Seismic detection of cracks in carbonates associated with potash mining

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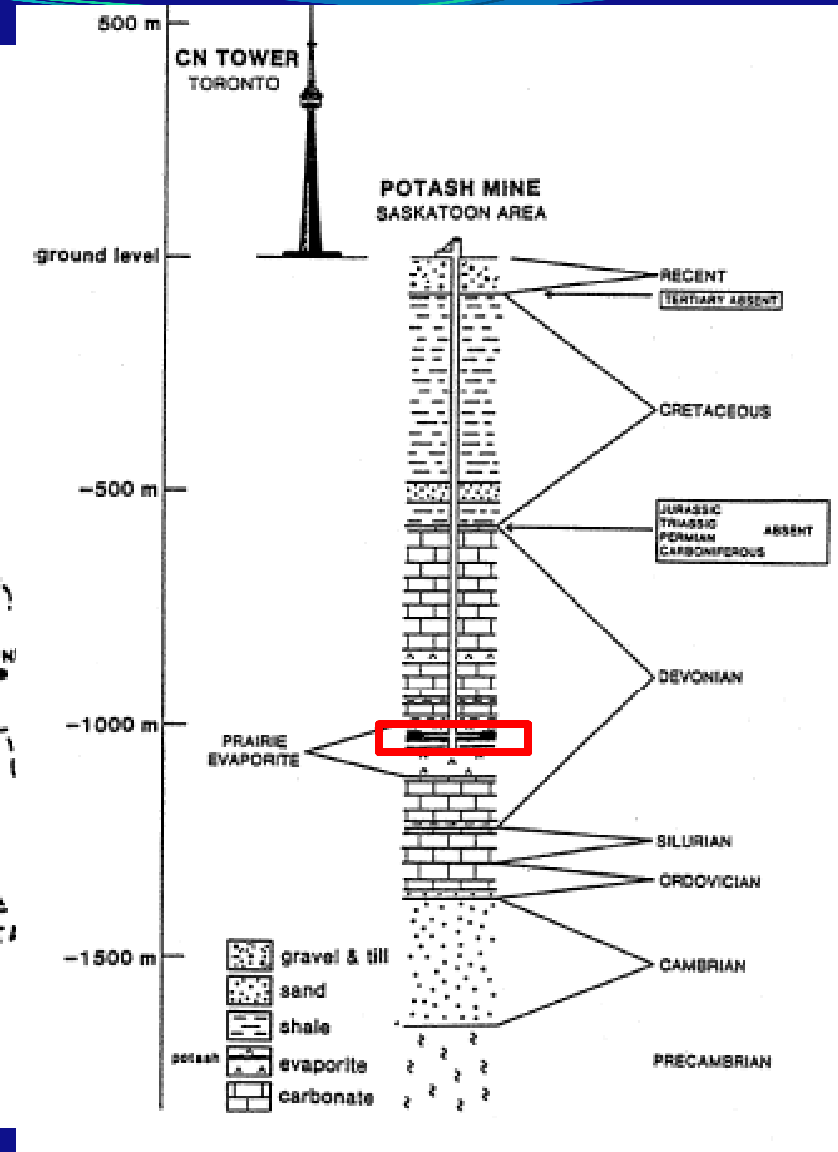
UNIVERSITY OF CALGARY

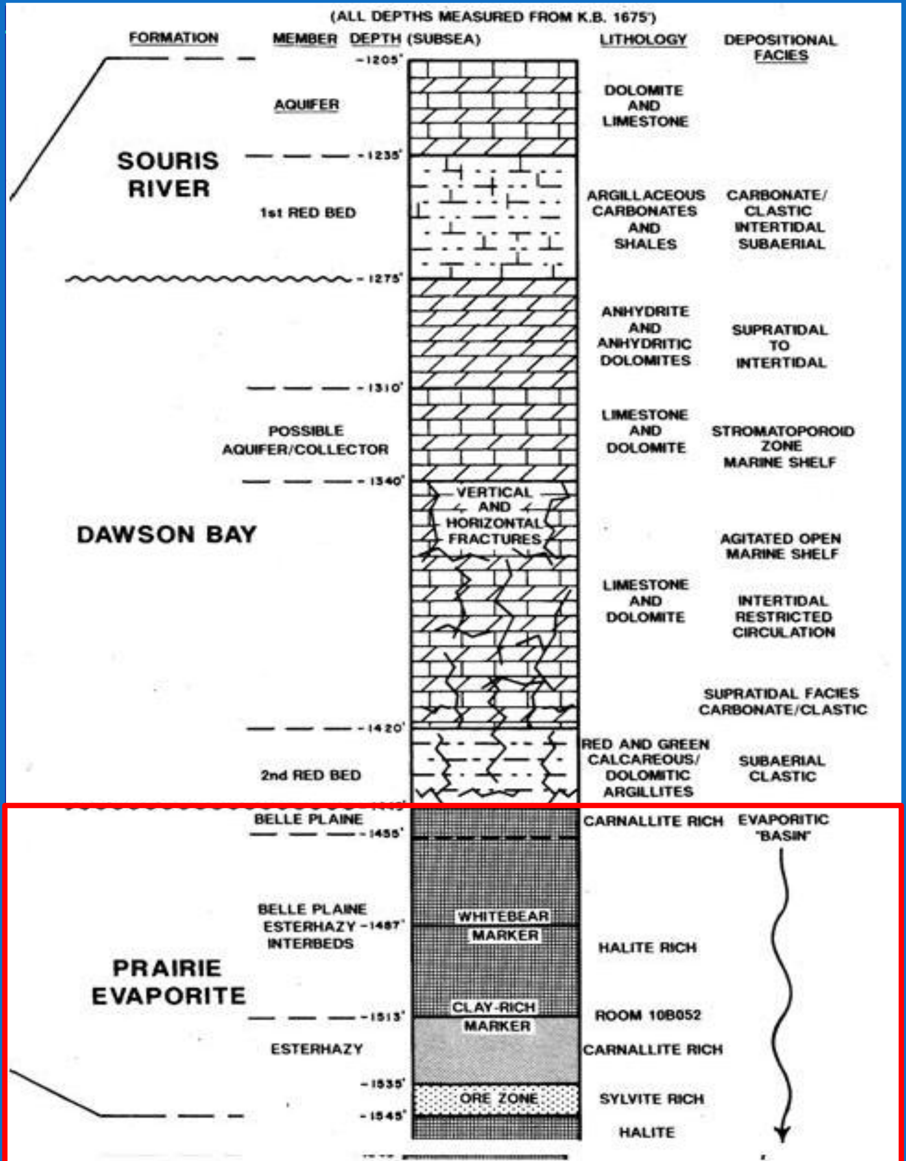
CREWES

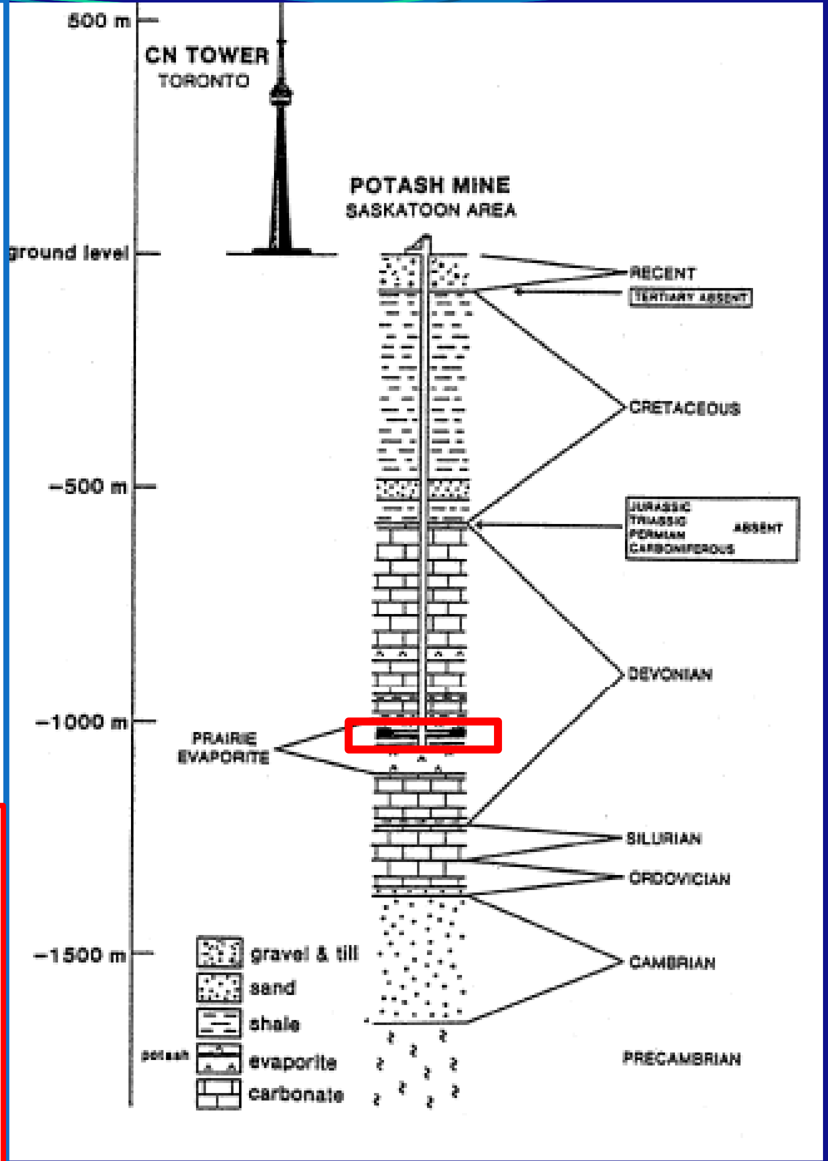
Outline

- **Introduction**
- **Modeling the cracks**
  - ✓ **Rock physics models for cracked media**
  - ✓ **Predicting shear velocity from Vp and ρ**
  - ✓ **Model results**
- **PP and PS synthetic seismograms**
- **Summary**



Areal distribution of potash-bearing rocks in the Elk Point Basin (from Fuzesy, 1982).





