Characterizing the Near-Surface with VSP and Well-logs: Case study from Priddis, Alberta

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CREWES Sponsors Meeting

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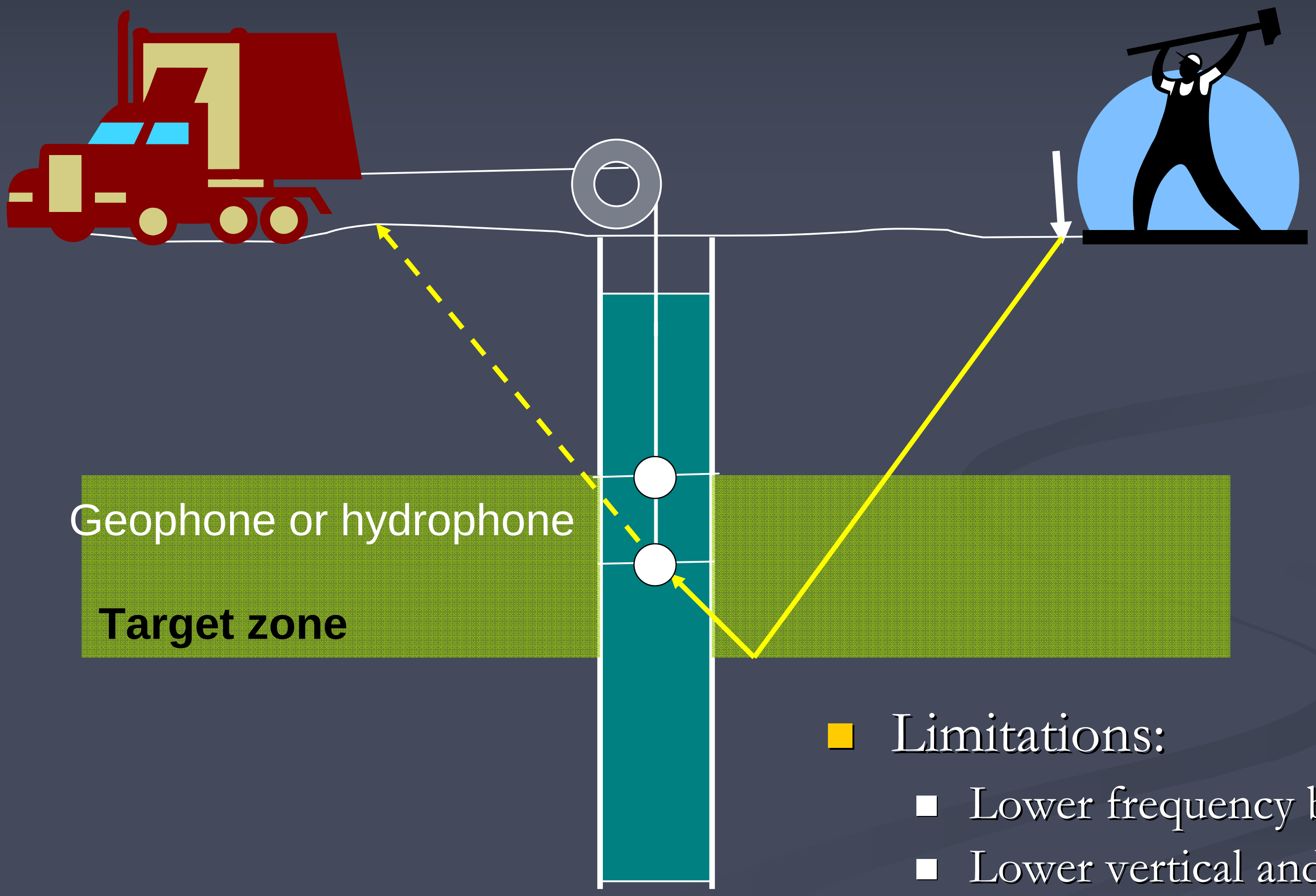
Outline

- Introduction
- Well-log and VSP data acquisition
- Quantitative log analysis
- Near-offset shallow VSP processing
- Well-log, VSP, and synthetic correlation
- Velocity Estimation from VSP data
- Conclusion

Introduction

- Geophysical application for near-surface characterization:
  - Mapping bedrock, detect abandoned coal mines, and delineate water saturated zones
- Limitations of surface seismics:
  - Low seismic resolution
  - Assume simple velocity (one to two layered velocity model) for depth of ~30 m

Vertical Seismic Profiling vs. Surface Seismics

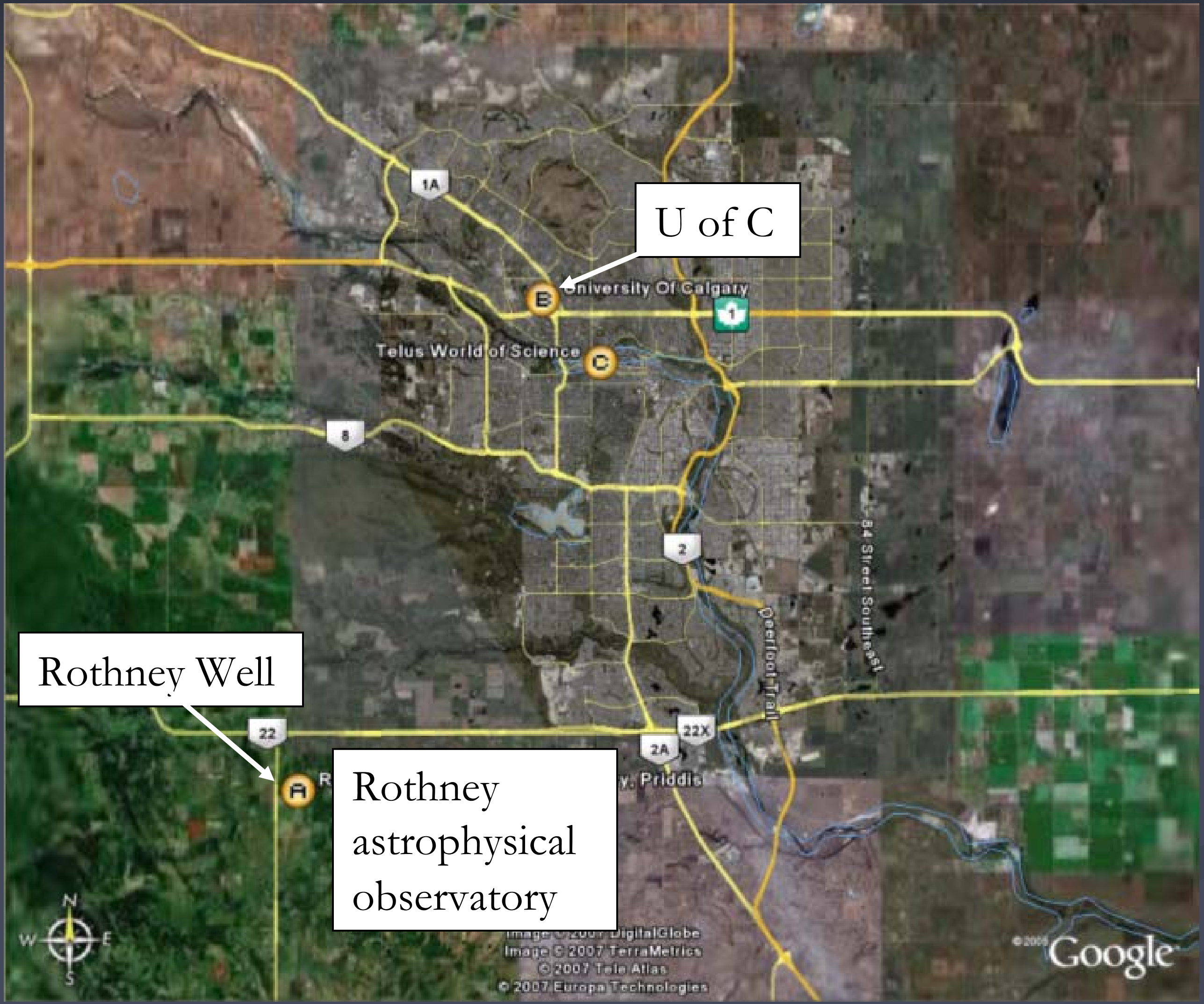


- Limitations:
  - Lower frequency bandwidth
  - Lower vertical and horizontal resolution

