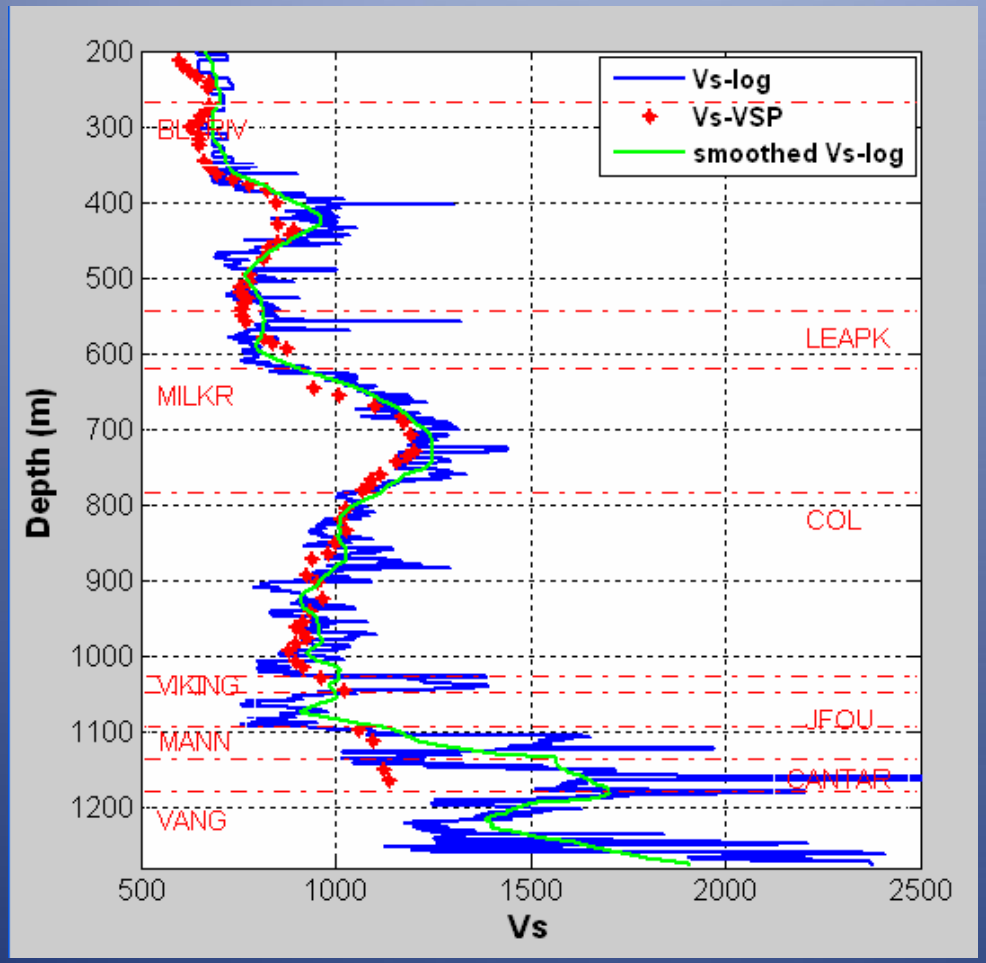
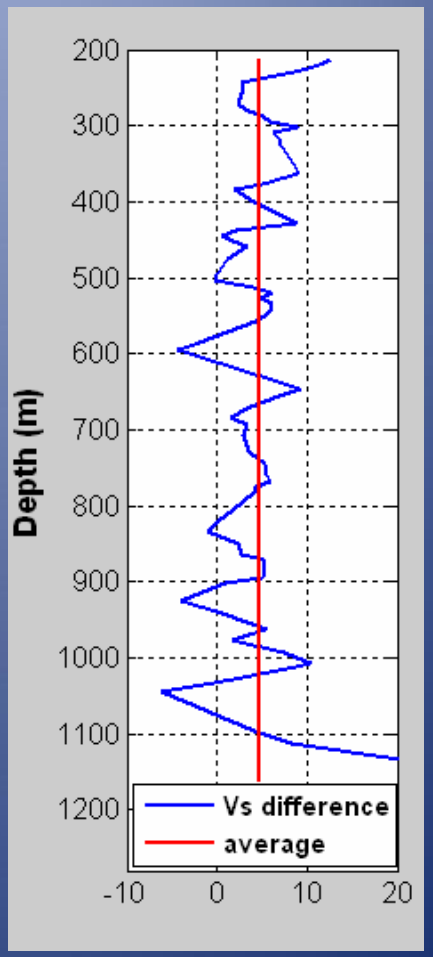