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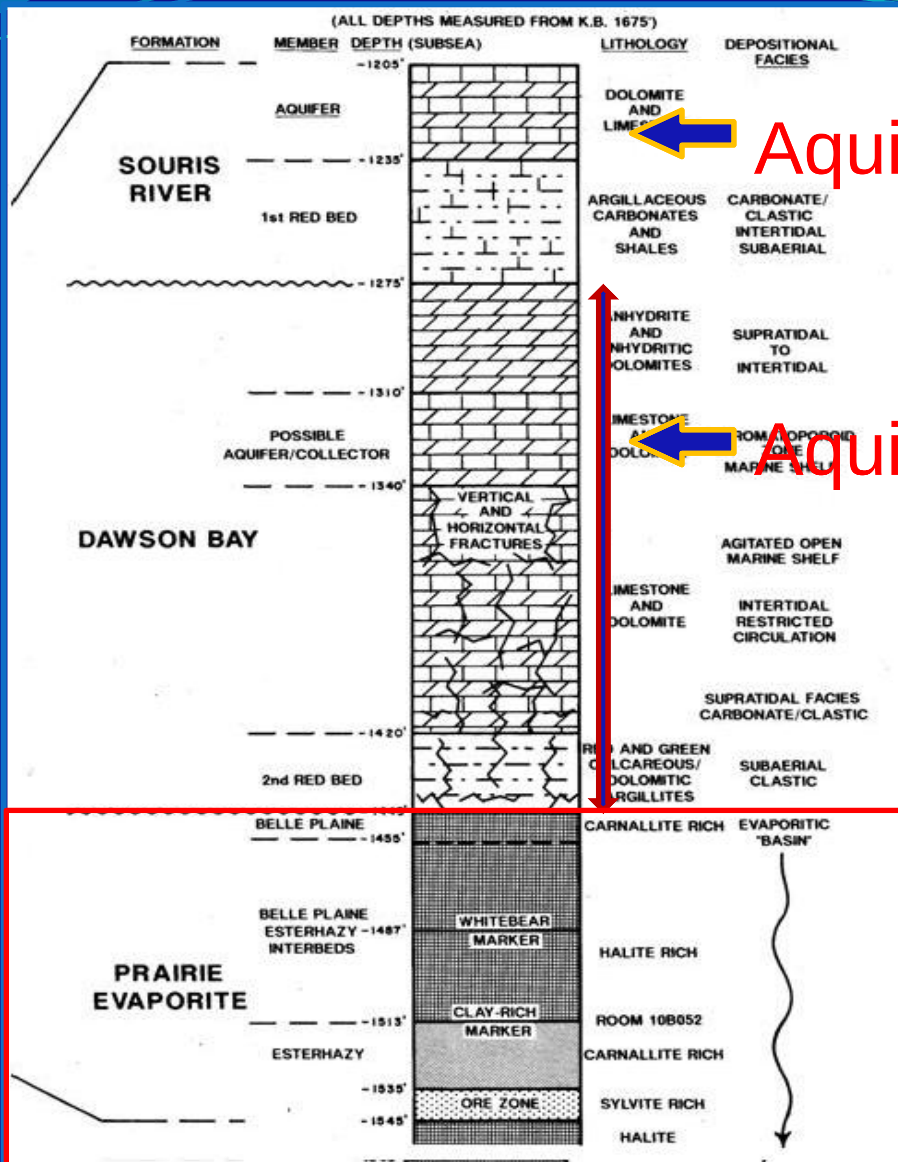
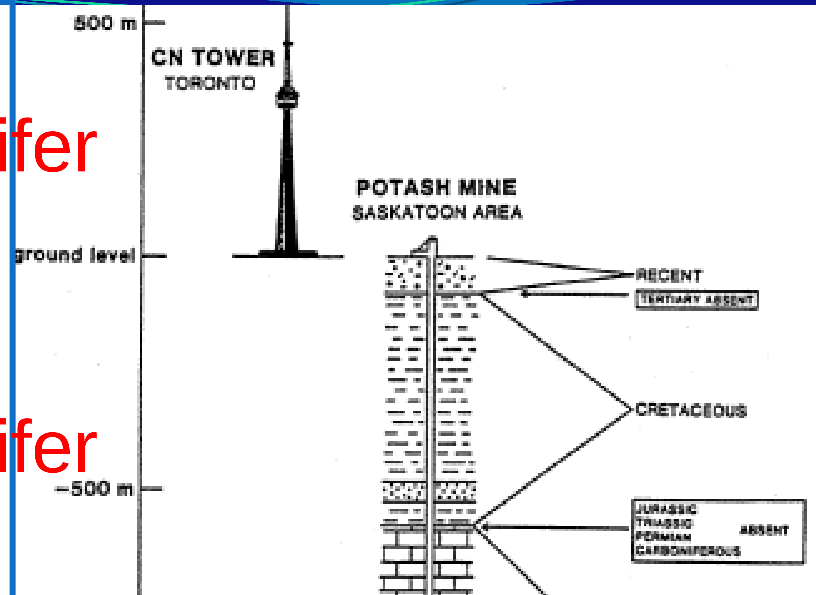


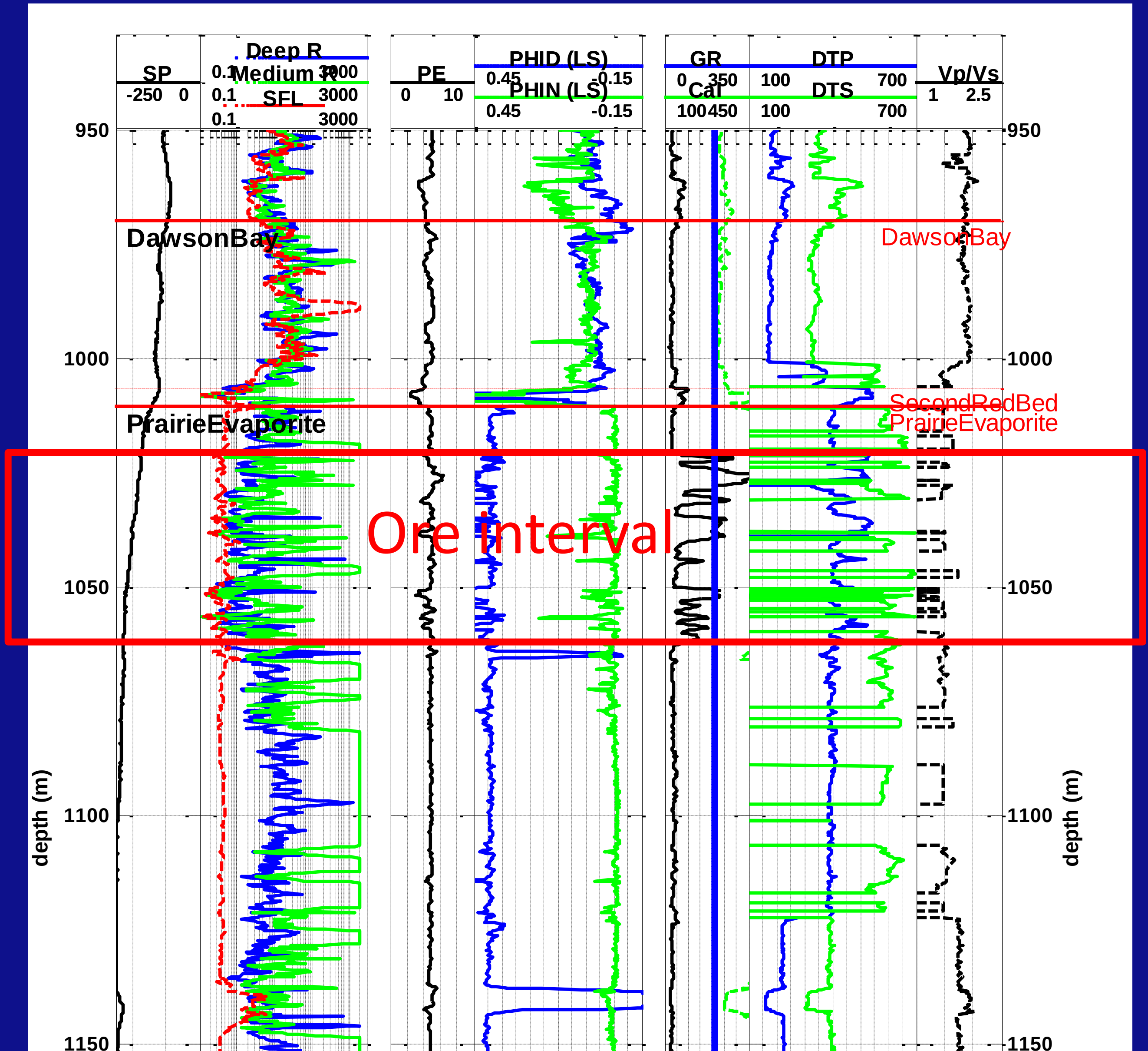


Areal distribution of potash-bearing rocks in the Elk Point Basin (from Fuzesy, 1982).

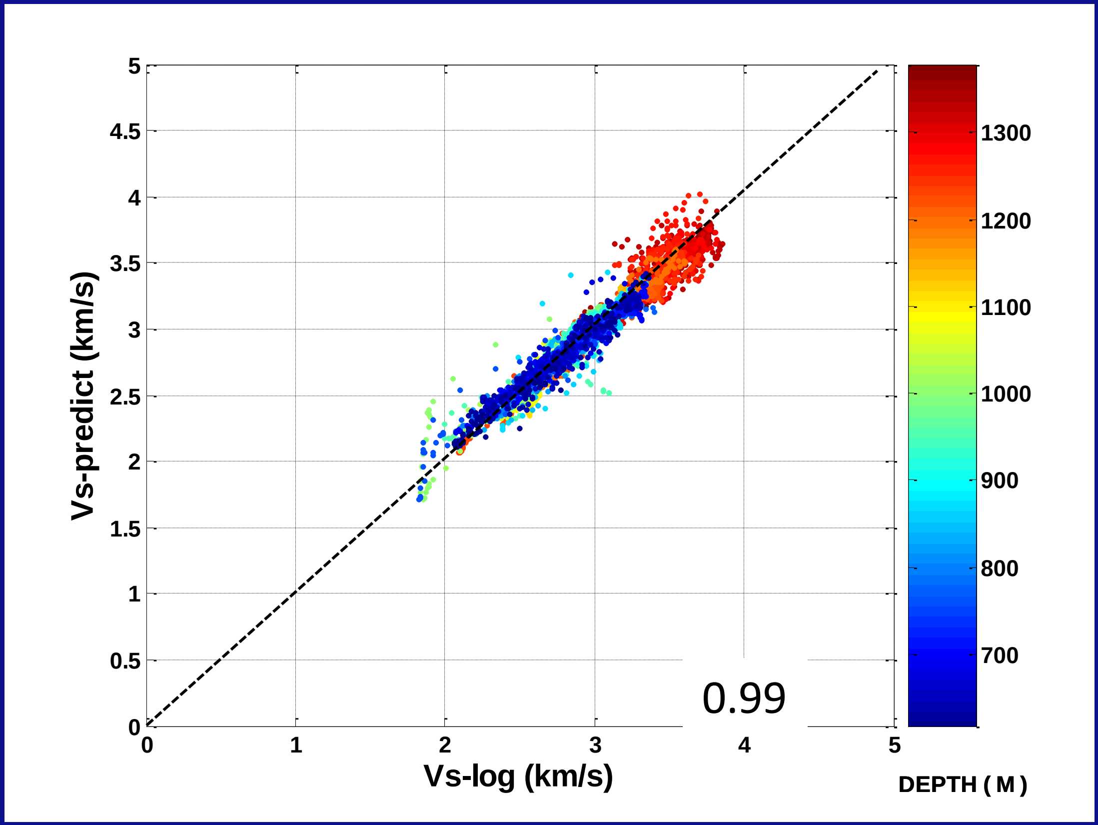
Objectives

1) Do cracked rocks have a seismic signature?
2) Can we use multicomponent seismic to detect it?