Introduction

- Objectives:
  - Characterize near-surface features near shallow borehole in Pridiss using well-logs and VSP data
  - Obtain detailed velocity model from VSP data

Field Data Acquisition-Priddis



- ~40 km away from U of C, in Priddis, AB
- Paskapoo formation:
  - Primarily composed of interlayering of sandstone and shale
  - 100,000 wells are in Paskapoo formation:

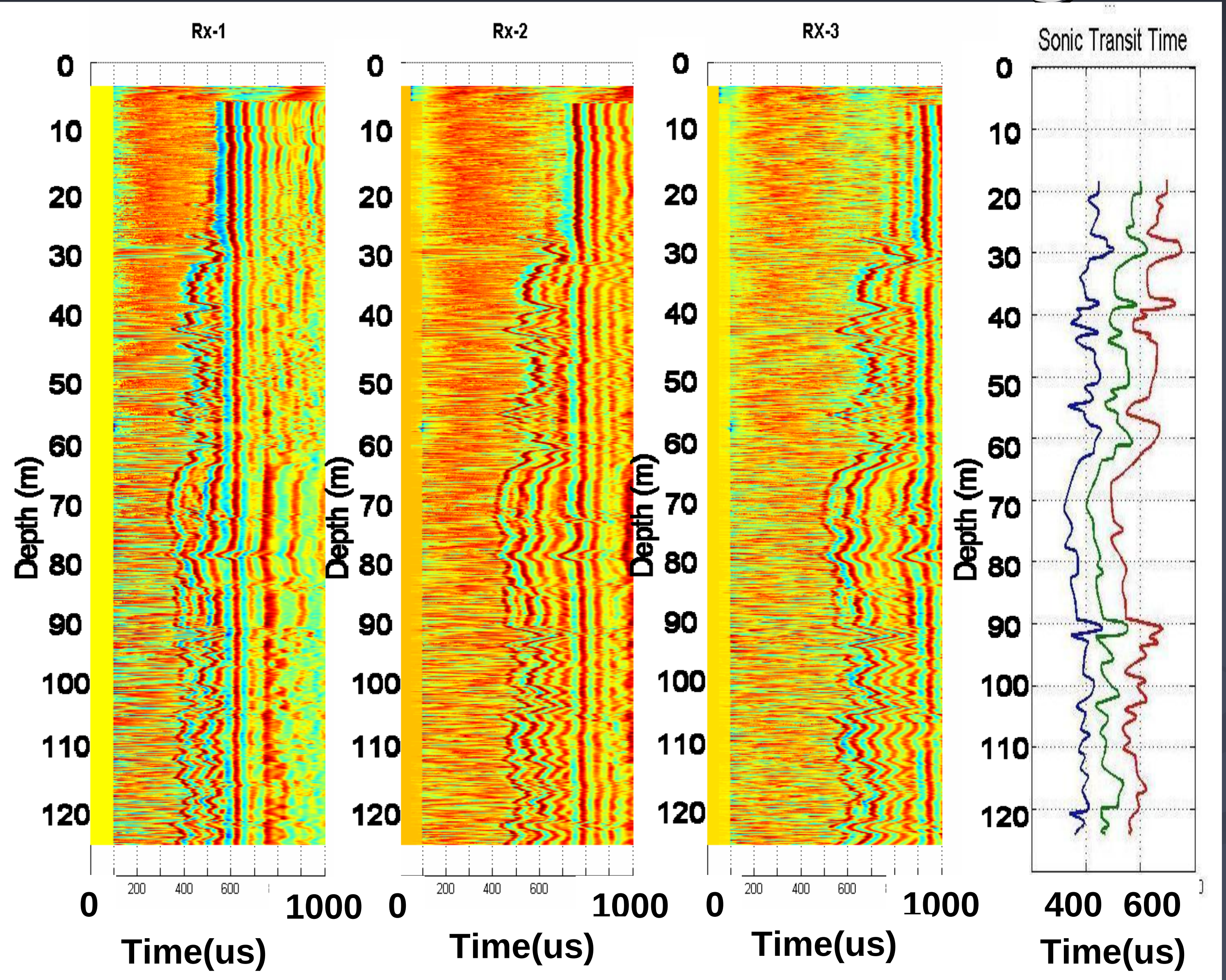
➔ Largest source of groundwater in the Canadian Praries