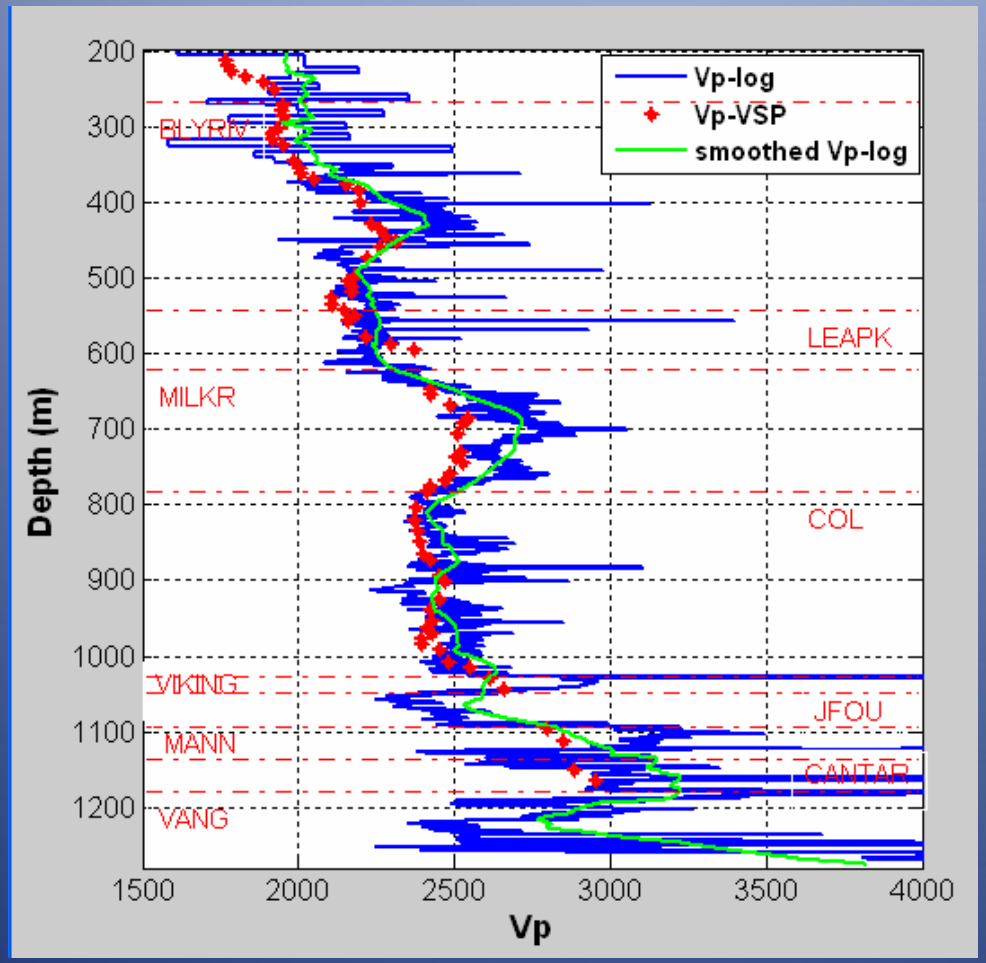
Velocity dispersion

