Sound and Fury: Air blast & ground roll

(Apologies, MacBeth)

1) Using microphones to suppress geophone noise (Alcudia & Stewart, 2008)

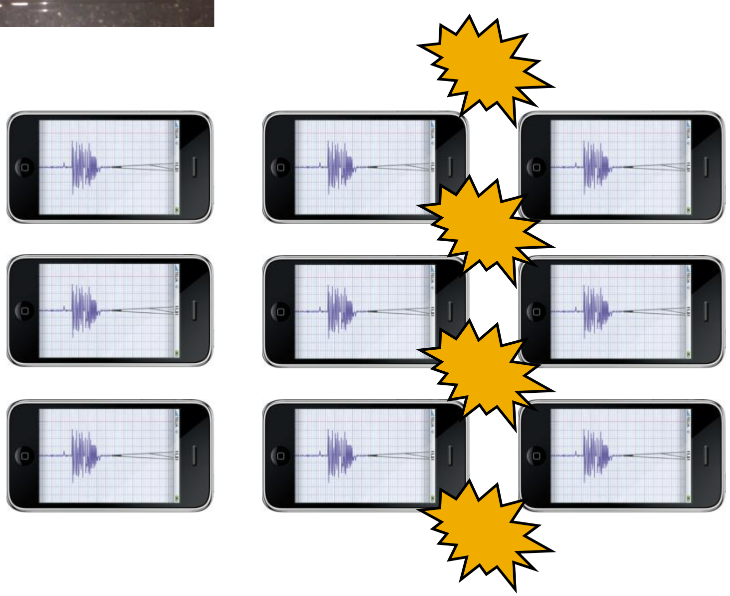
2) Using ground roll to find S-wave statics (Al-Duliajan, MSc., 2008)

20th Annual CREWES Sponsors Meeting
Canmore, Alberta   Nov. 21st, 2008

The future of seismic acquisition (c. 2000)

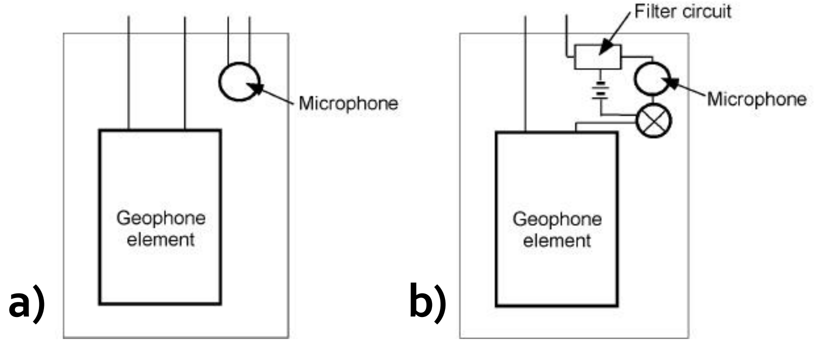
The future of seismic acquisition (2008)

- The $i^{G}E_{O}$Phone: 3C accelerometer, microphone, wireless, light, lasting, 16GB, & can order a pizza



www.apple.com

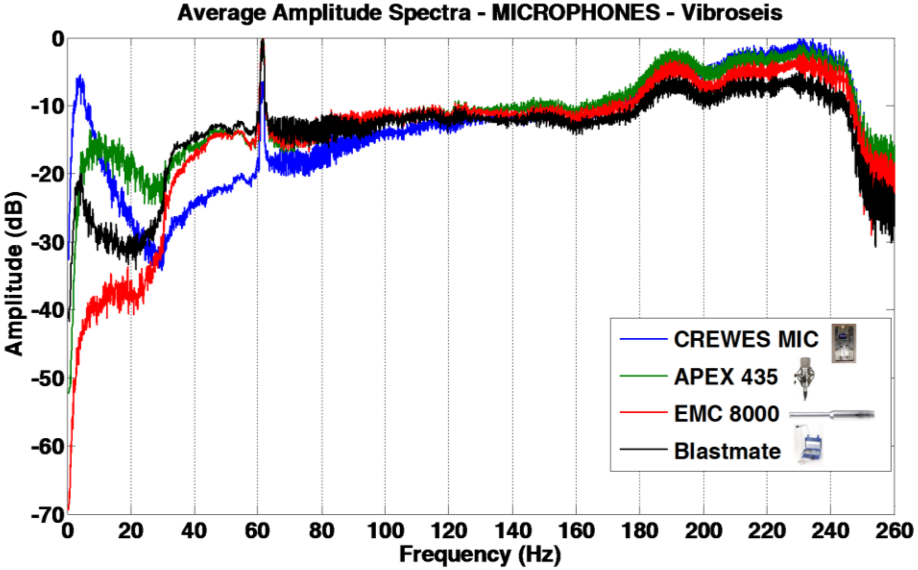
Can we suppress air-coupled noise on geophones using microphones?

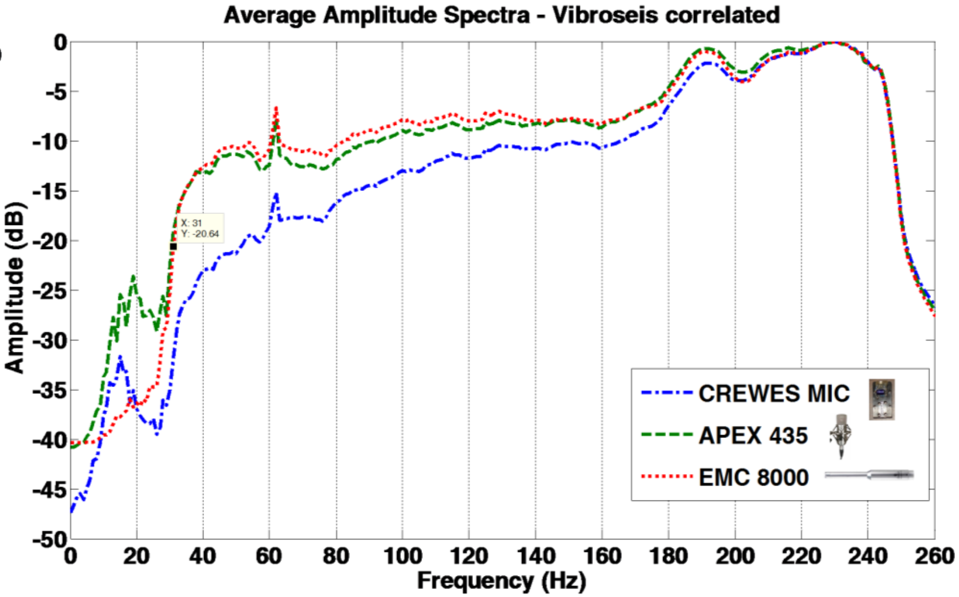


Two-channel (microphones and geophone) motion sensor (a) and single-channel, active noise suppressing geophone (b). (Stewart 1998)