Well logs (Well A)



Predicting Vs from Vp and ρ

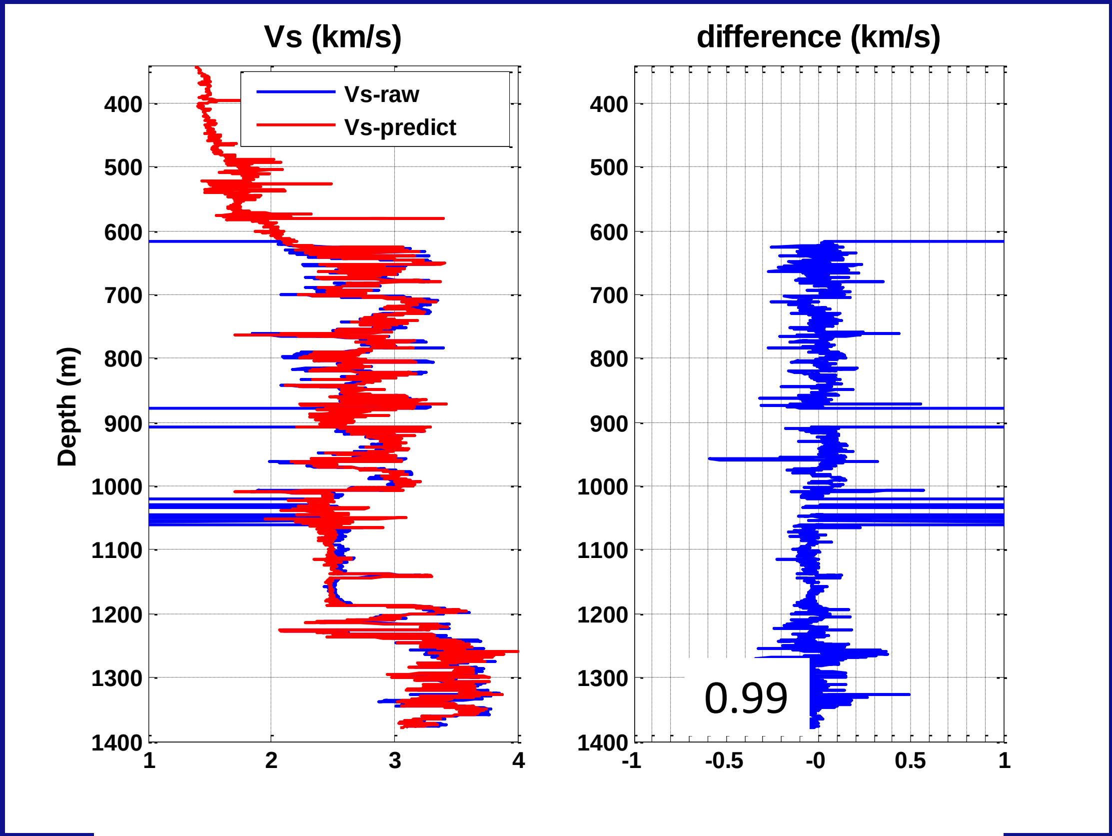


$$\mu = 0.0 * M^2 + 0.2687 * M + 1.7864$$

μ: shear modulus; M: P-modulus

(Han and Batzle, 2004)

Predicting Vs from Vp and ρ



$$\mu = 0.0 * M^2 + 0.2687 * M + 1.7864$$

μ: shear modulus; M: P-modulus

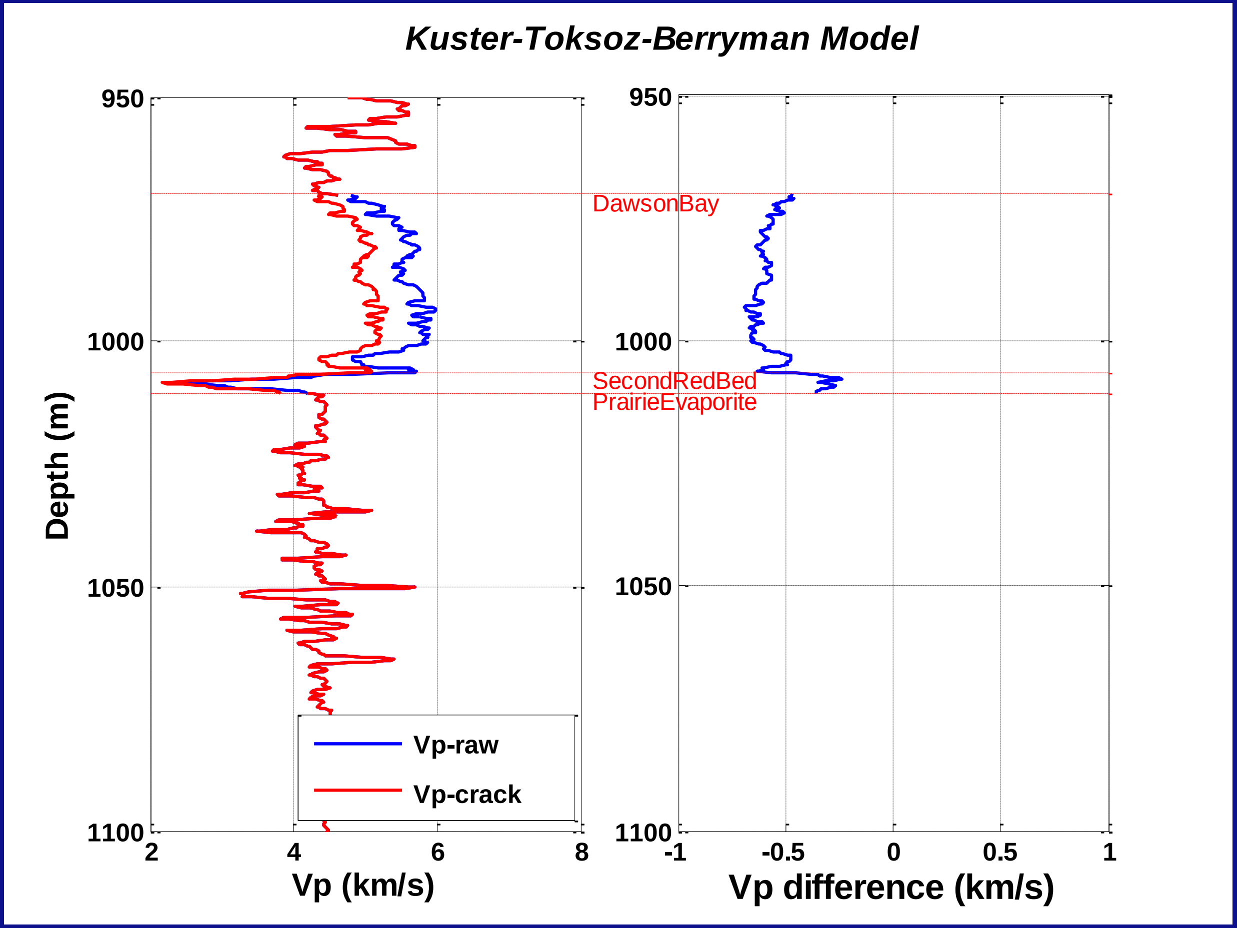
(Han and Batzle, 2004)

Modeling cracked rocks

- Penny-shaped, water-saturated cracks in rocks using:
  - ✓Kuster-Toksöz model: isotropic
    randomly oriented and distributed cracks
  - ✓Hudson's model: anisotropic
    vertically aligned cracks
- Can we detect cracks?
  - ✓model fractures/cracks
  - ✓find the difference between uncracked & cracked

Results of crack modeling on logs (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)

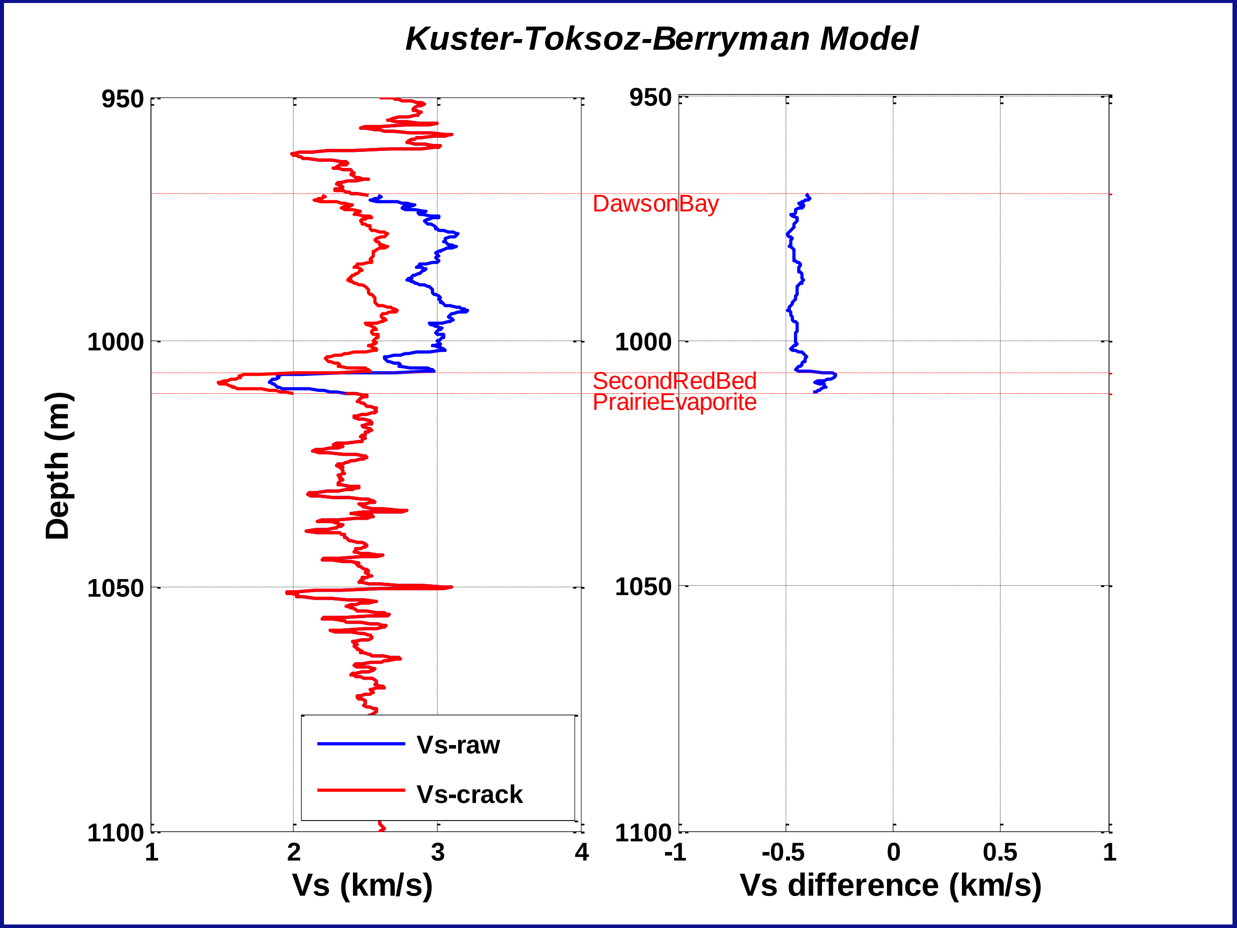


12.5% lower with cracks

Penny-shaped cracks (aspect ratio = 0.01)

Results of crack modeling on logs (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)



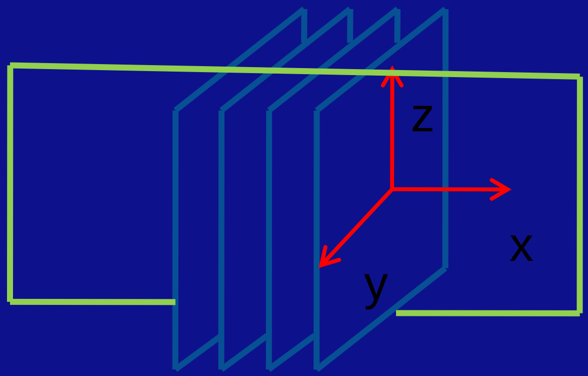
20% lower with cracks

Penny-shaped cracks (aspect ratio = 0.01)

Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)

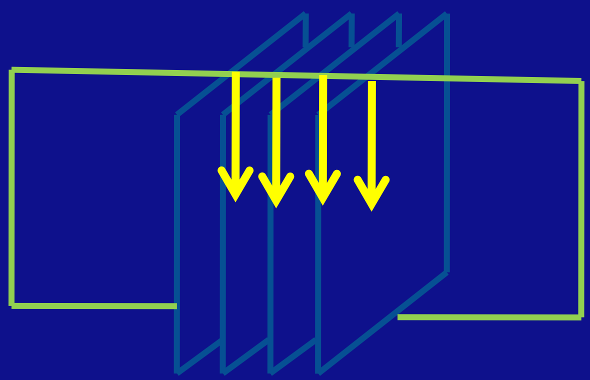
vertical cracks



Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)