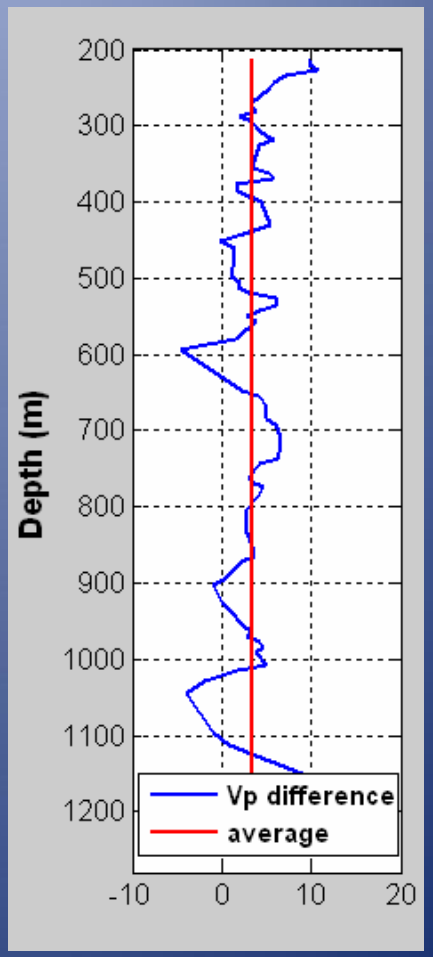




average Vp difference: 3.4%

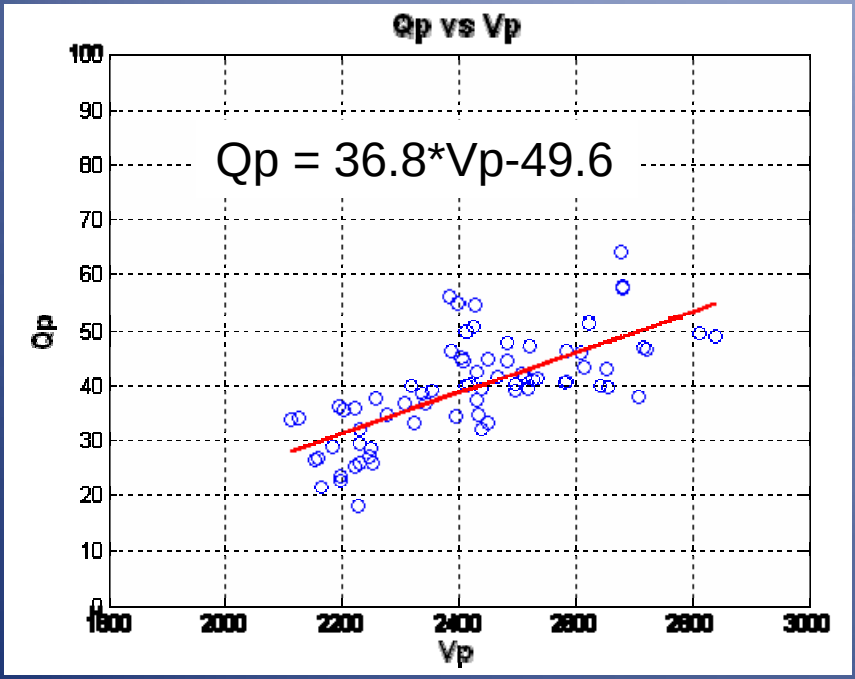
Velocity dispersion



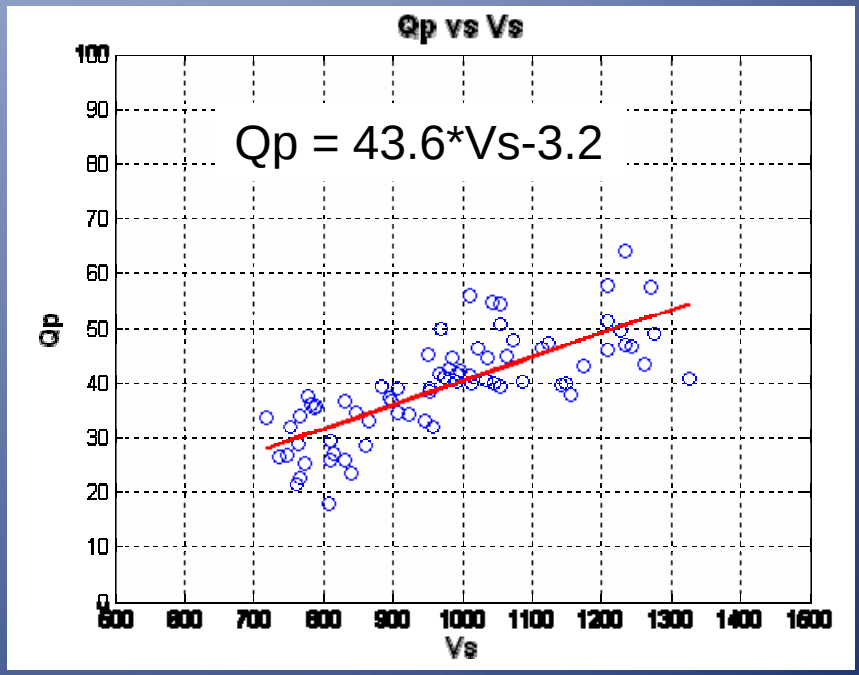


average Vs difference: 4.8%

Qp vs. velocity

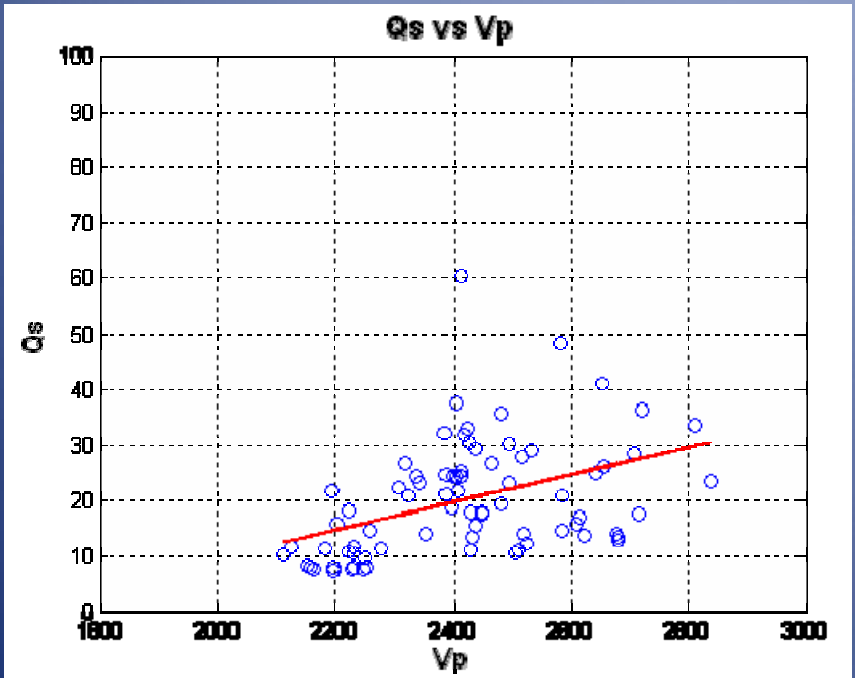


Qp vs. Vp

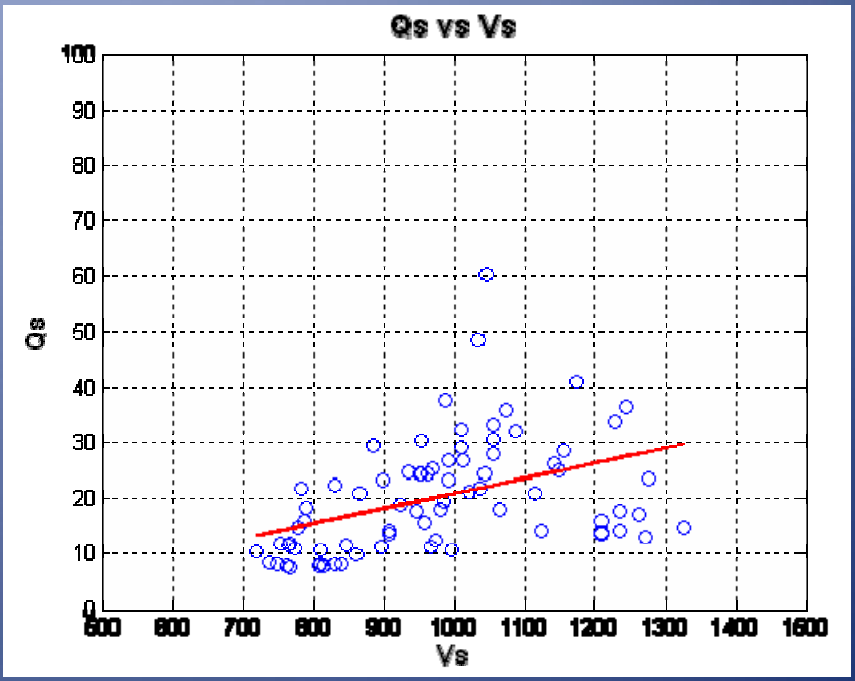


Qp vs. Vs