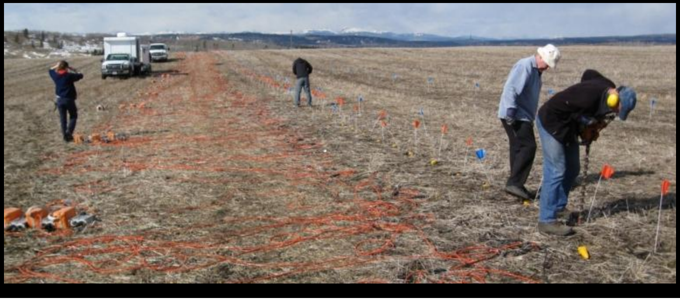
Photos by Alejandro Alcudia

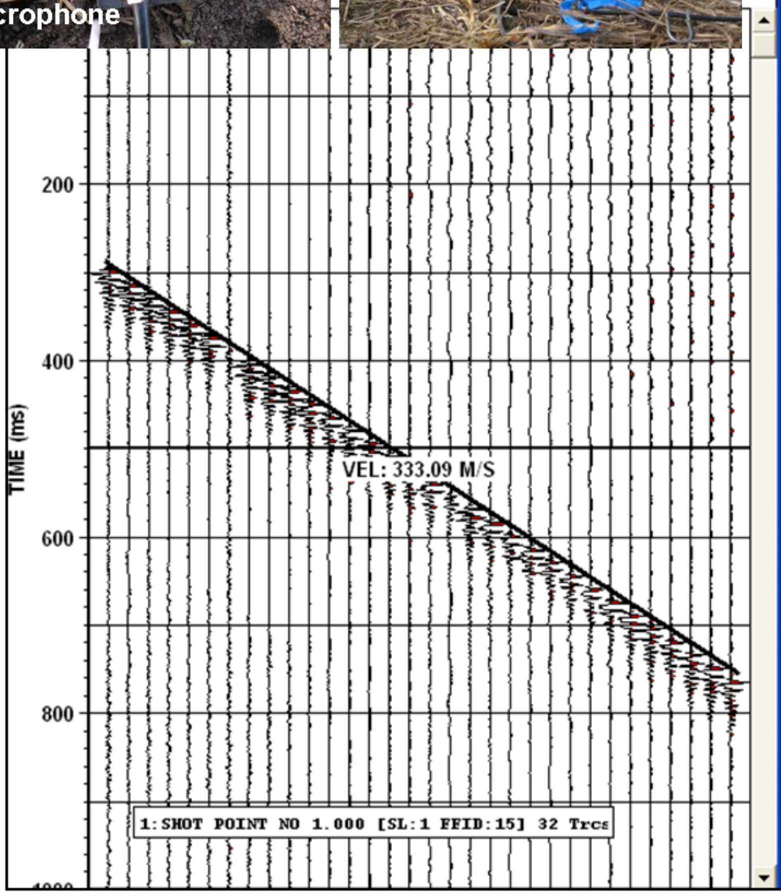
Microphone comparison – Vibroseis



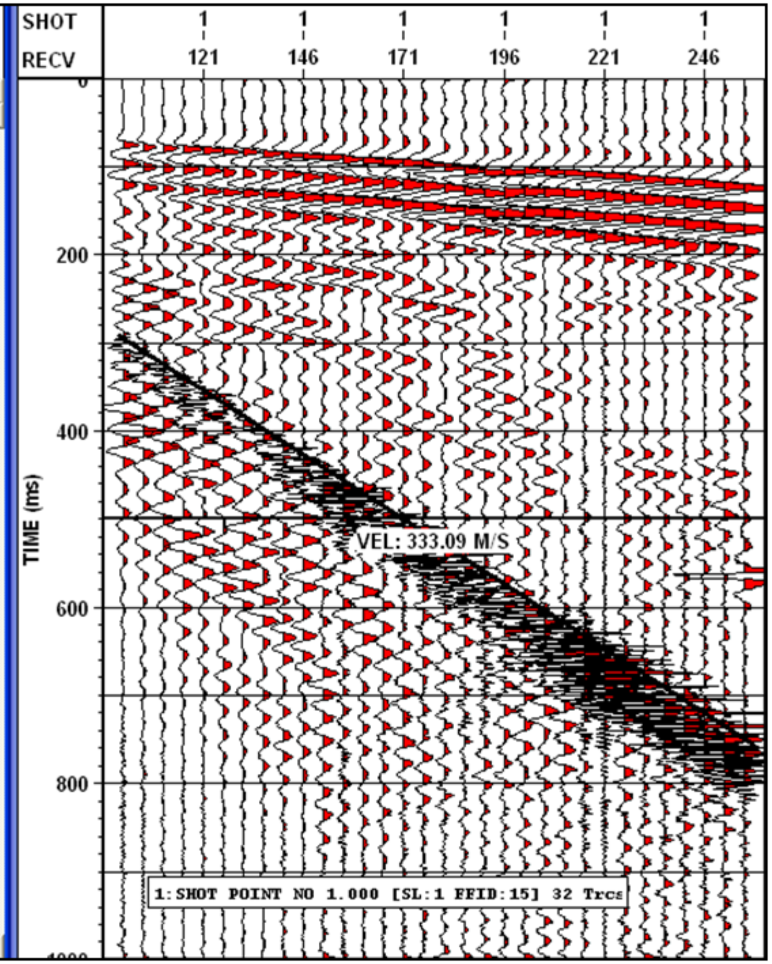


Priddis Winter 2008 Microphone-geophone experiment