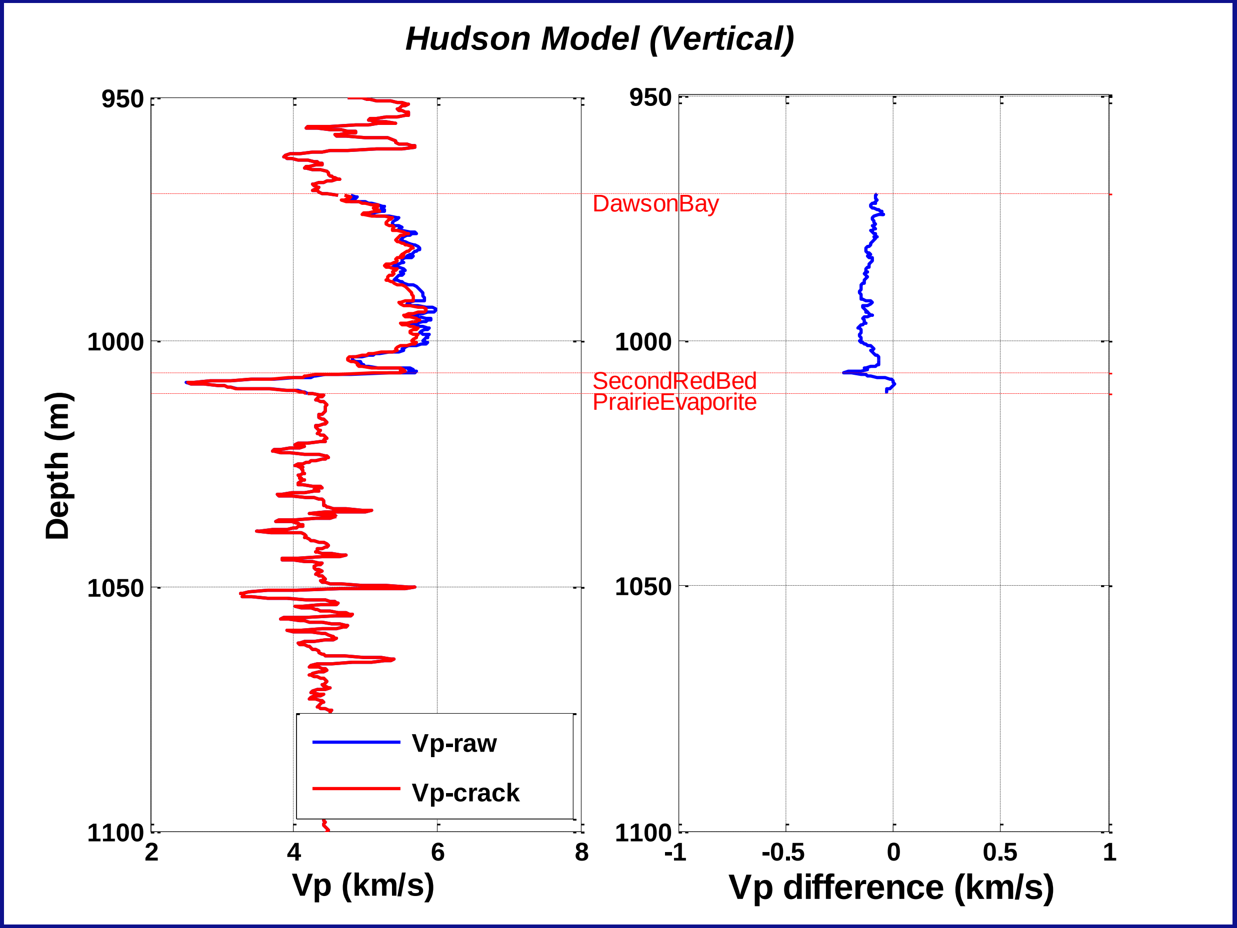
vertical cracks



Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)

vertical cracks



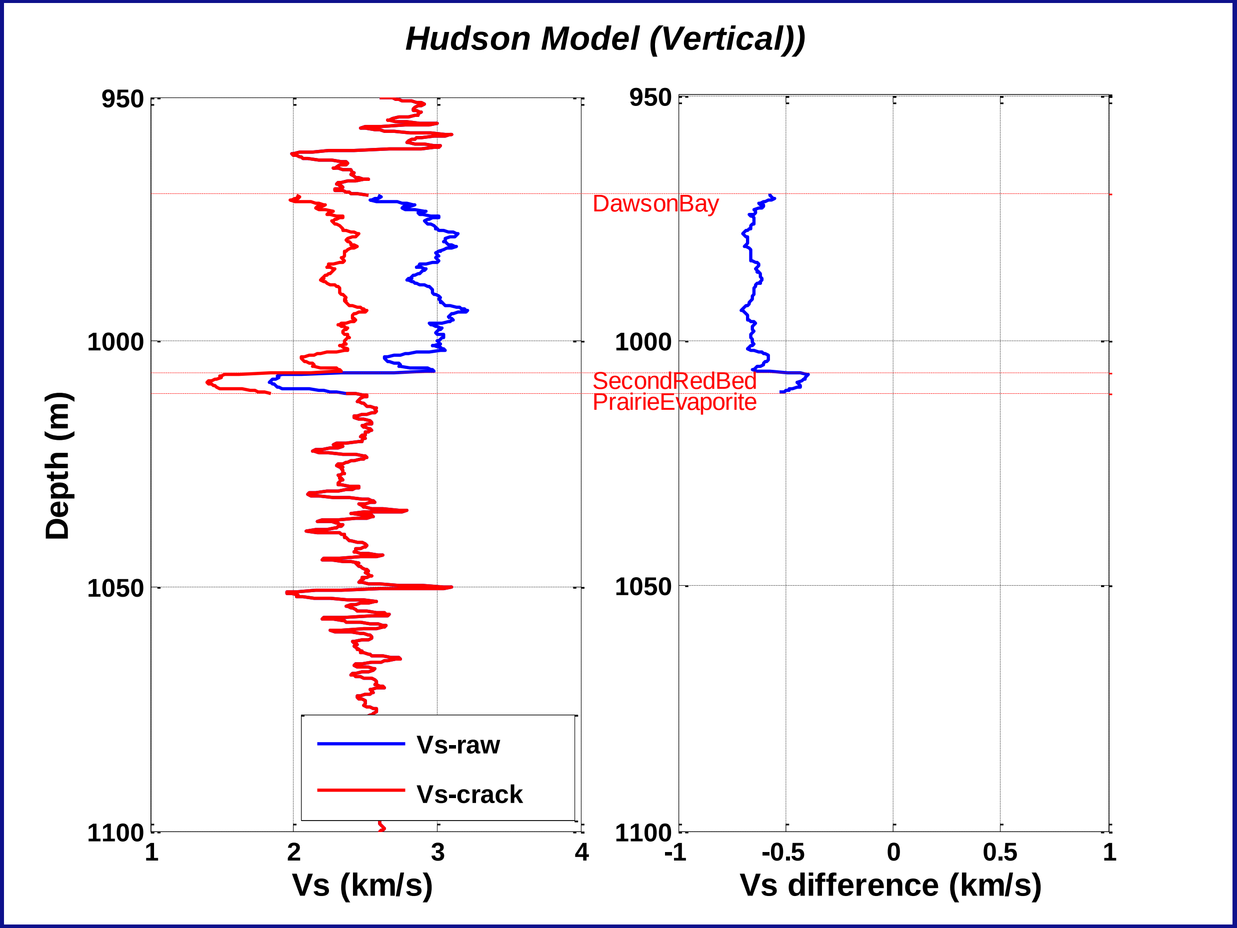
3.5% lower with cracks

vertical propagation velocity

Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)

vertical cracks



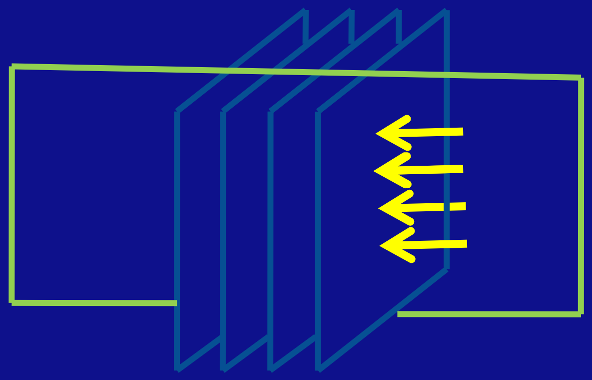
26% lower with cracks

vertical propagation velocity

Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)

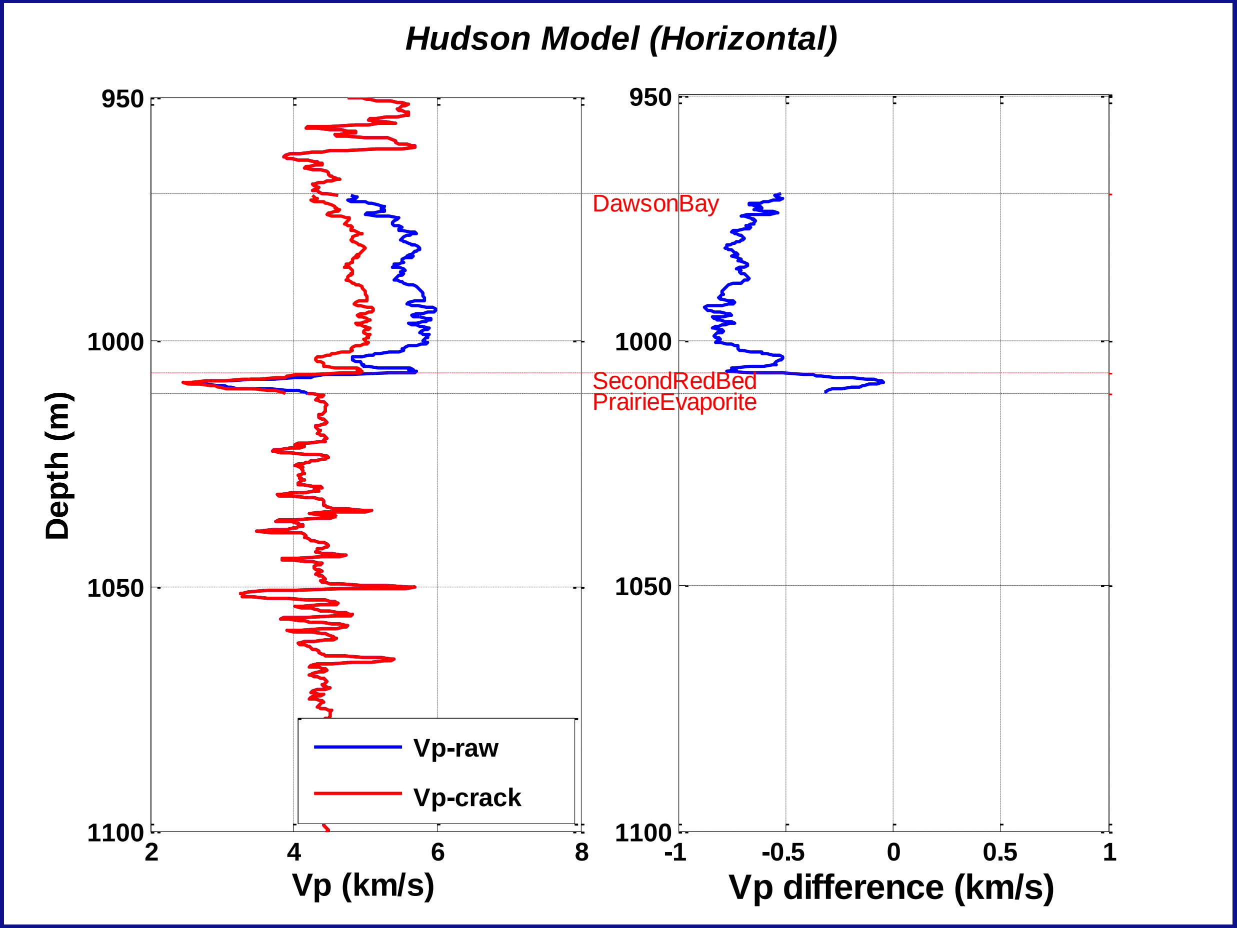
vertical cracks



Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)