Qs vs. velocity

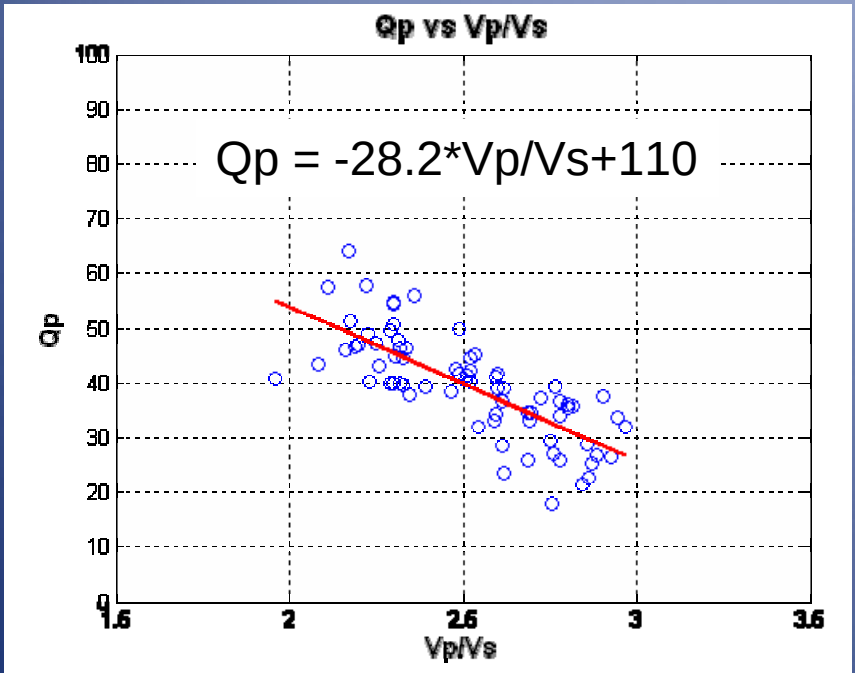


Qs vs. Vp

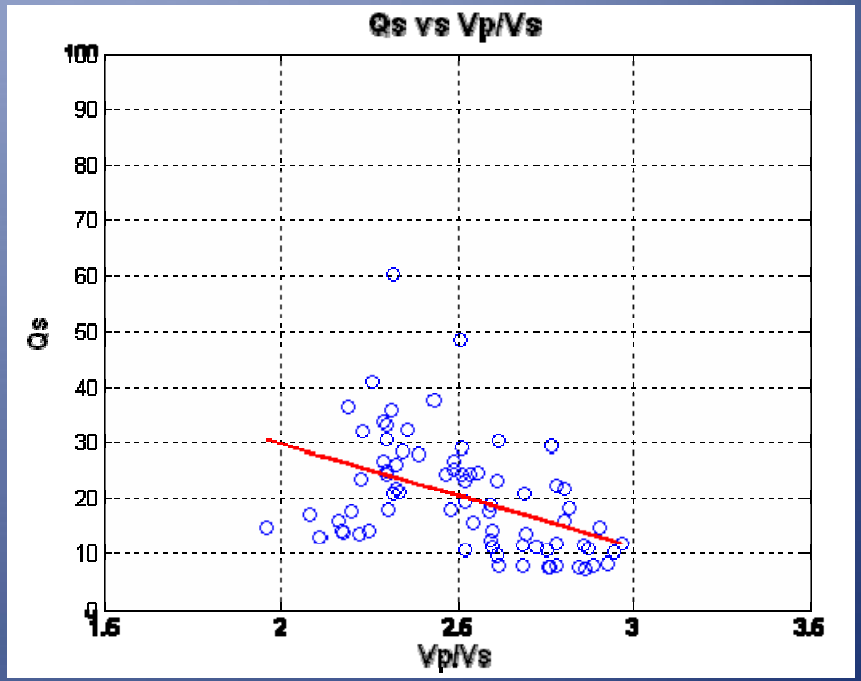


Qs vs. Vs

Q vs. Vp/Vs

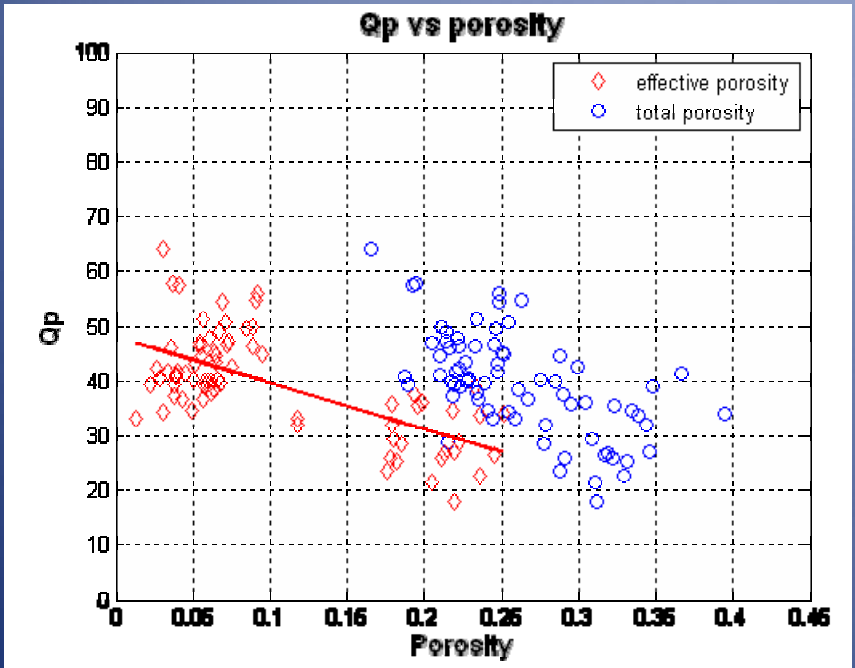


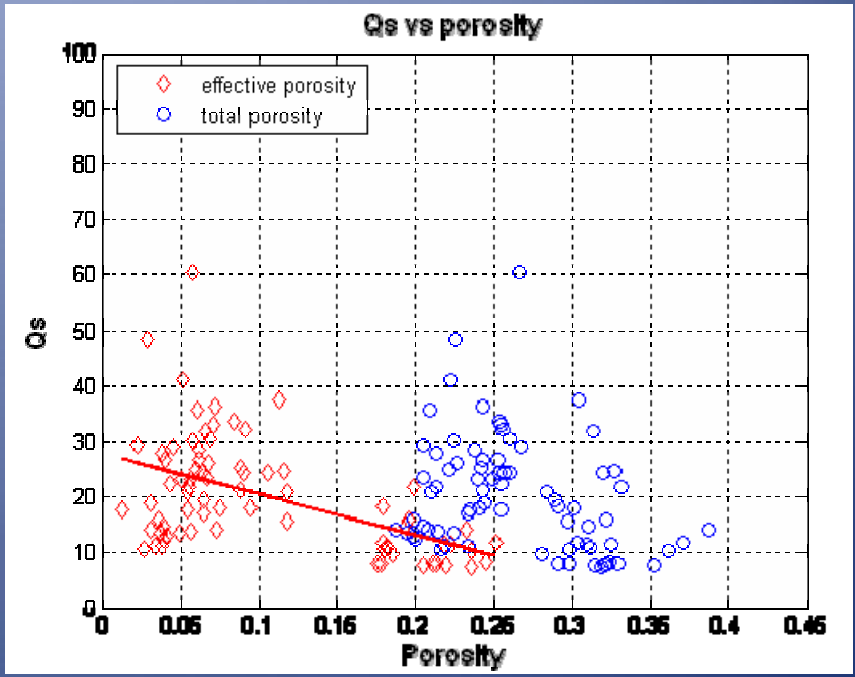
Qp vs. Vp/Vs



Qs vs. Vp/Vs

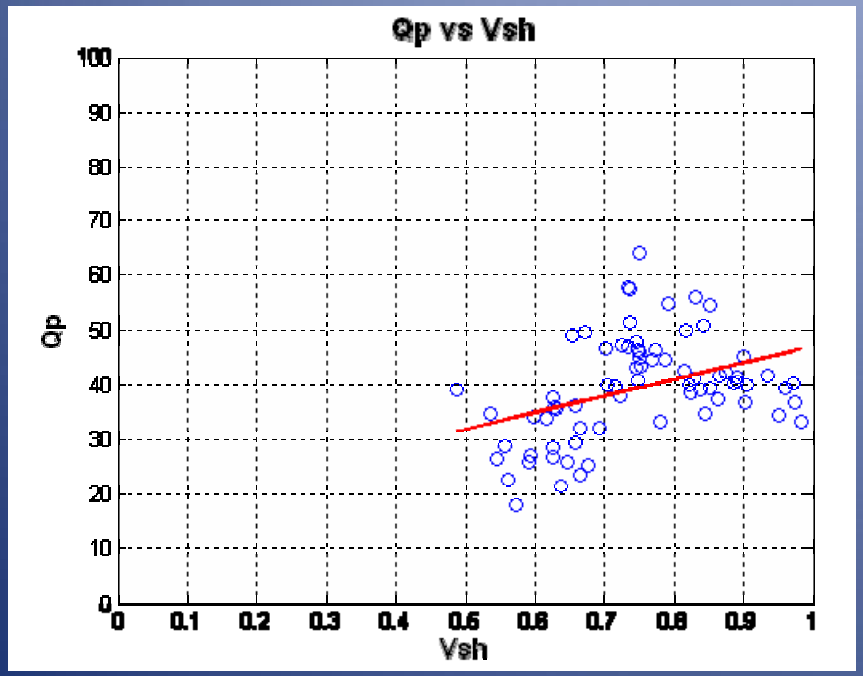
Q vs. porosity



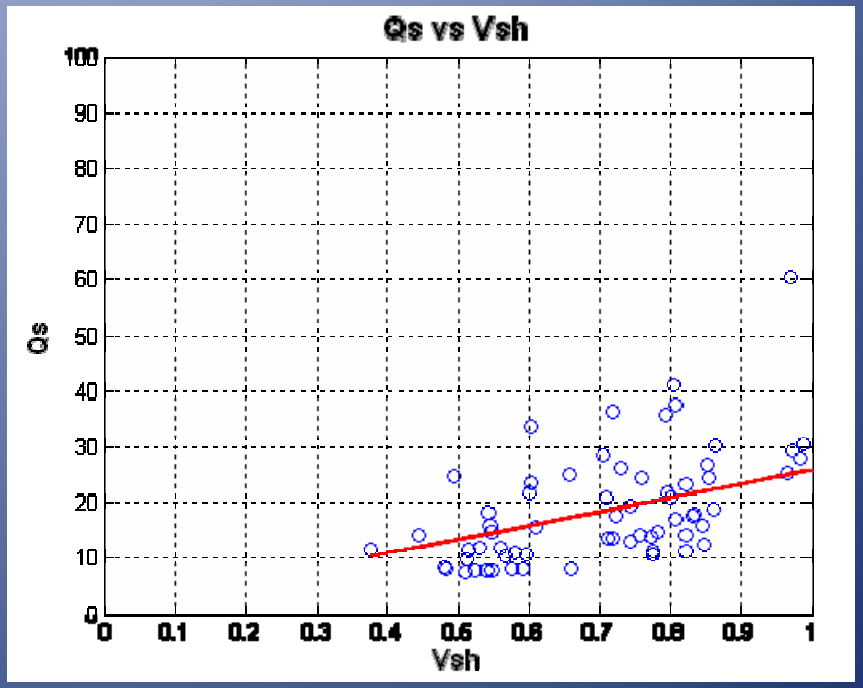