Field Data Acquisition: Well-logs

SP, GR, RES, CAL, and DEN acquired by Roke Well Logging Company

Sonic Log acquired by CREWES staff and U of Calgary students

Full-waveform sonic log

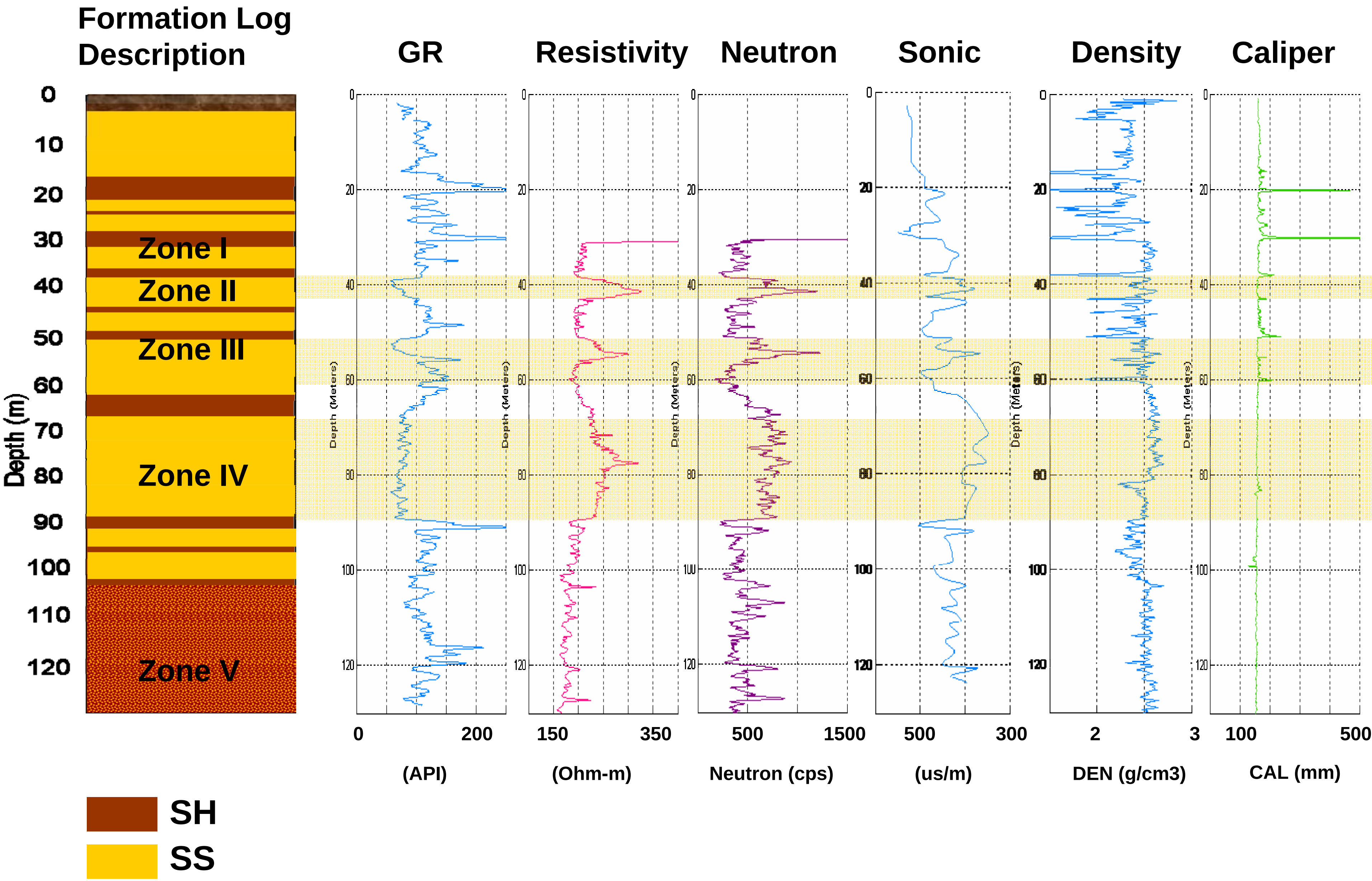


Dominant frequency: 10 kHz

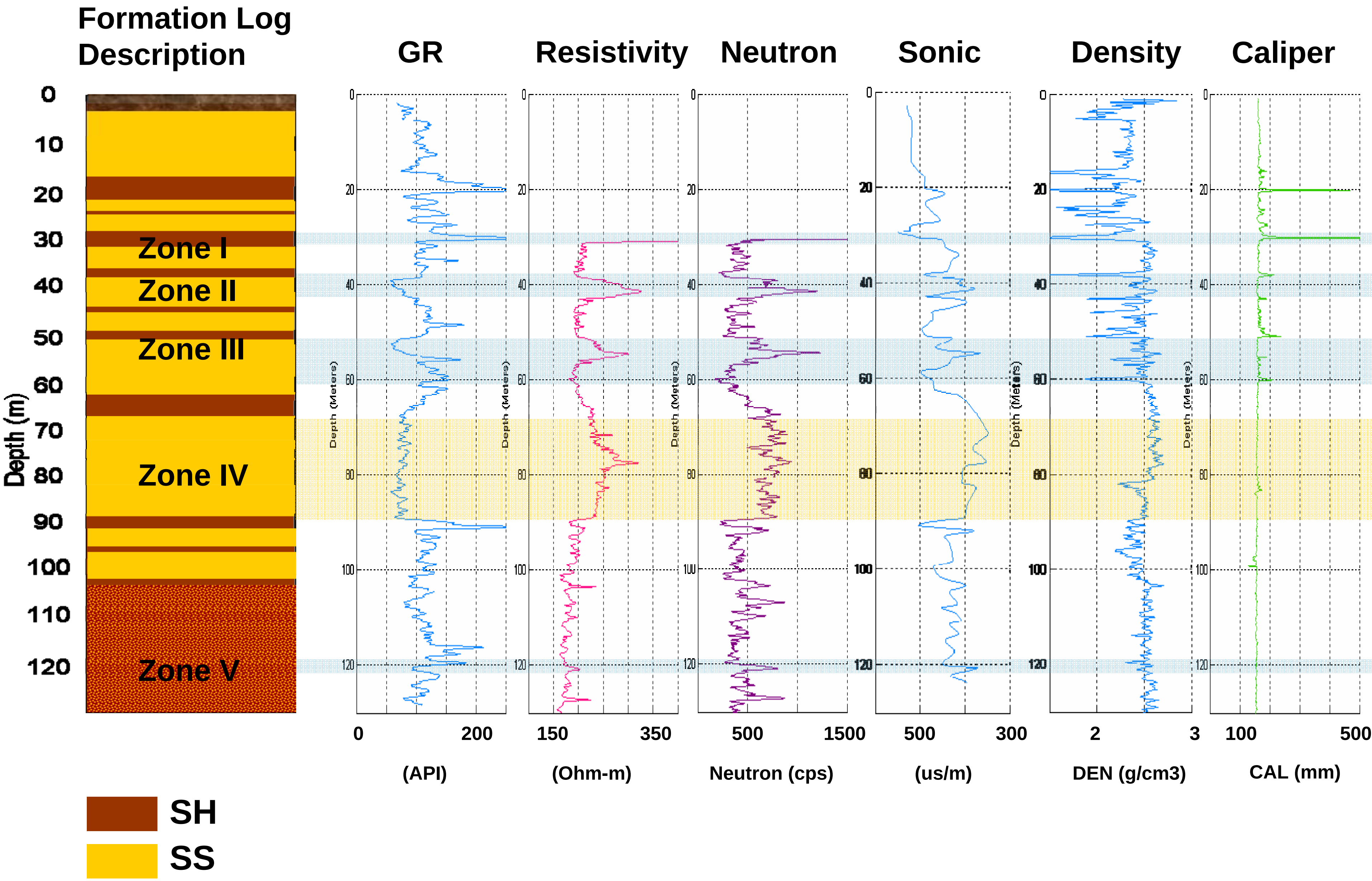
Sampling rate: 4 us

(Wong, 2007)

Open Hole Logs:



Open Hole Logs:



Quantitative Log Analysis: Porosity

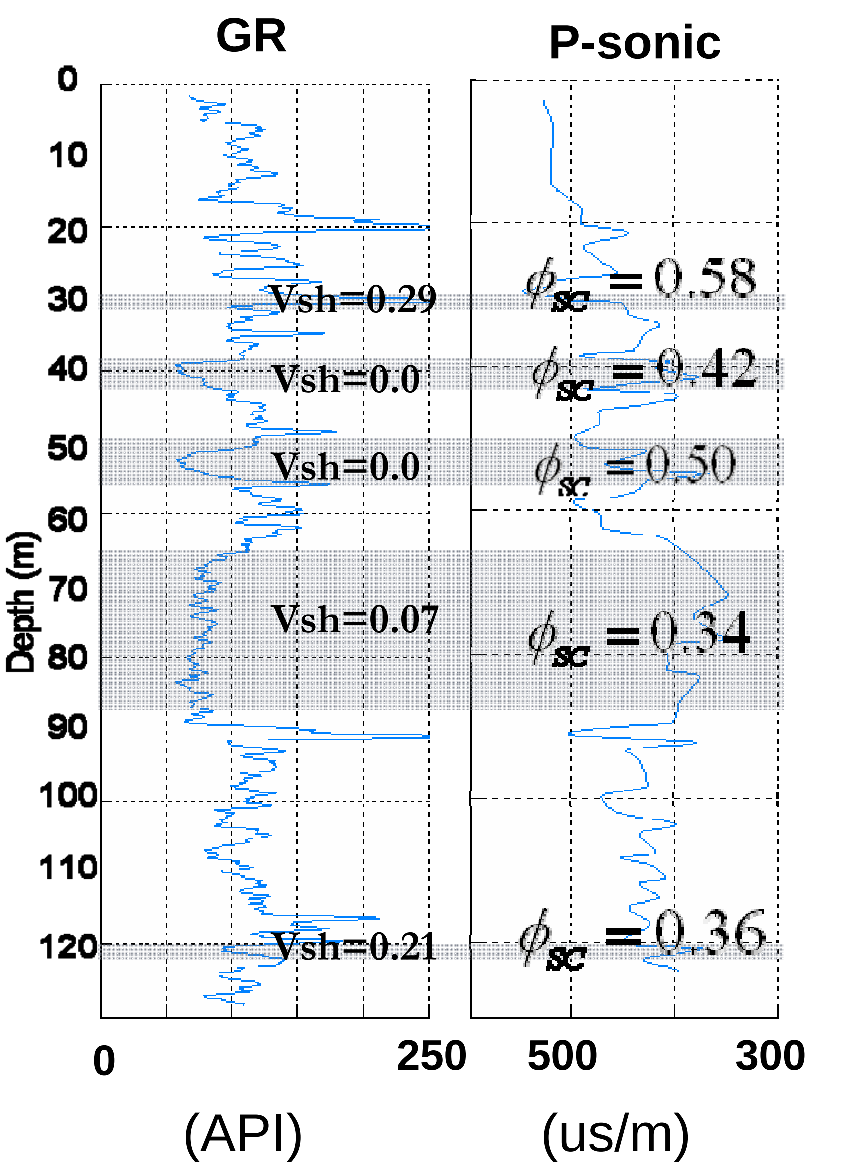
$$\phi_{sh} = \frac{\Delta t_{sh} - \Delta t_{ma}}{\Delta t_{w} - \Delta t_{ma}}$$

$$\phi = \frac{\Delta t - \Delta t_{ma}}{\Delta t_{w} - \Delta t_{ma}}$$

$$\phi_{SC} = \phi - V_{sh}(\phi_{sh})$$

Slowness Constants:
(Asquith and Krygowski, 2004)