vertical cracks



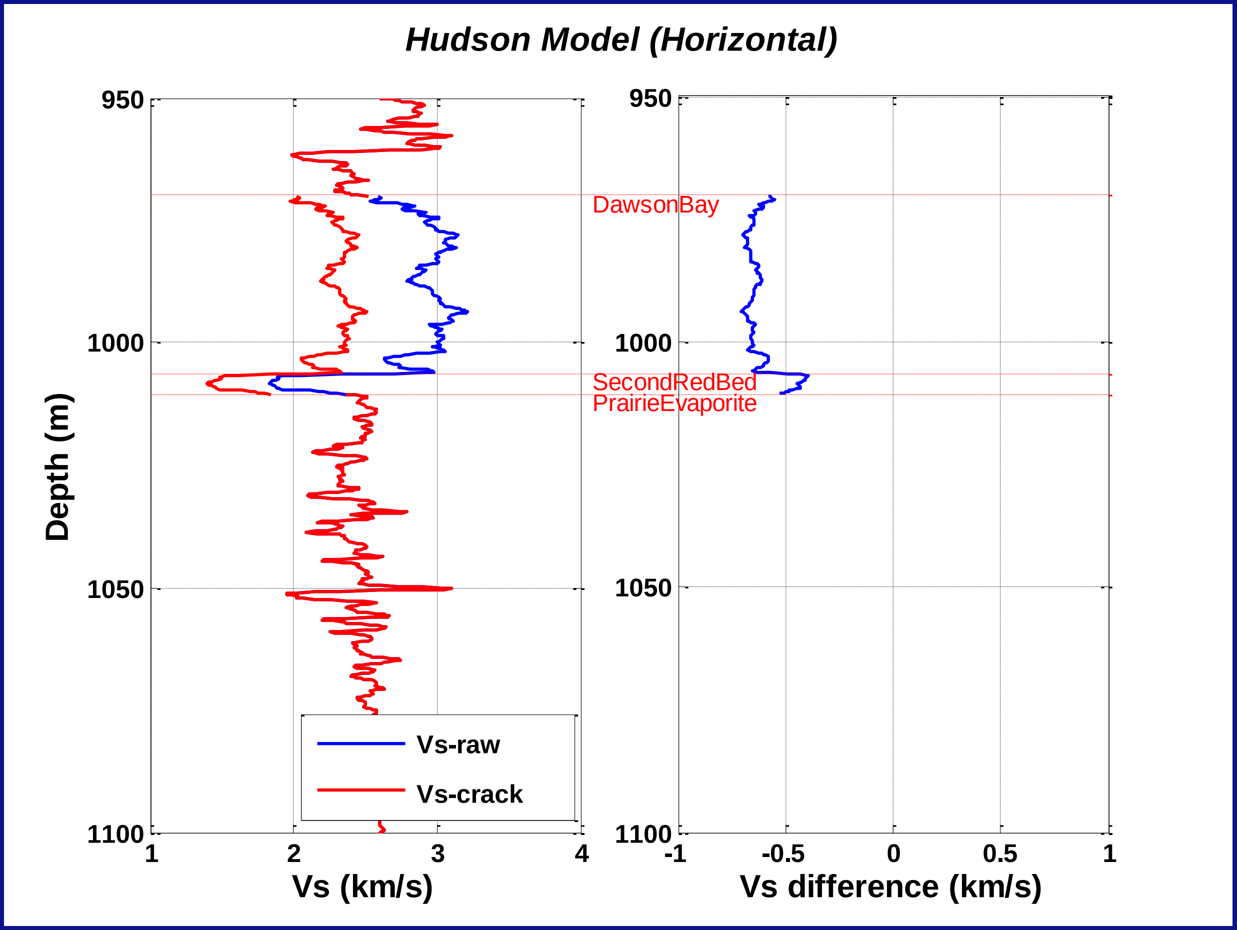
13.5% lower with cracks

horizontal propagation velocity

Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)

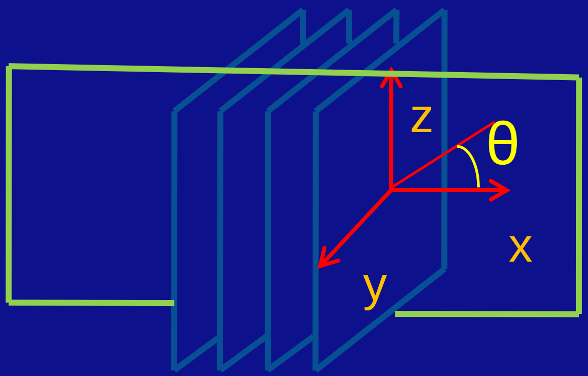
vertical cracks



26% lower with cracks

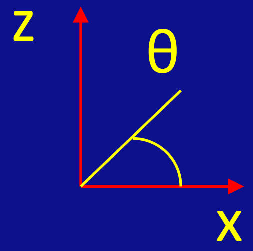
horizontal propagation velocity

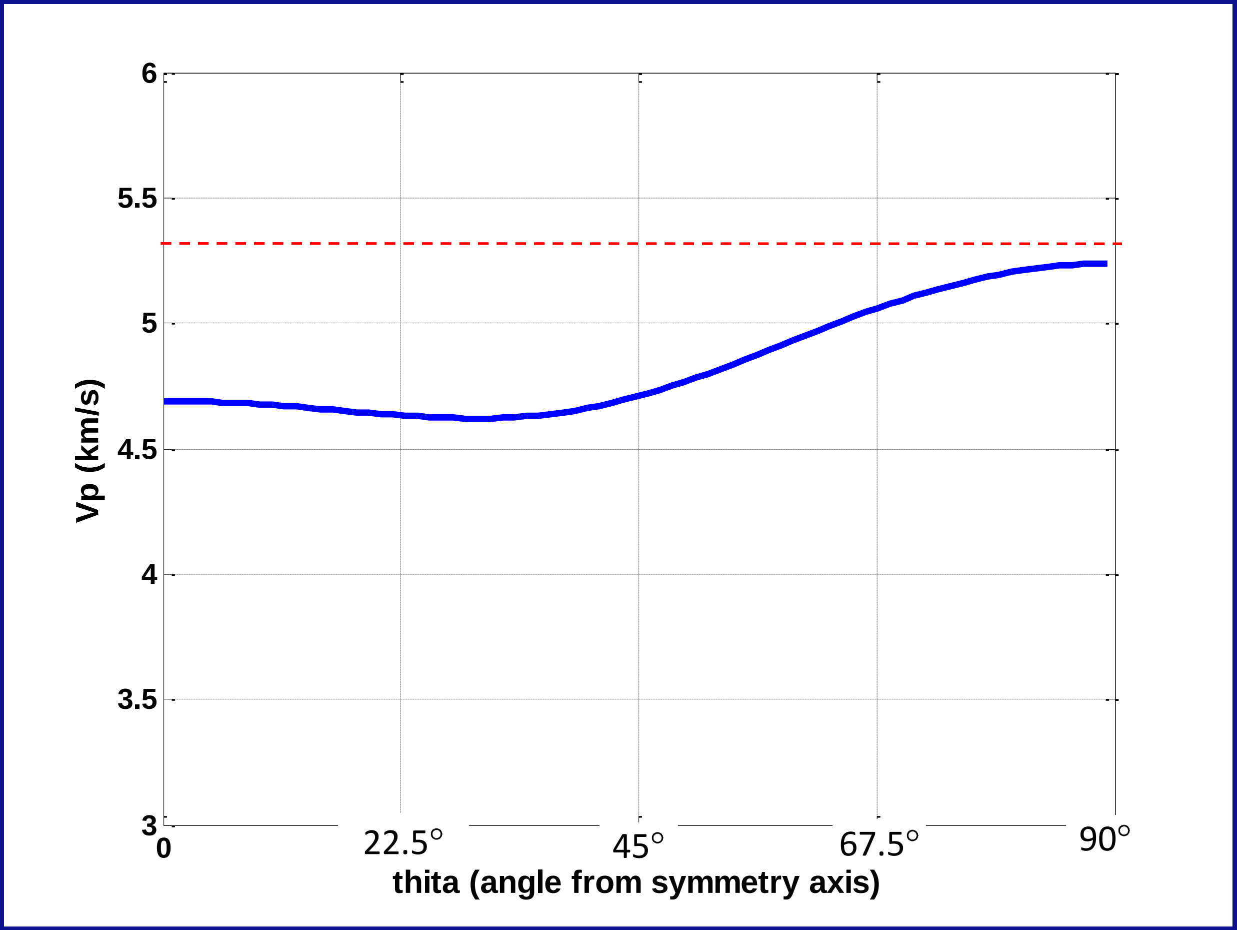
P-wave velocity anisotropy
from vertical cracks
(the isotropic background averaged over the Dawson Bay)



Hudson’s model

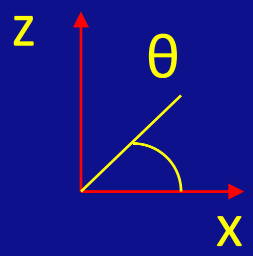
P-wave velocity anisotropy
from vertical cracks
(the isotropic background averaged over the Dawson Bay)

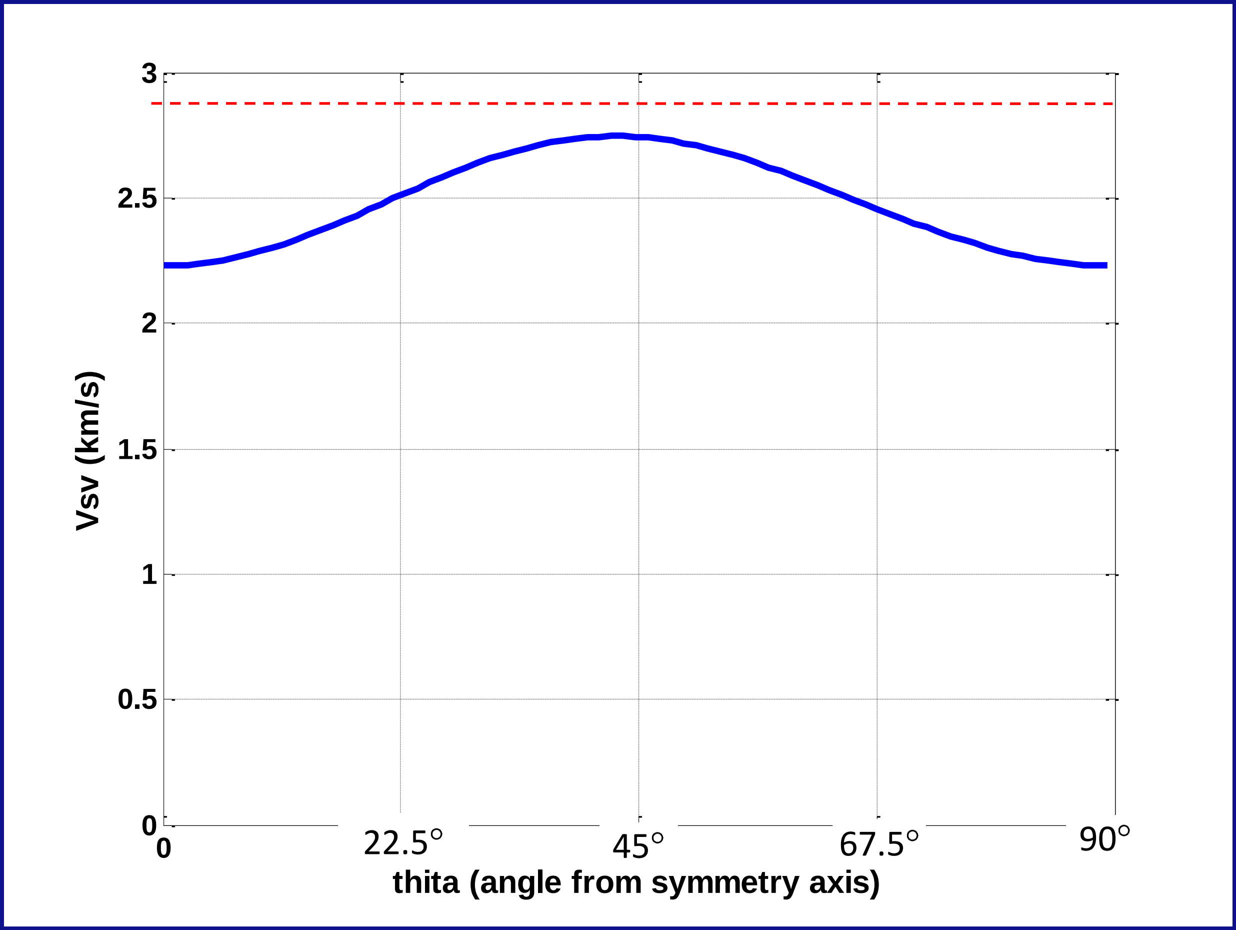




Hudson's model

S-wave velocity anisotropy
from vertical cracks
(the isotropic background averaged over the Dawson Bay)