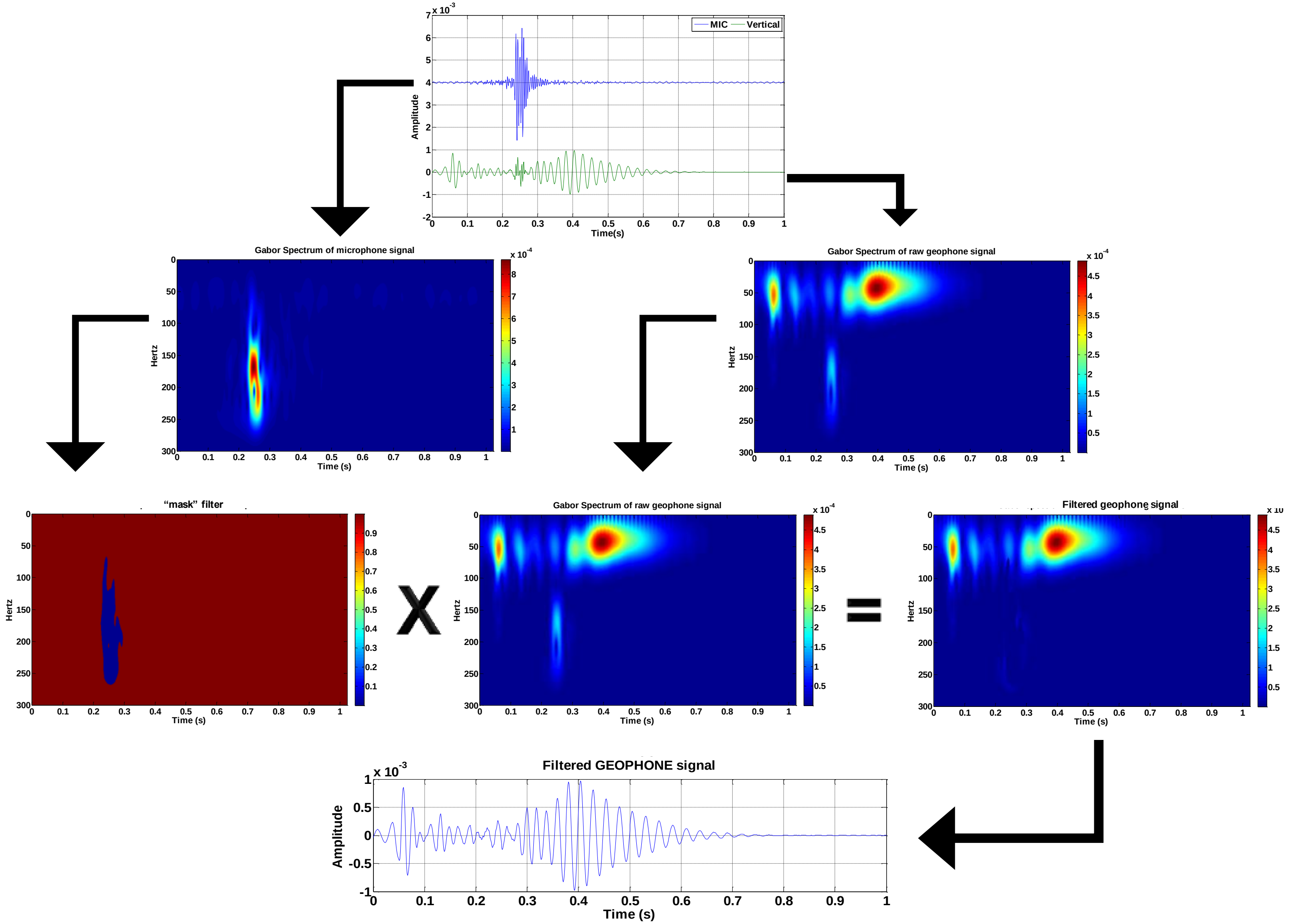


MICROPHONE

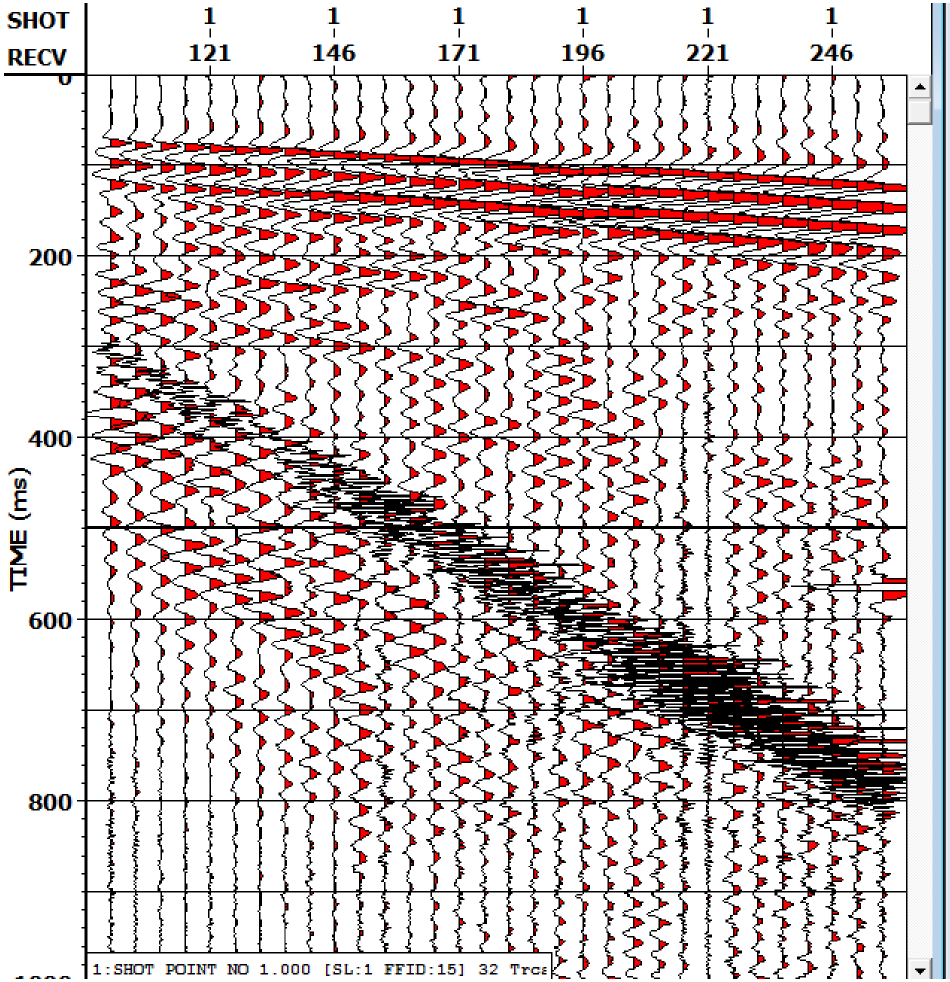


GEOPHONE

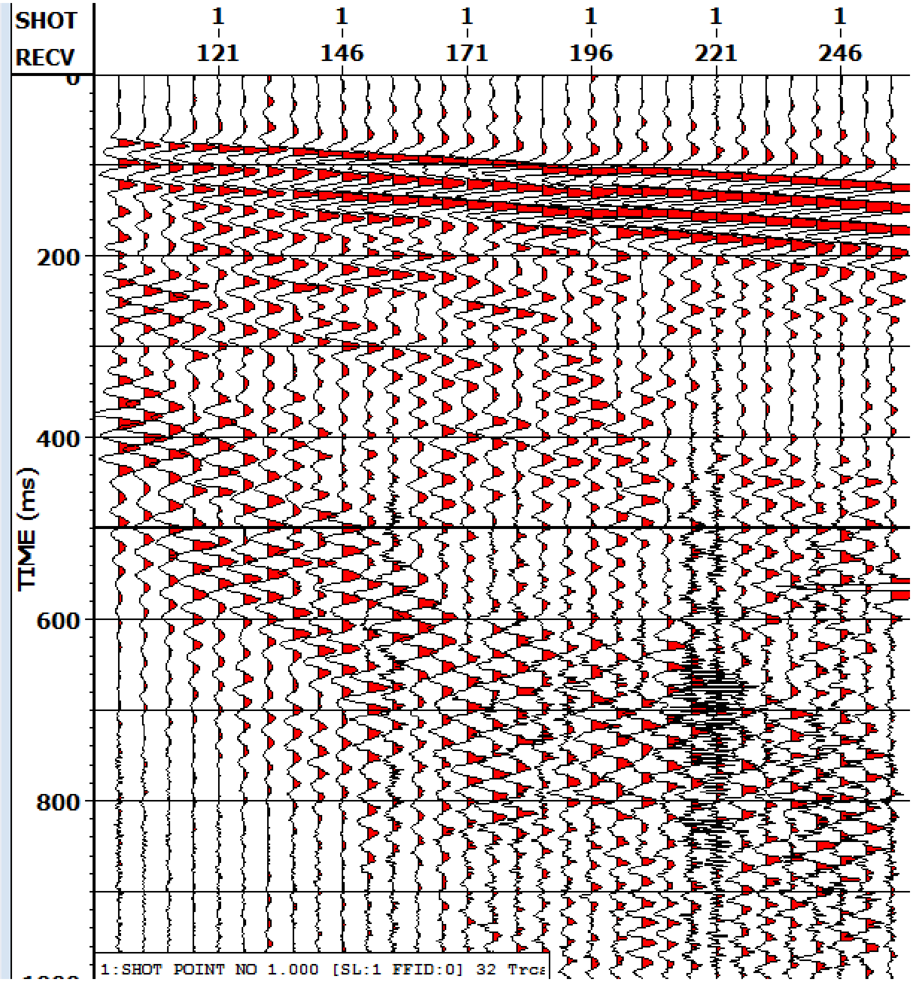
Method for air blast attenuation by combining microphone and geophone signals in the Gabor transform domain