Δt_{ma} (us/m)	182
Δt_{w} (us/m)	656
Δt_{sh} (us/m)	280



Quantitative Log Analysis: Water Saturation

$$S_w = \left(\frac{a \cdot R_w}{R_t \cdot \phi^m} \right)^{\frac{1}{n}}$$

S_w = water saturation of the uninvaded zone

R_w = resistivity of formation water at formation temperature

ϕ = porosity

a = tortuosity factor

m = cementation exponent

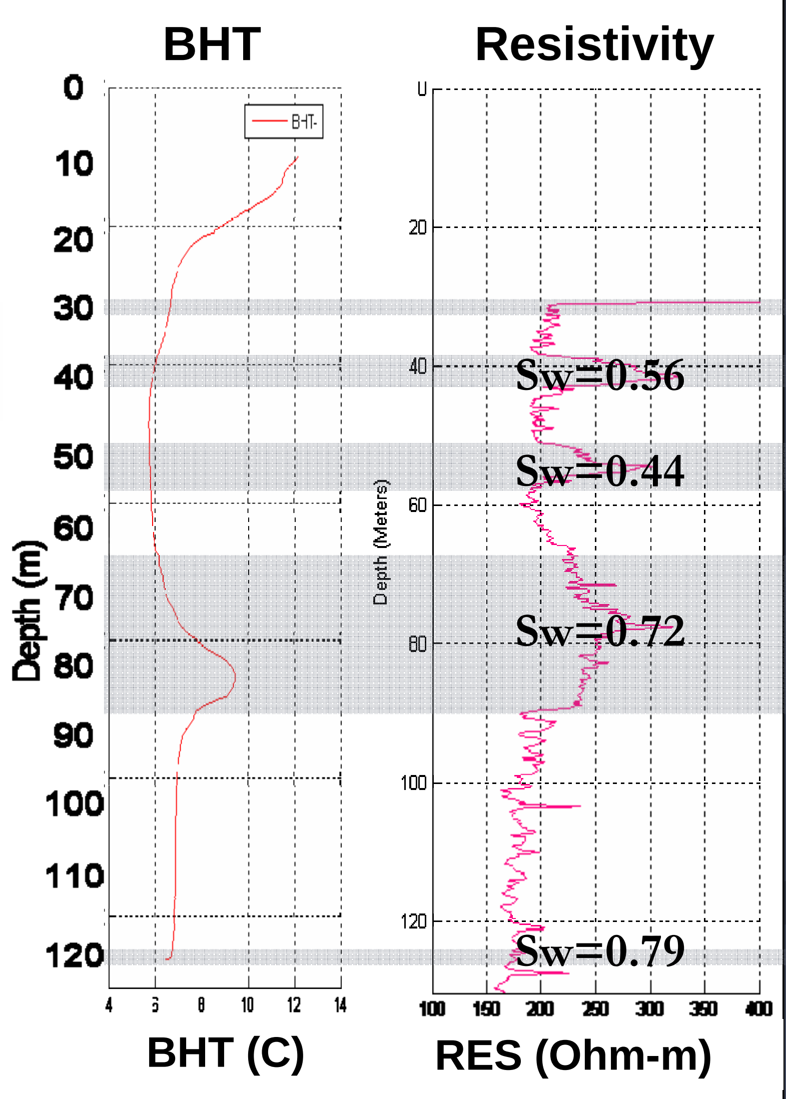
n = saturation exponent

for sandstone A = 0.62 M = 2.15 N = 2.00

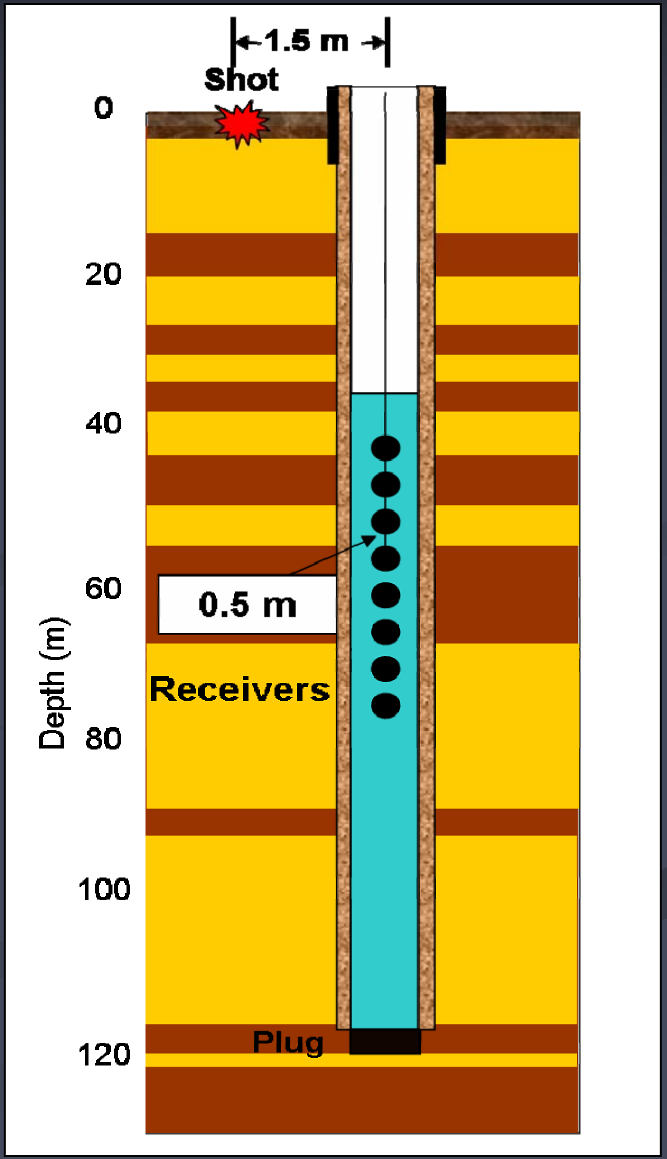
for fractured zones M = 1.2 to 1.7

RW@FT = RW@TRW * (TRW + KT1) / (FT + KT1)