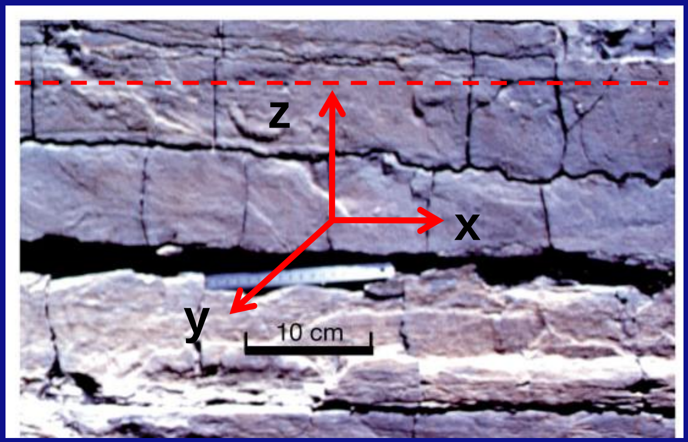


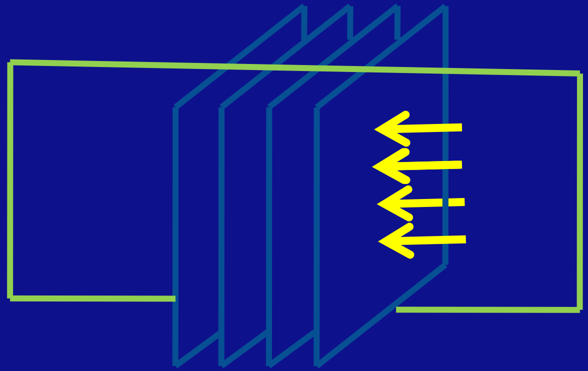
Hudson's model

Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)

vertical + horizontal cracks

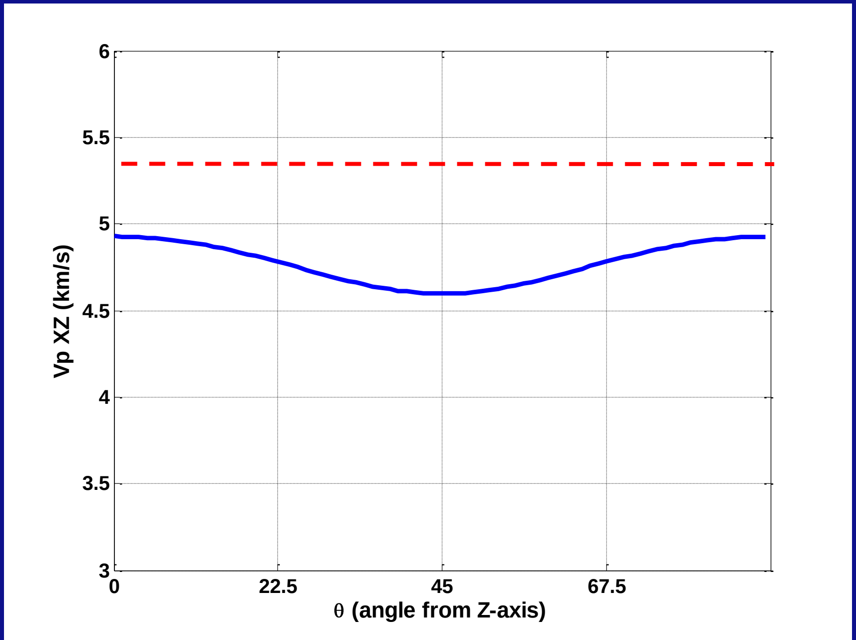




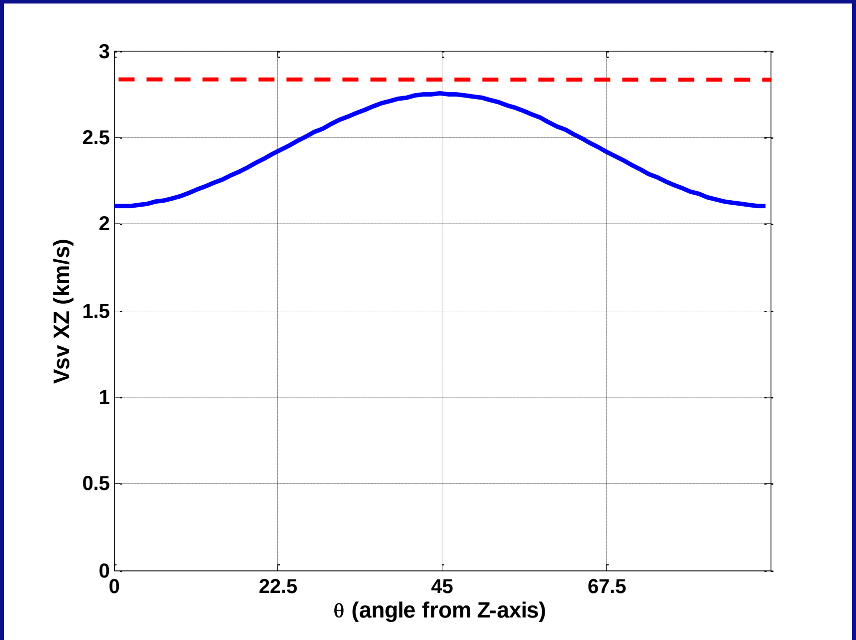
Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)
vertical + horizontal cracks

Vp



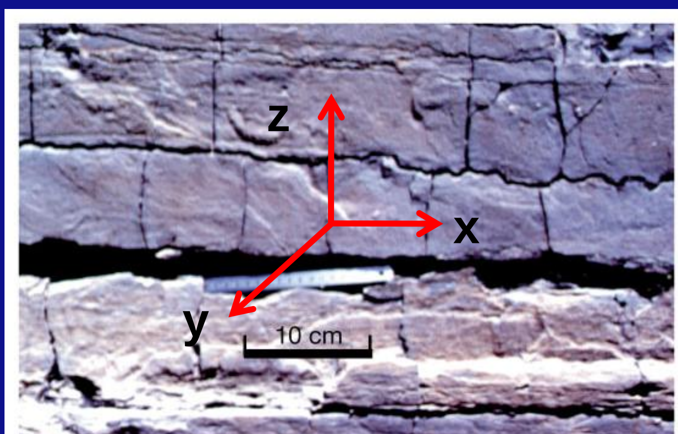
Vsv

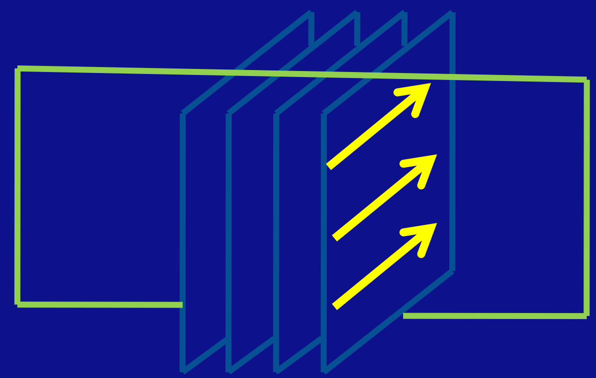


Propagation in XZ plane

Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)
vertical + horizontal cracks

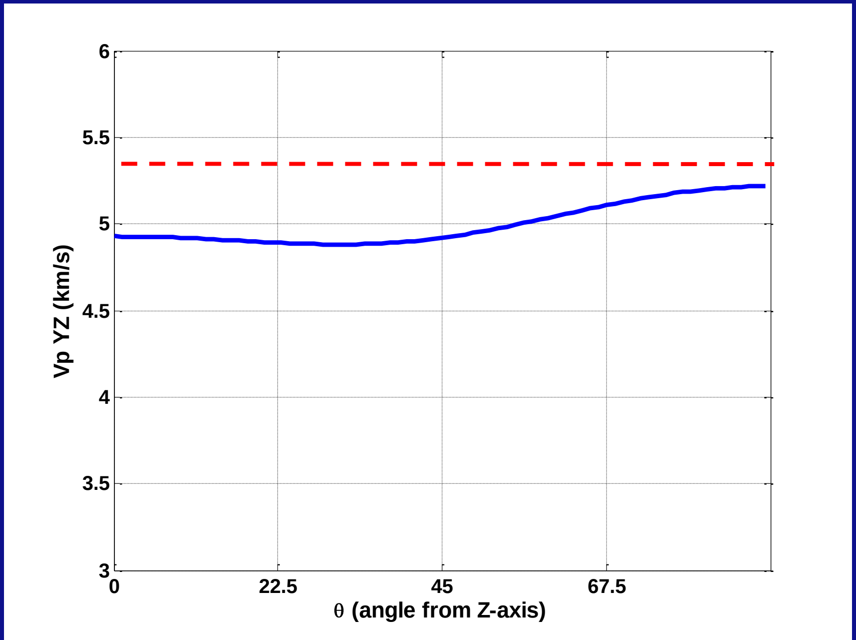




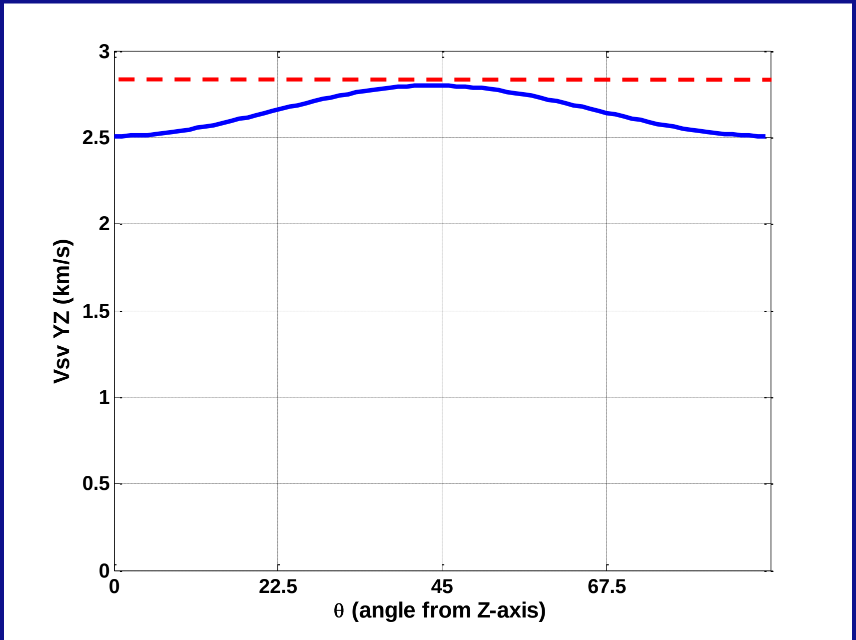
Modeling cracked formations (1% crack porosity)