Priddis experiment – air noise reduction on geophones

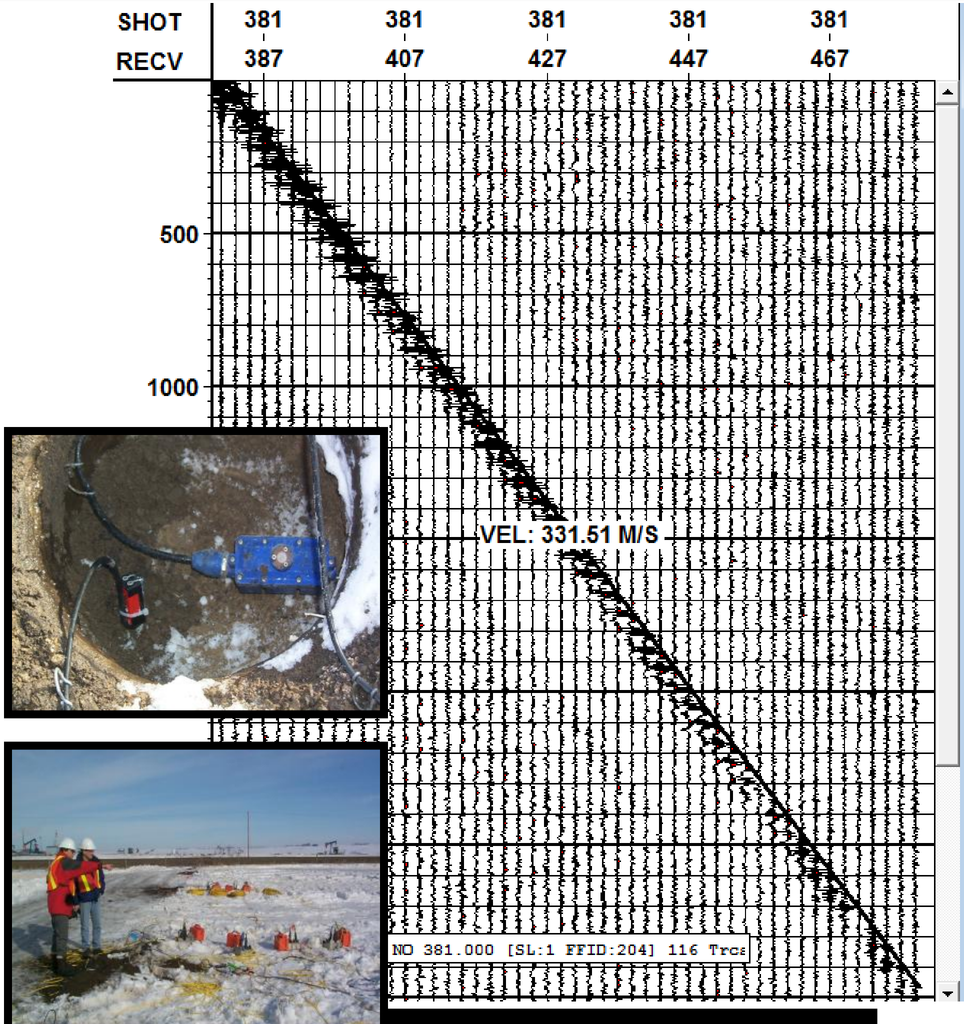


BEFORE

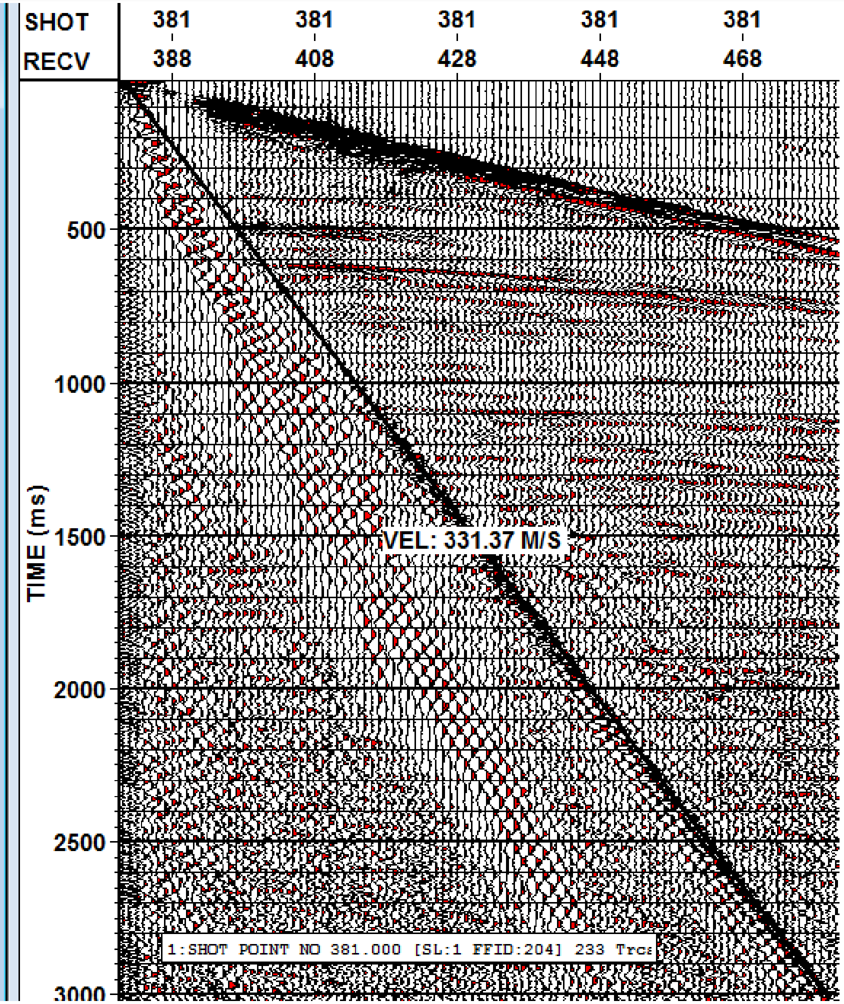


AFTER

Microphone and geophone records Pikes Peak, SK