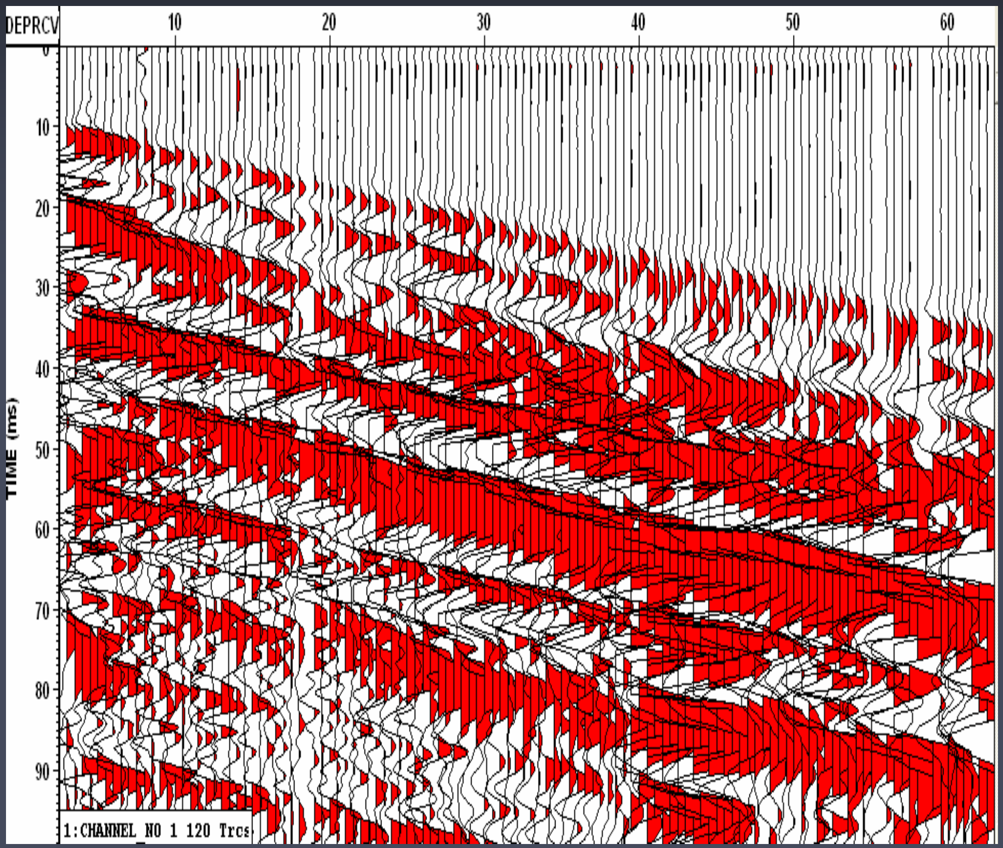
KT1=21.5C, RW@TRW=15.4 ohm-m @ 20 C

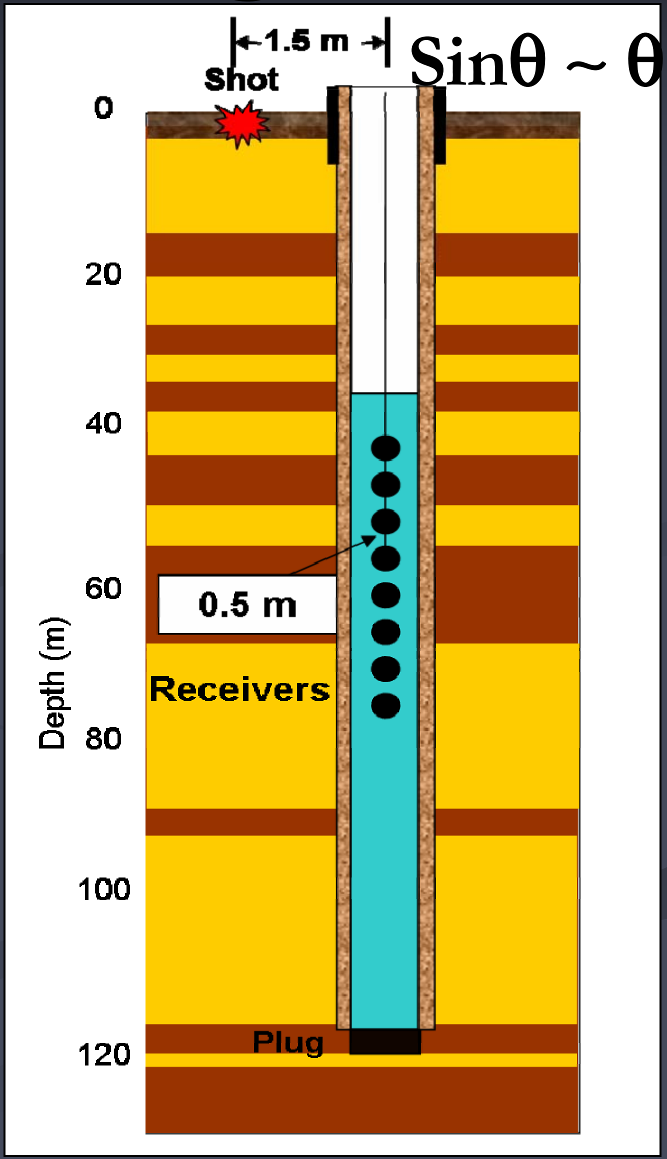


Field Data Acquisition: Shallow VSP



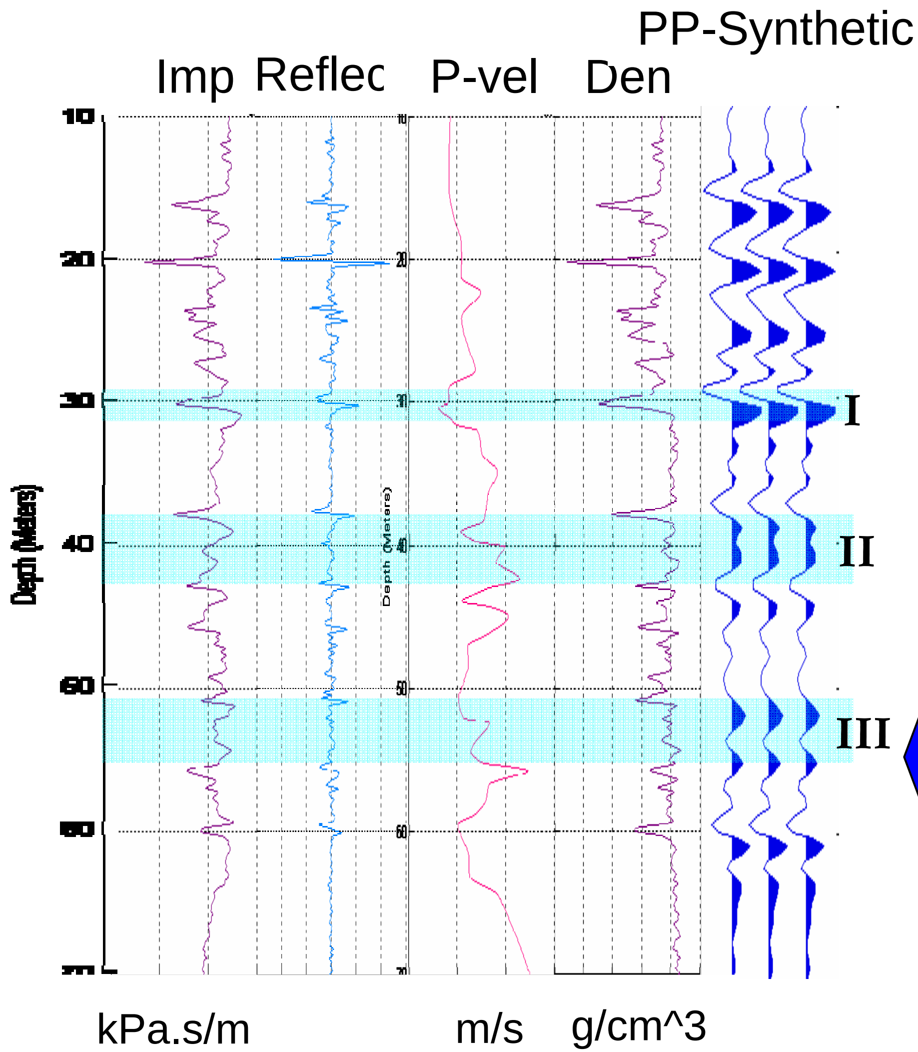
Near-Offset VSP Processing

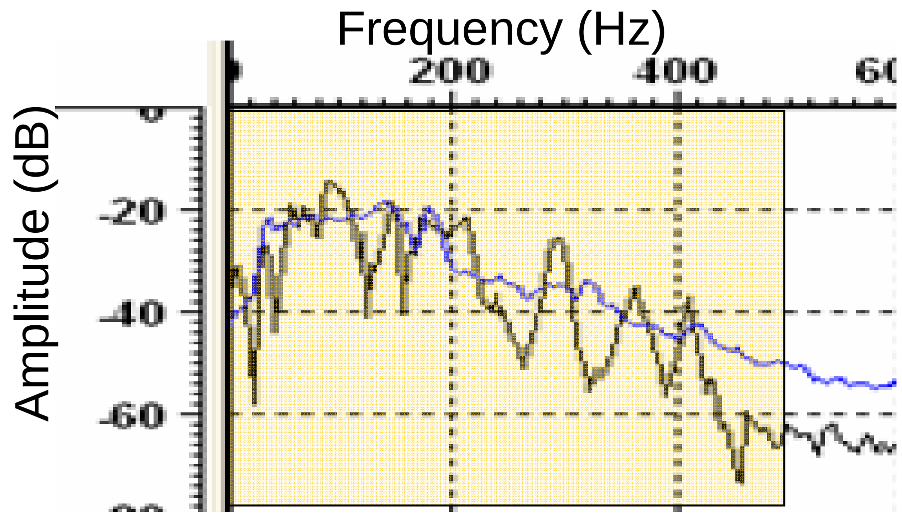


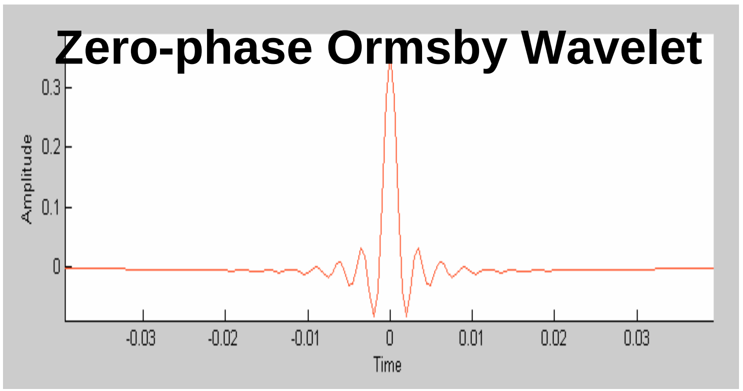


- 0.5 ms sample rate, 0.5m receiver spacing
- Less than 1 hour of acquisition time