(Dawson Bay including Second Red Bed Shale)
vertical + horizontal cracks

Vp



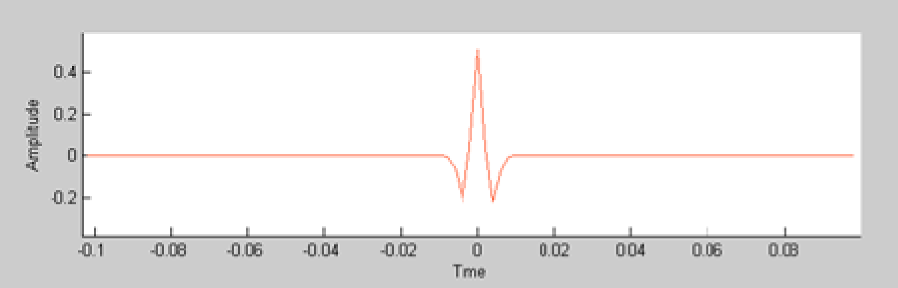
Vsv

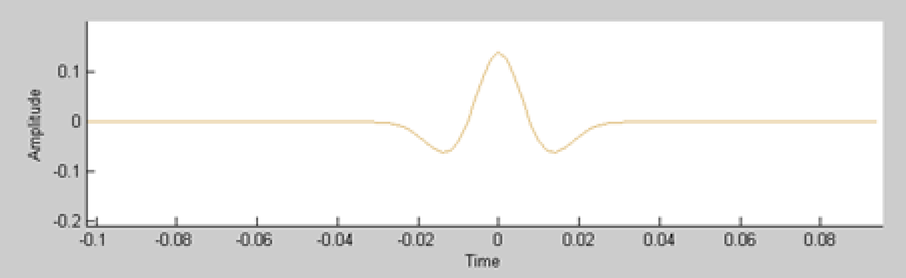


Propagation in YZ plane

Synthetic seismograms

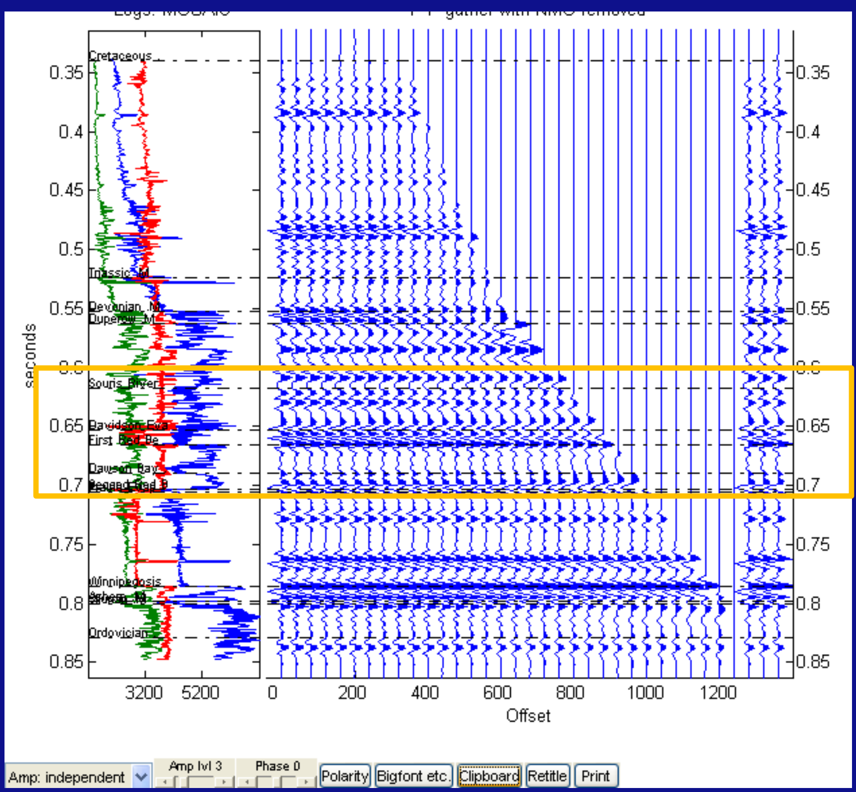
- Ricker wavelet
- Dominant frequency (based on the amplitude spectrum of surface seismic)
  - ✓ PP section: 106Hz
  - ✓ PS section: 29Hz

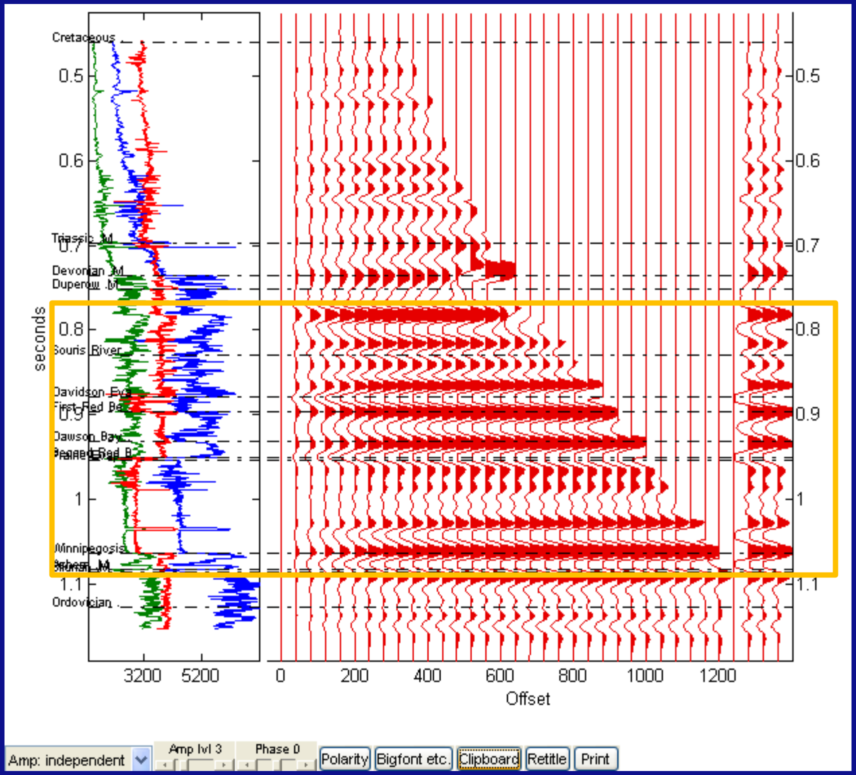




PP and PS synthetic seismograms

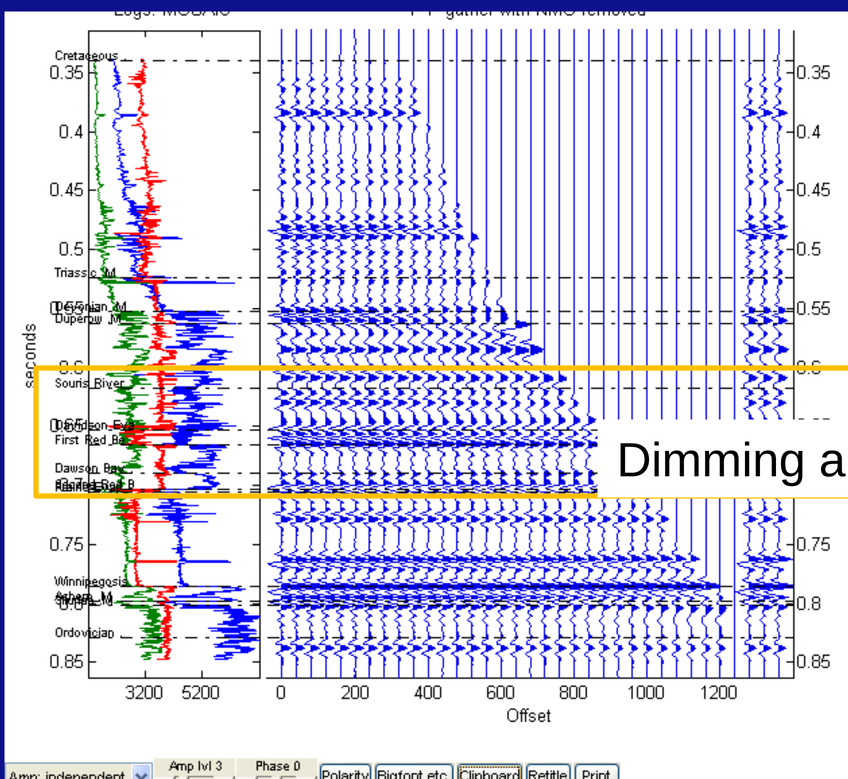
(using Hudson’s vertical P and S velocities)



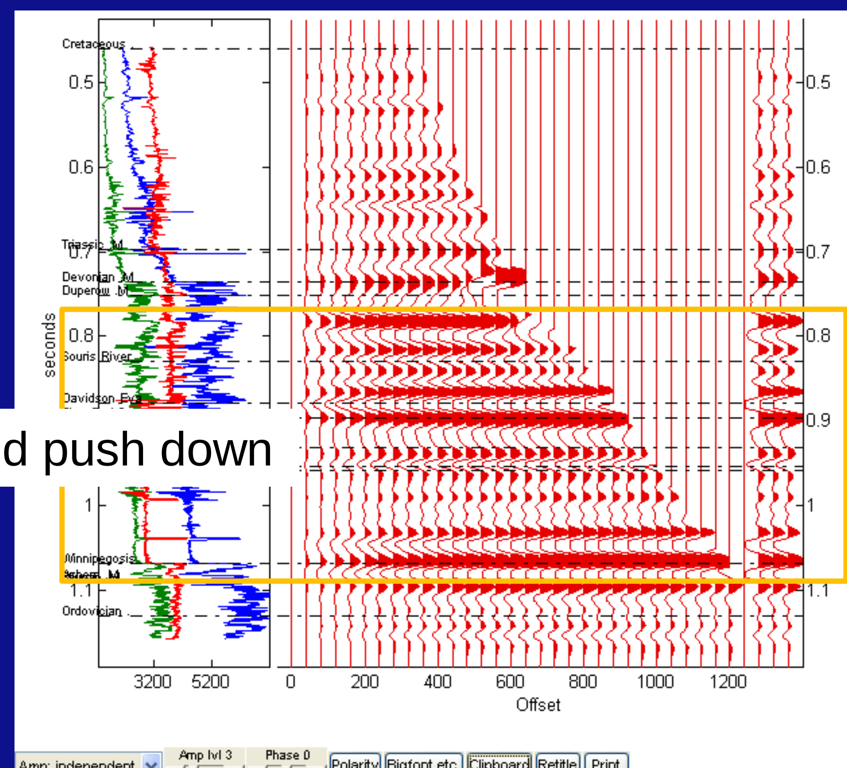


PP and PS synthetic seismograms

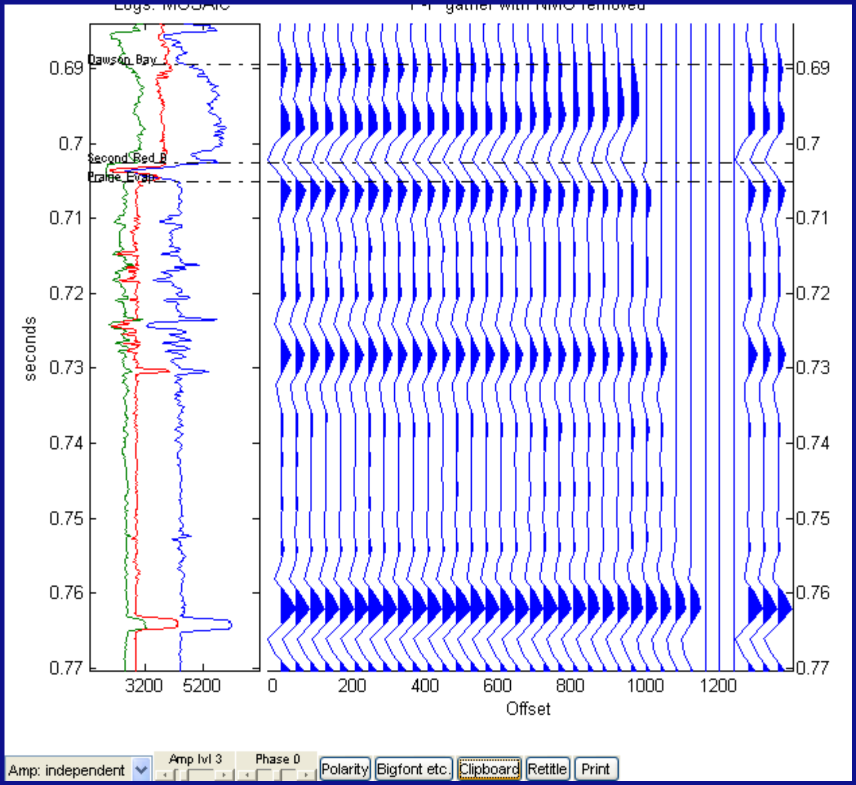
(using Hudson's vertical P and S velocities)