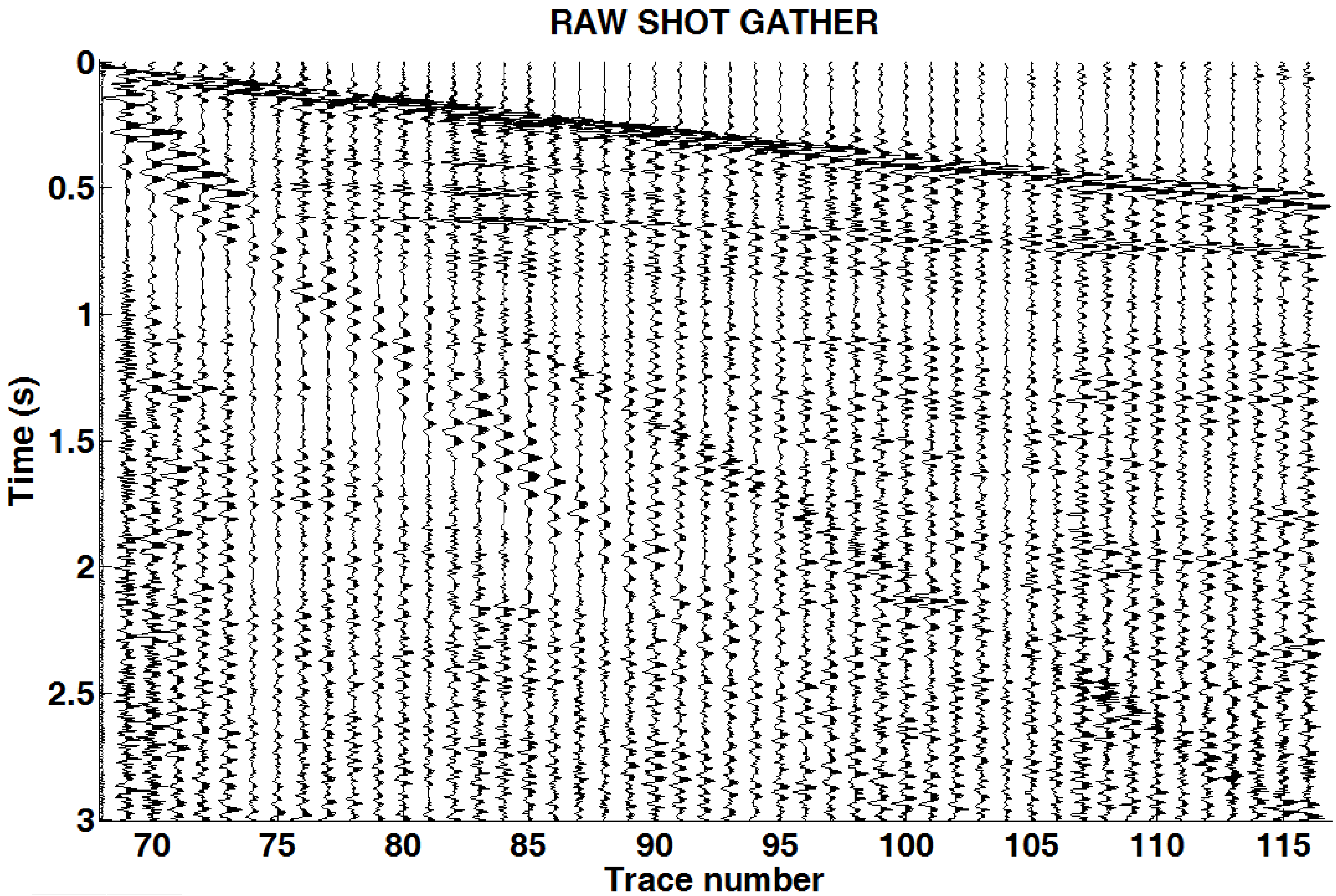


MICROPHONE

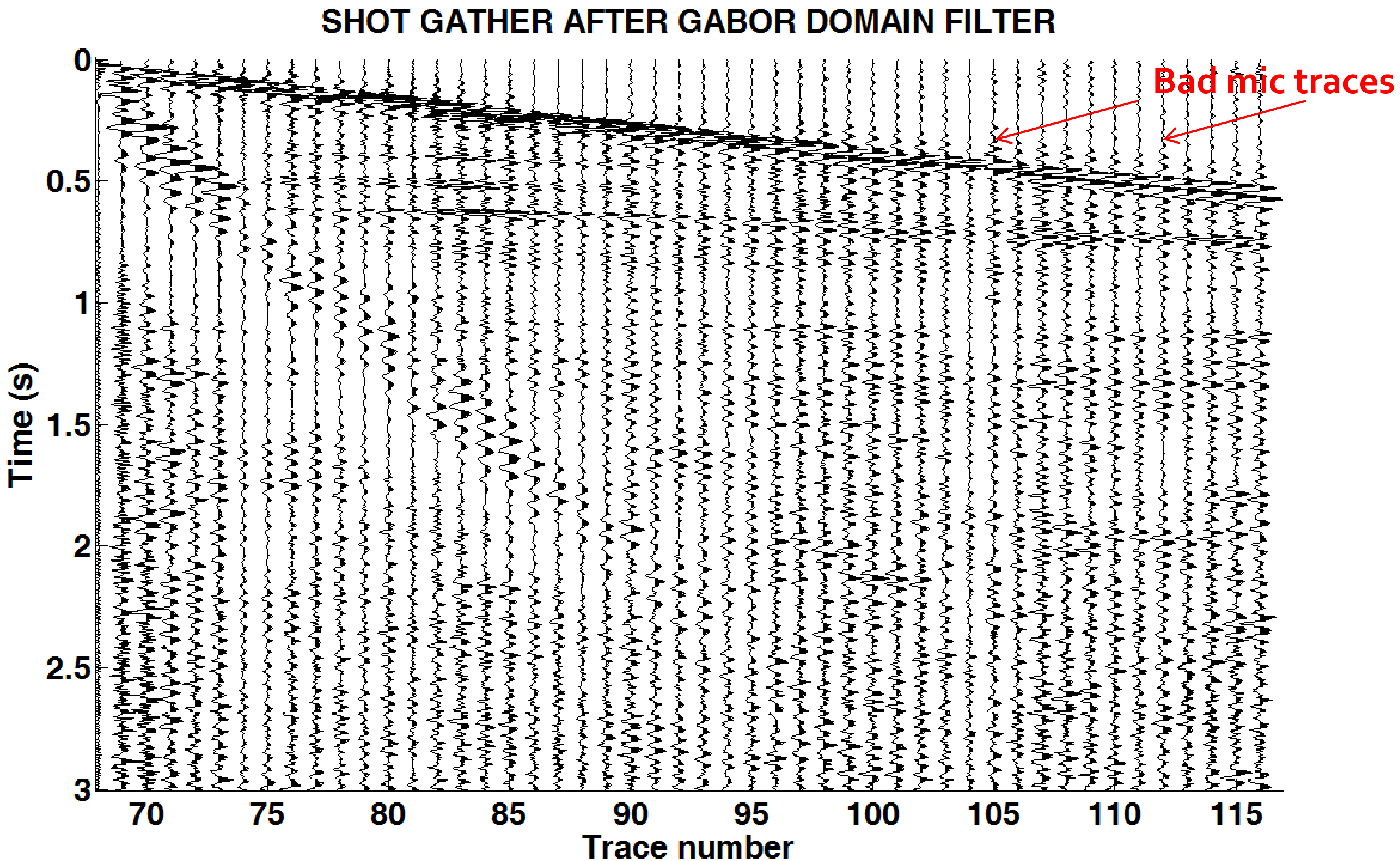


GEOPHONE

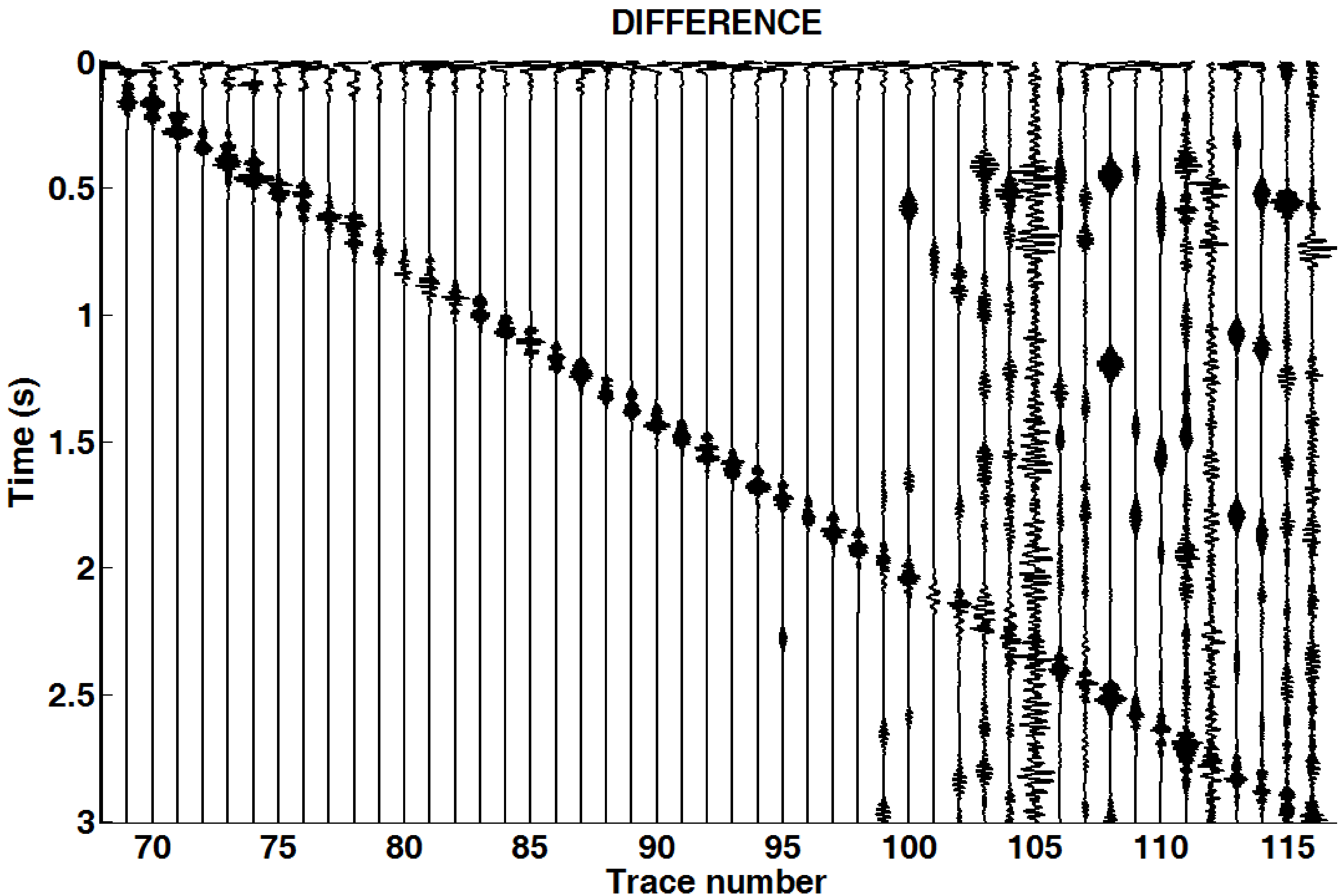
Pikes Peak – Geophone data before filtering