Red diamond: effective porosity;
blue circle: total porosity

Attenuation in shale and shaly sandstone

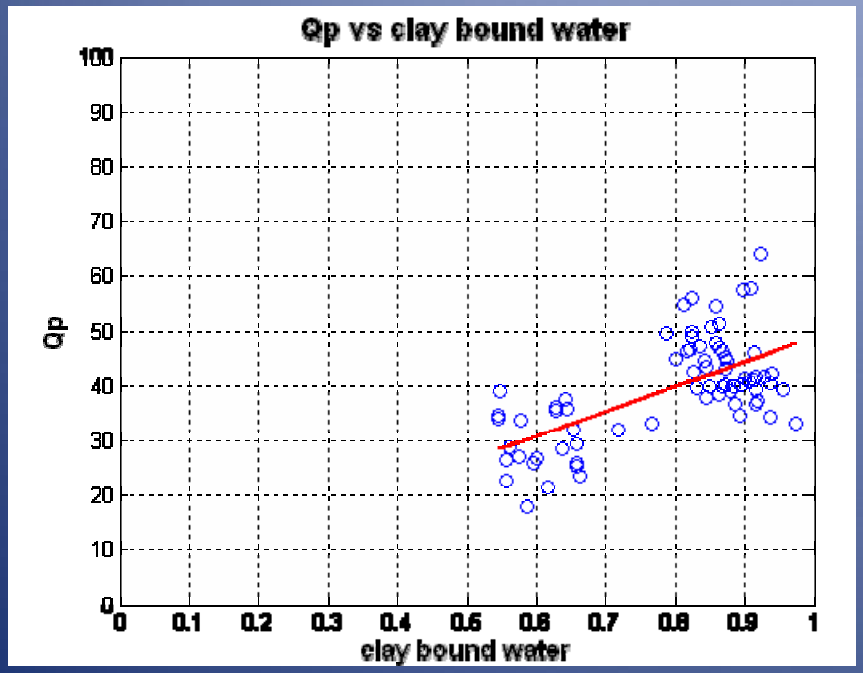


Qp vs. shale volume

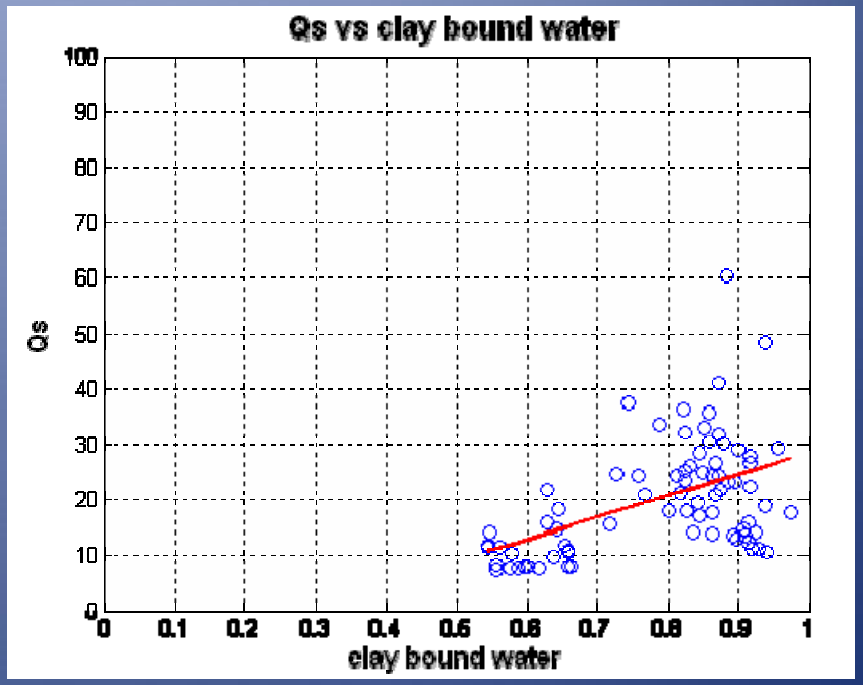


Qs vs. shale volume

Attenuation in shale and shaly sandstone

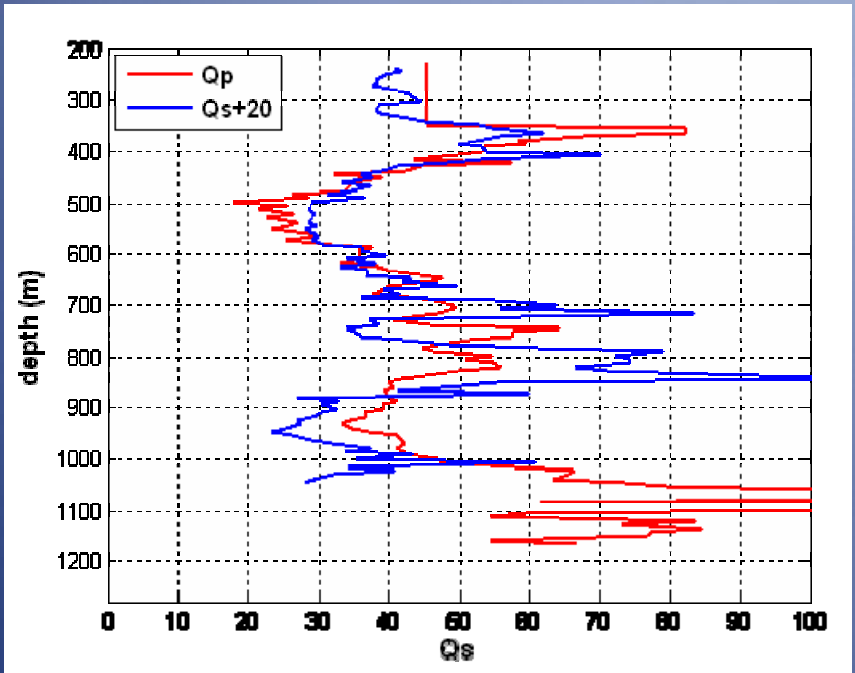