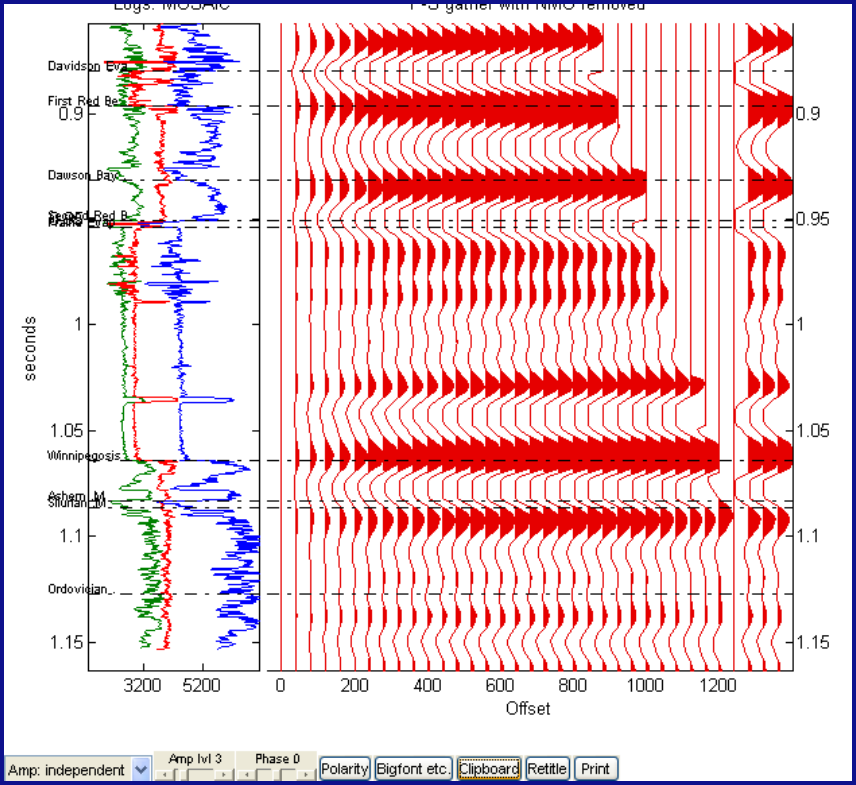


Dimming and push down



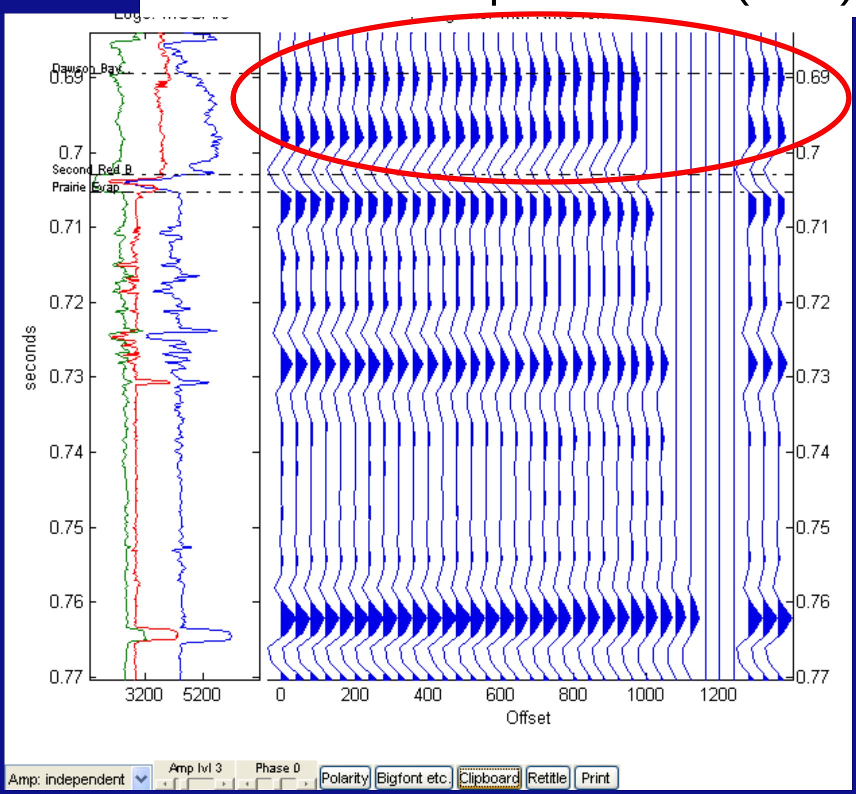
PP and PS seismograms (zoomed)

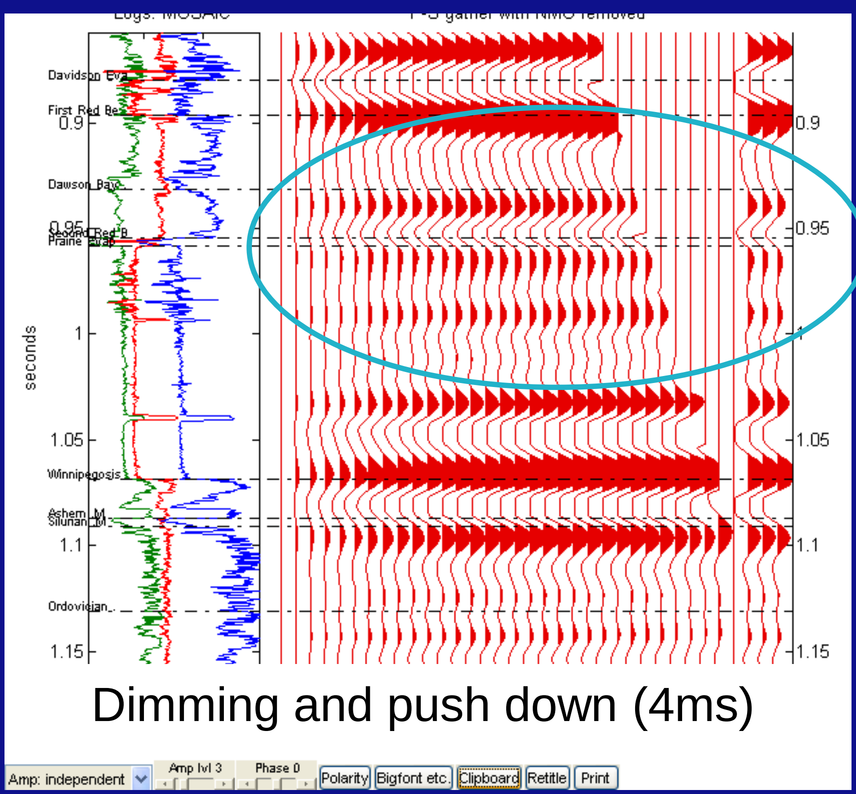




PP and PS seismograms (zoomed)

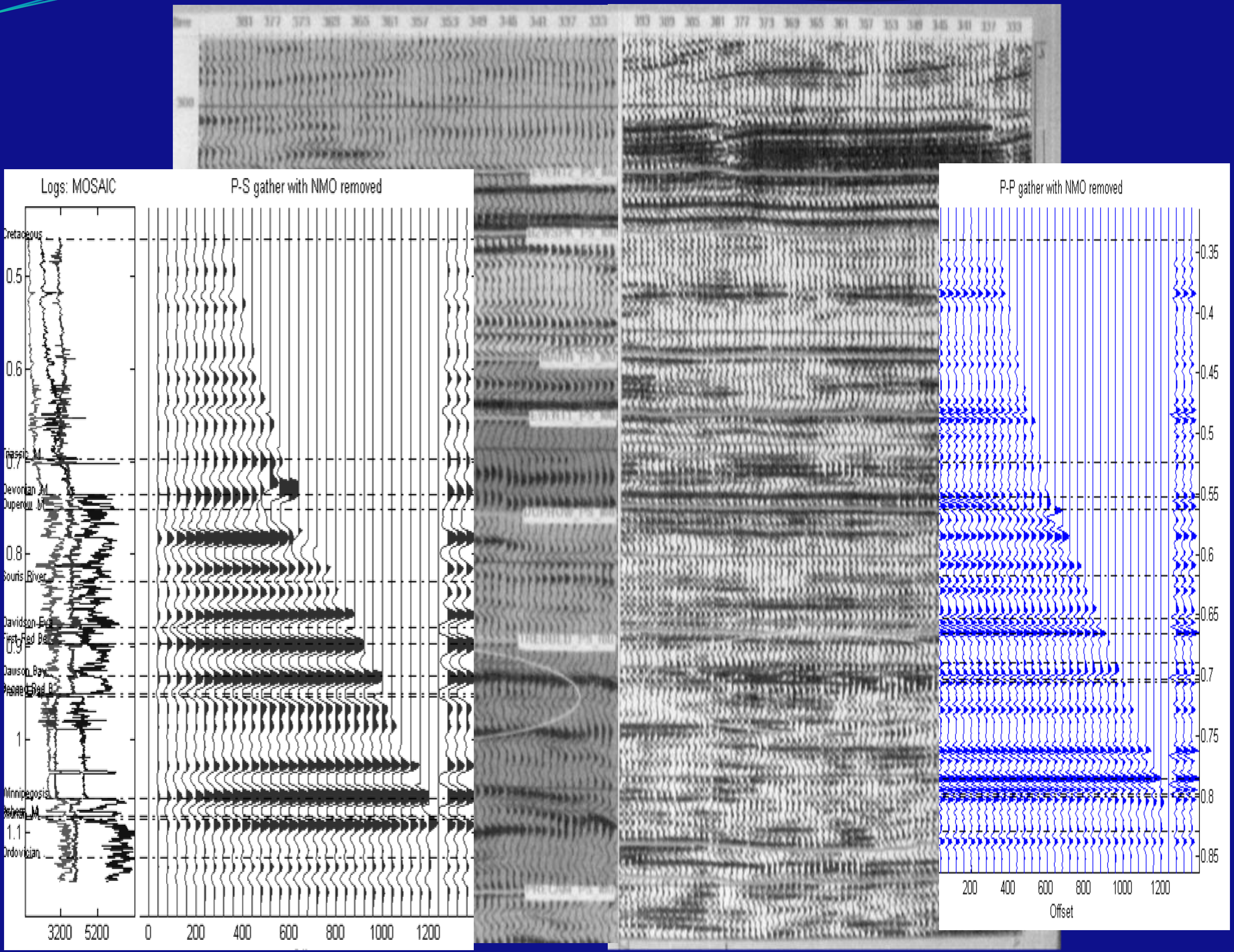
AVO and small push down (2ms)





Dimming and push down (4ms)

Correlation with surface seismic



Summary

- Velocity decreases when cracks are present (Kuster-Toksöz & Hudson)
- S velocity drops significantly (over 20%)
- Vp/Vs increases with cracking
- P- and S-velocity anisotropy with aligned cracks
- Visible changes in PP and PS synthetic seismograms with cracking
- Changes in converted-waves (PS) with cracking show promise as an indicator of rock alteration

Acknowledgements

- **CREWES sponsors**