Geophone after filter



Difference – Amplitude correction for display

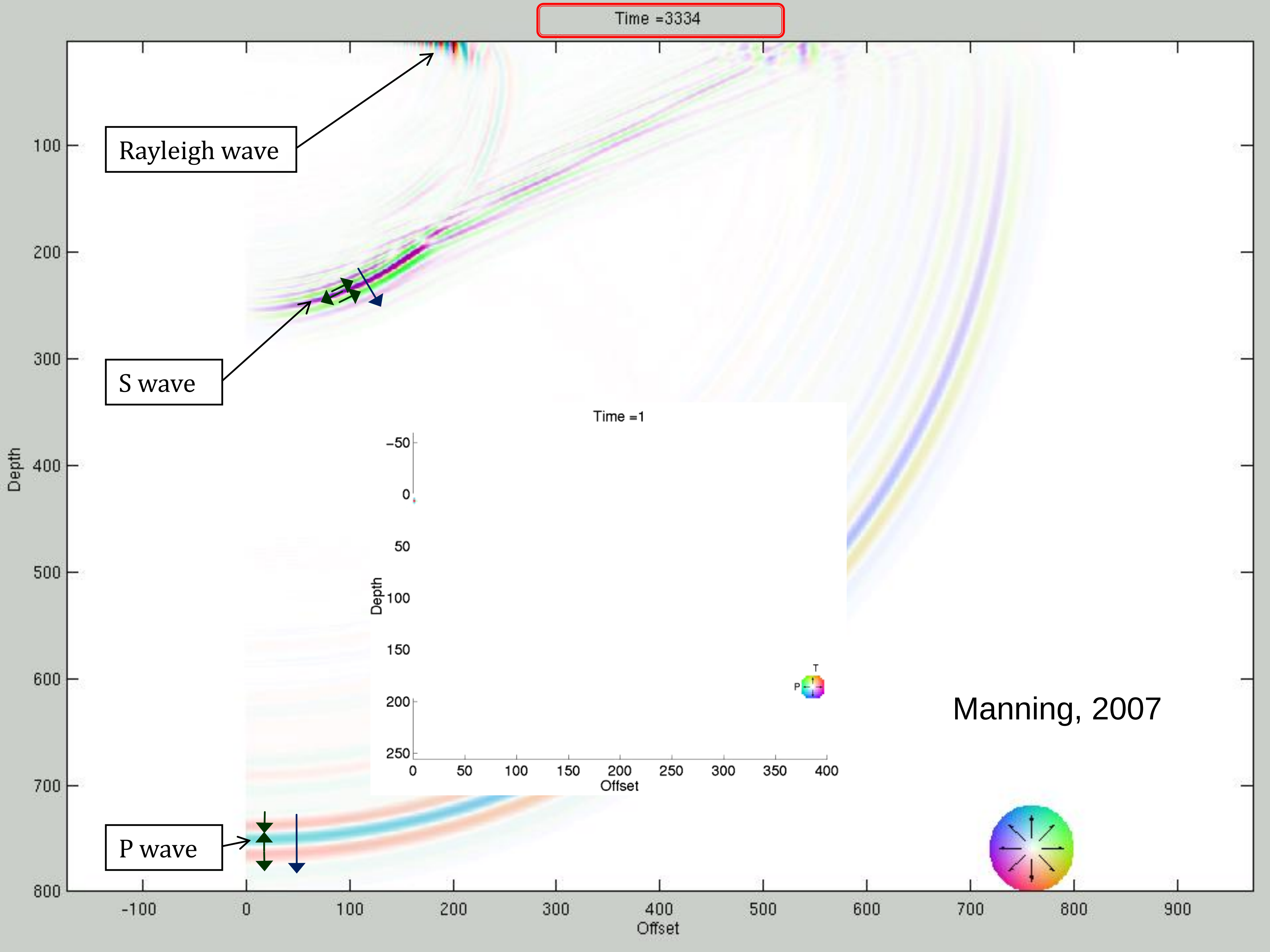


Conclusions

- Microphones and geophones record similar air blasts
- A time-frequency (Gabor) filter, designed on the microphone data, reduces air-blast geophone noise
- Broader band microphones may allow further noise reduction (ground roll)
- Lots of promise to automatically reduce air-borne noises on geophones using microphones

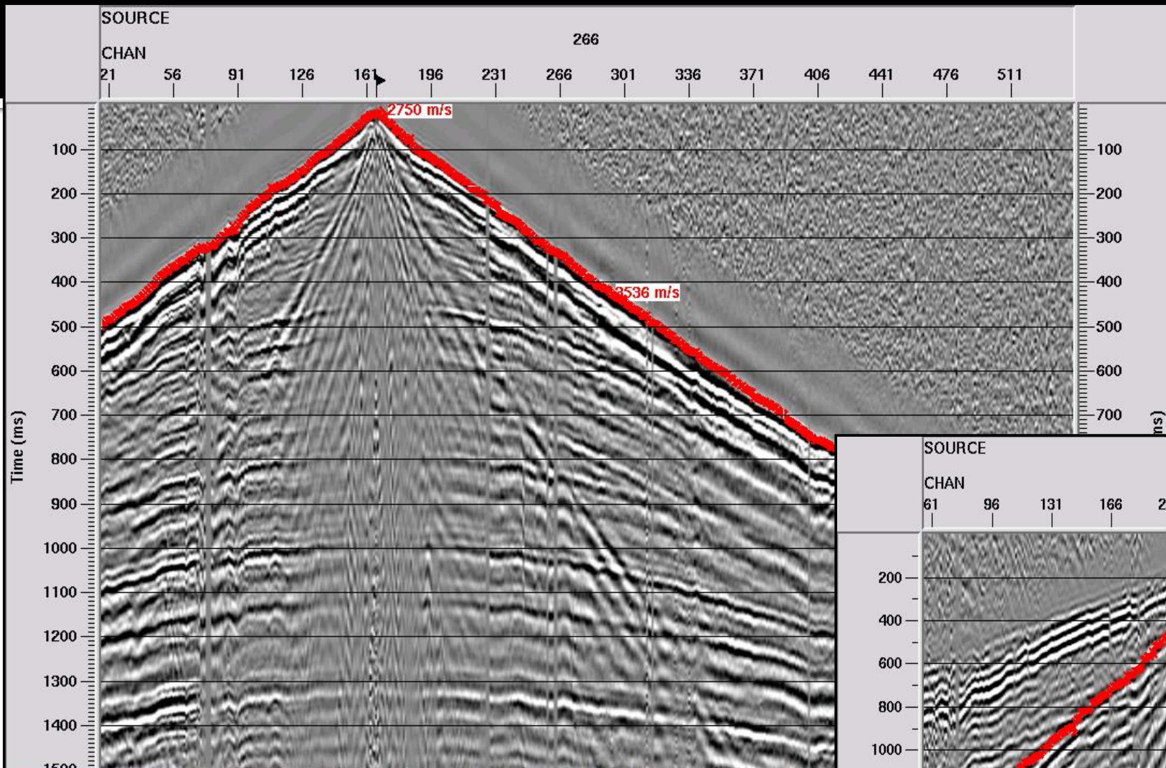
Can we use ground roll to find S statics?