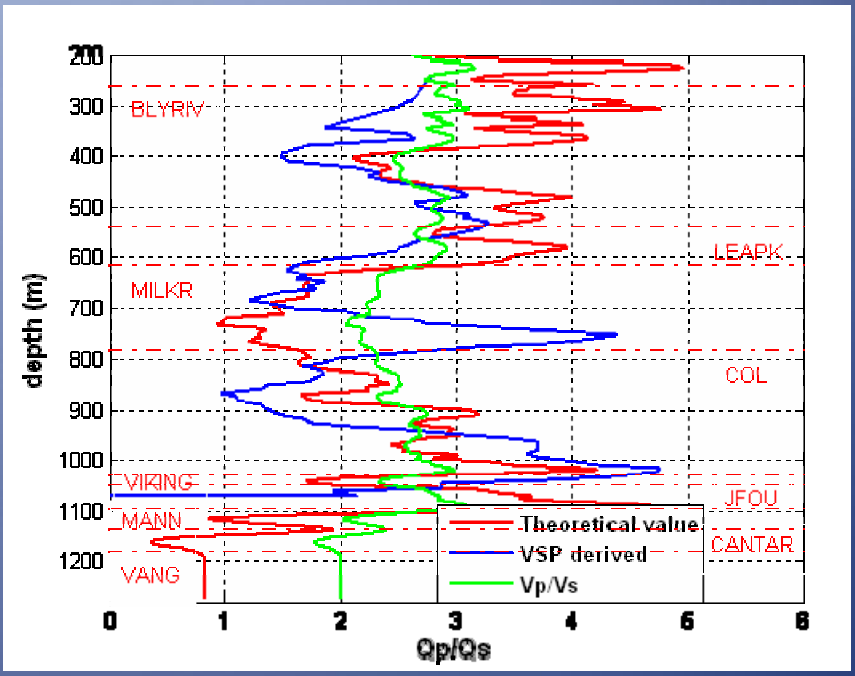
Qp vs. clay-bound water



Qs vs. clay-bound water

Relationship between Qp and Qs





Right: Vp/Vs – green; Qp/Qs (VSP derived) – blue; Qp/Qs (theoretical value) – red.

Theoretical values (red line in right figure) are given by

$$\frac{Q_p^{-1}}{Q_s^{-1}} = \frac{1}{4}\frac{\left((v_p/v_s)^2-2\right)^2\left(3*(v_p/v_s)^2-2\right)}{\left((v_p/v_s)^2-1\right)*(v_p/v_s)^2}$$

(Mavko et al., 2005)

Summary

- Plenty of attenuation in the data
- Velocity dispersion (log vs seismic) evident for Vp and Vs
- Generally, increasing velocities accompany increasing Q
- Greater porosity and higher Vp/Vs coincide with higher attenuation
- Attenuation was decreases with Vsh for clay-rich sandstone
- Clean sand has less attenuation than shaly sandstone.
- More attenuation in shaly sandstones possibly linked to mobile and clay-bound water interaction.
- Qp and Qs have same variation and can be linked by Vp/Vs.

Acknowledgements

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