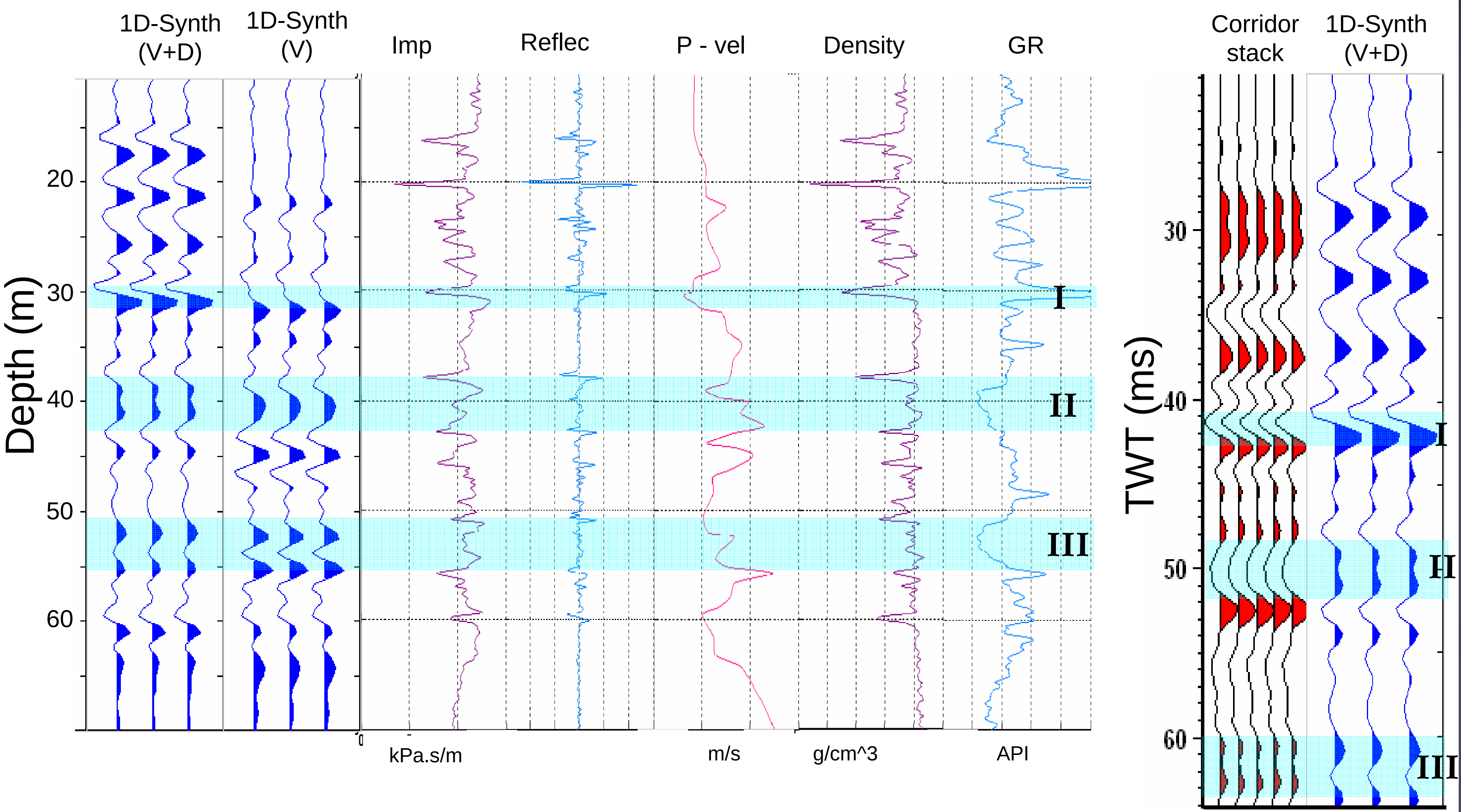
1-D Synthetic Seismogram Generation



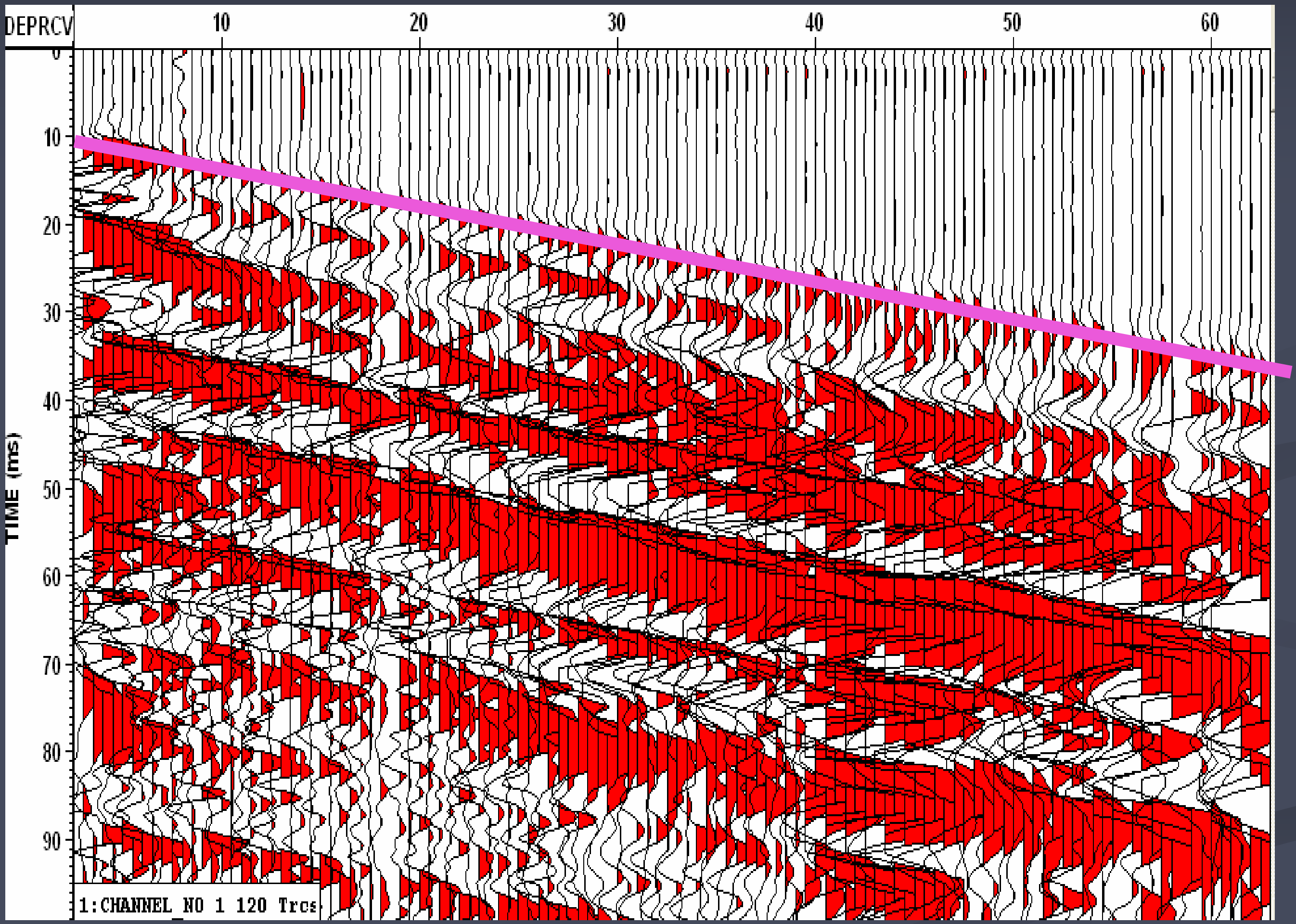


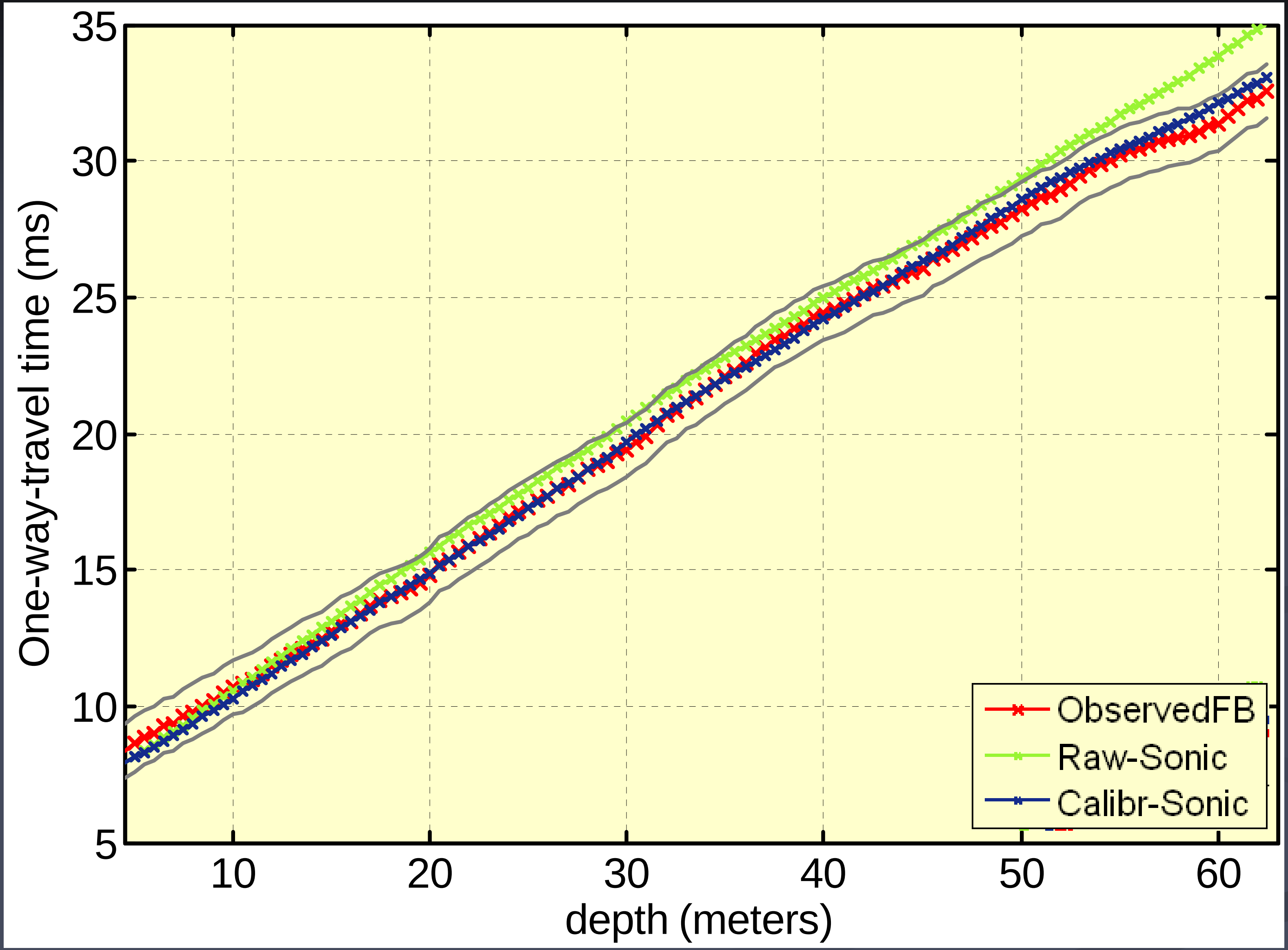


Priddis: Synthetic, Seismic and Well-log correlation



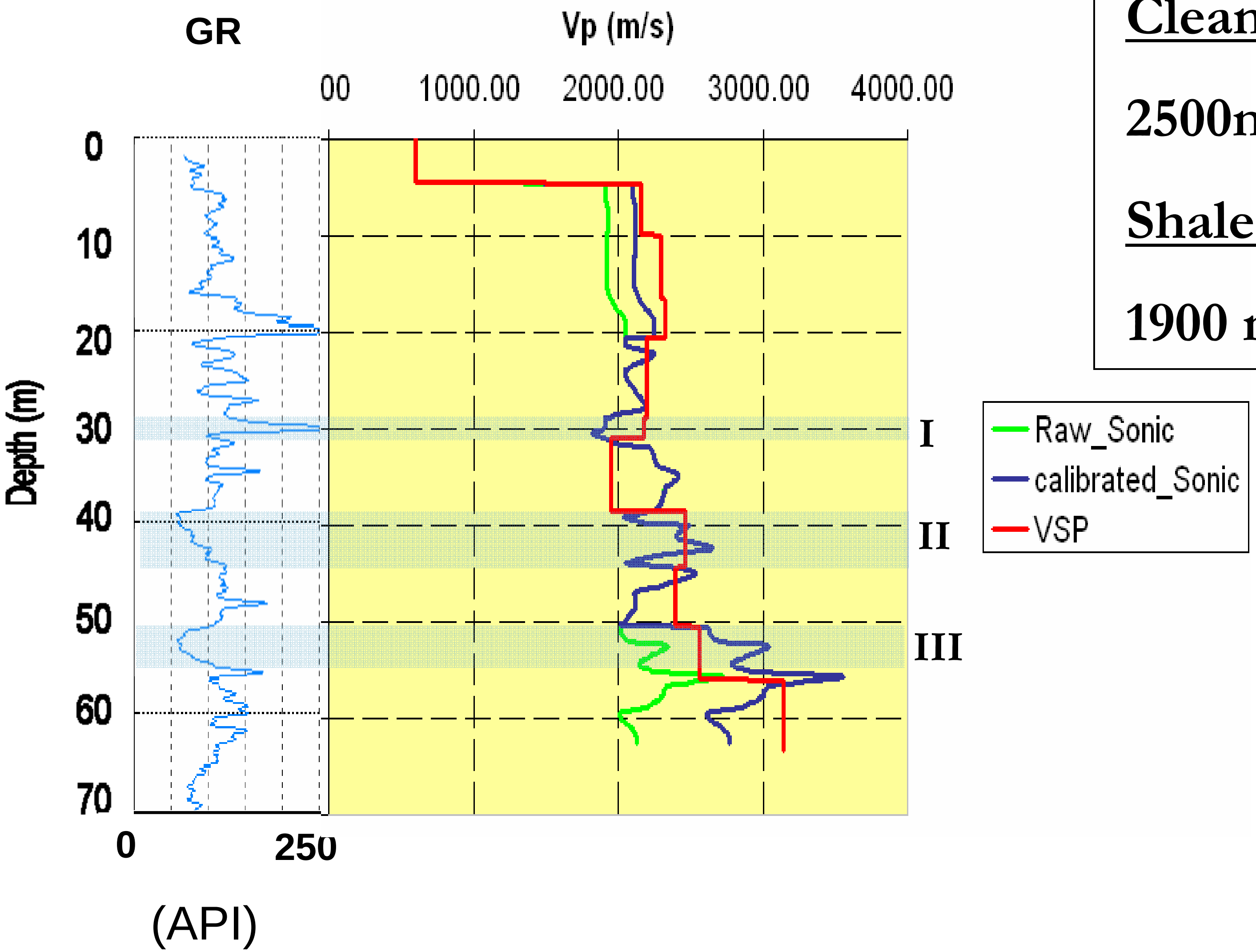
Sonic Calibration using VSP data





35
30
25
20
15
10
5
10
20
30
40
50
60
depth (meters)
One-way-travel time (ms)
ObservedFB
Raw-Sonic
Calibr-Sonic

Sonic vs. VSP velocity



Clean Sand:

2500m/s – 3100 m/s

Shale:

1900 m/s – 2200 m/s

Summary

- The qualitative and quantitative analysis of shallow well logs and VSP data analysis used for shallow hydrogeological characterization

- VSP corridor stack show major reflectors and also correlate well with the synthetic 1-D seismogram and other well-log informations

- The calibrated sonic log and the VSP velocities match quite well

➔ The quality of various well logs and VSP provide considerable promise for the technique's use in near-surface characterization and the velocity information obtained from them can be used for statics determination

Summary

- The qualitative and quantitative analysis of shallow well logs and VSP data analysis provided useful information regarding the near-surface lithological and hydrogeological characteristics of the Paskapoo Formation

- VSP corridor stack show major reflectors and also correlate well with the synthetic 1-D seismogram and other well logs

- The calibrated sonic log and the VSP velocities match quite well

➔ The quality of various well logs and VSP provide considerable promise for the technique's use in near-surface characterization and the velocity information obtained from them can be used for statics determination

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Thank you

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