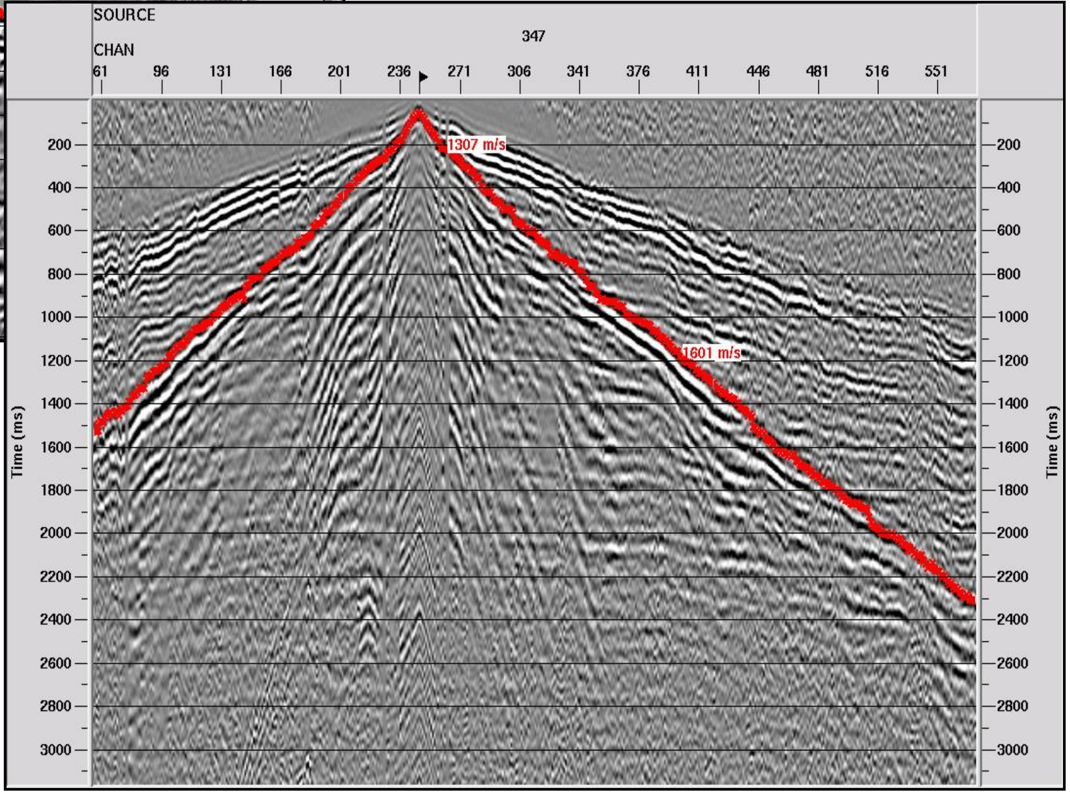
- S-wave statics important & difficult to find
- Ground roll (Rayleigh wave) often strong
- Rayleigh wave velocity dependent on Vs
- Layers give rise to dispersion
- Invert dispersion to find Vs
- Use Vs to estimate S-wave statics

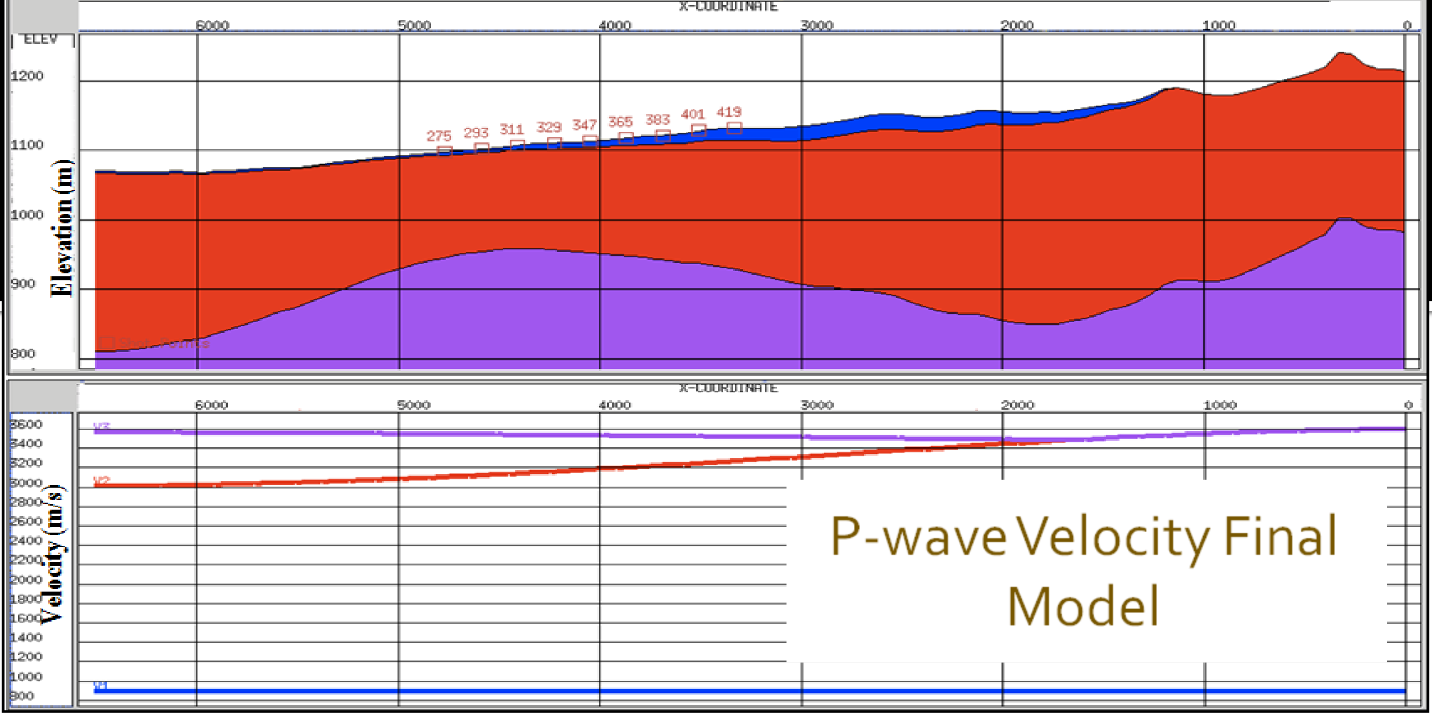


Time =3334
Rayleigh wave
S wave
P wave
Depth
Offset
Time =1
P
T
Manning, 2007

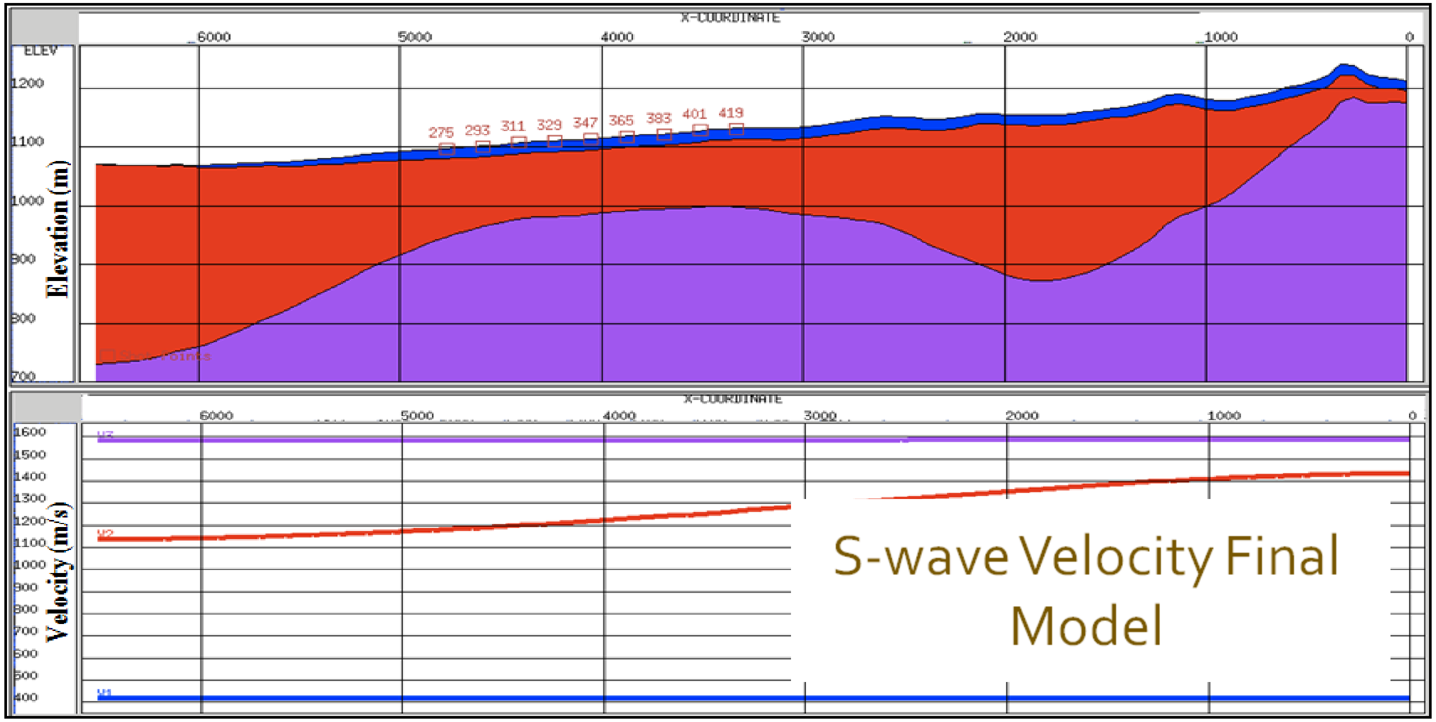
Spring Coulee: Refracting events







X-COORDINATE
ELEV
Elevation (m)
275 293 311 329 347 365 383 401 419
Velocity (m/s)
V3
V2
V1
P-wave Velocity Final Model



X-COORDINATE
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Elevation (m)
275 293 311 329 347 365 383 401 419
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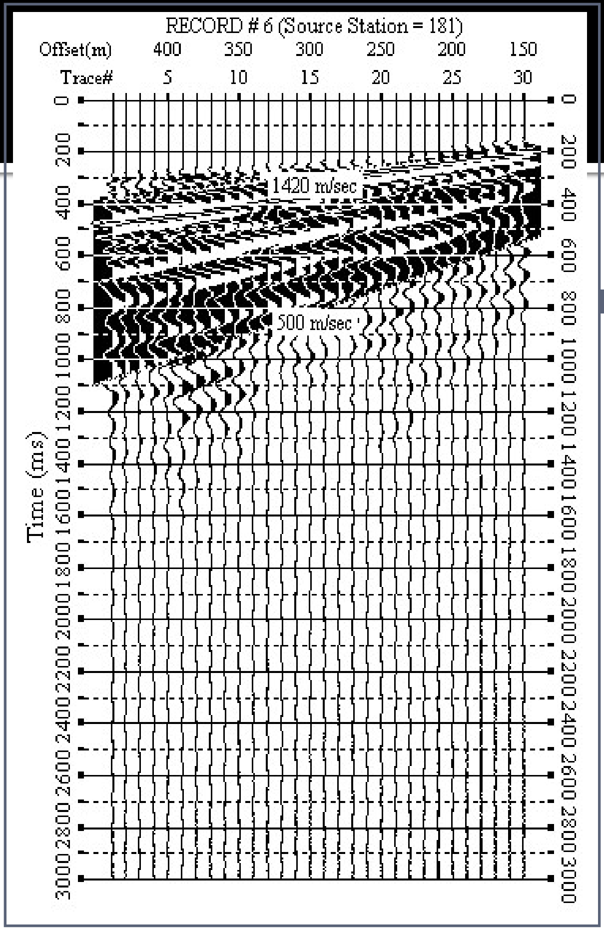
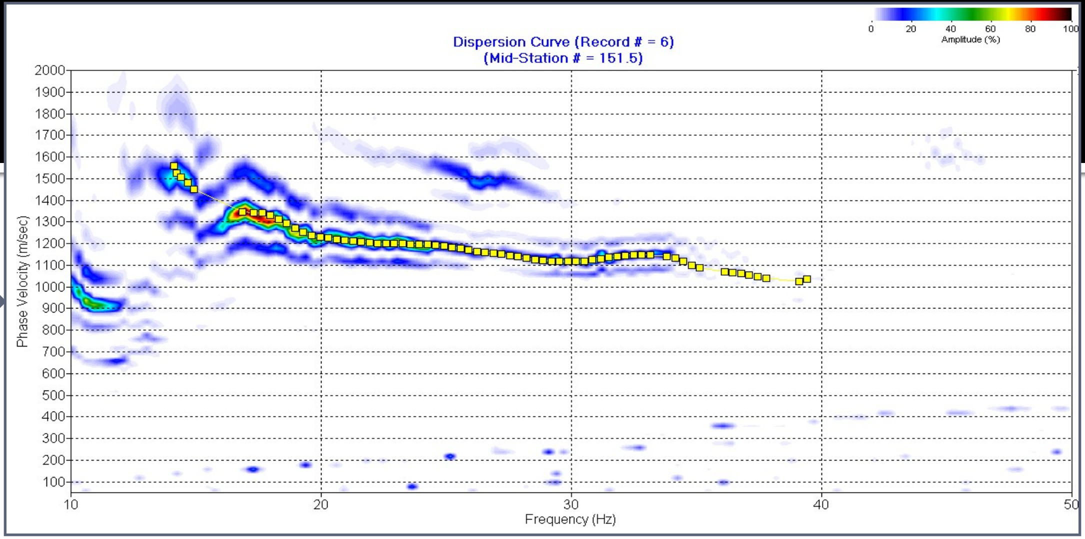
V2
V1
S-wave Velocity Final Model

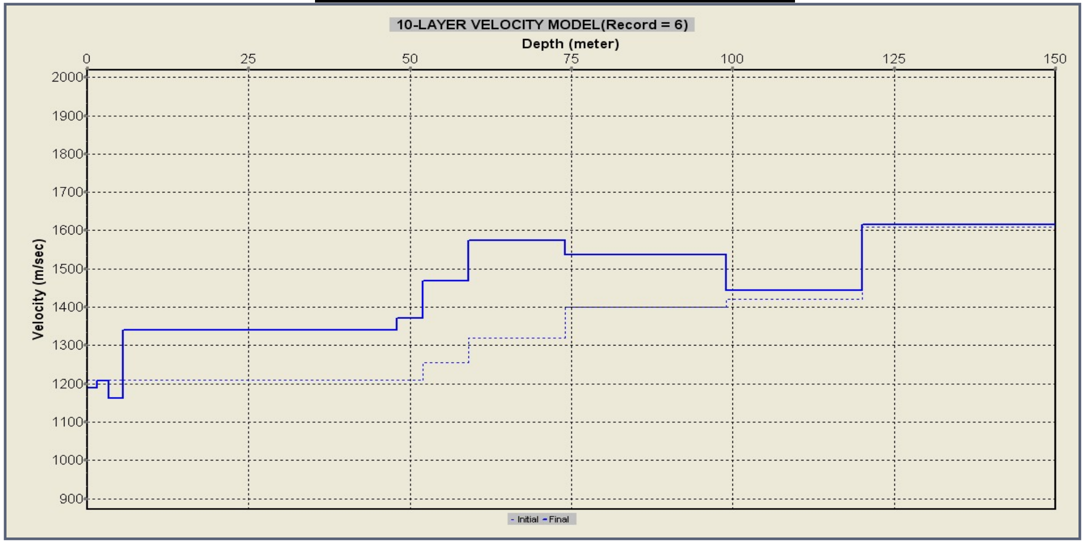
(1) Shot Gather



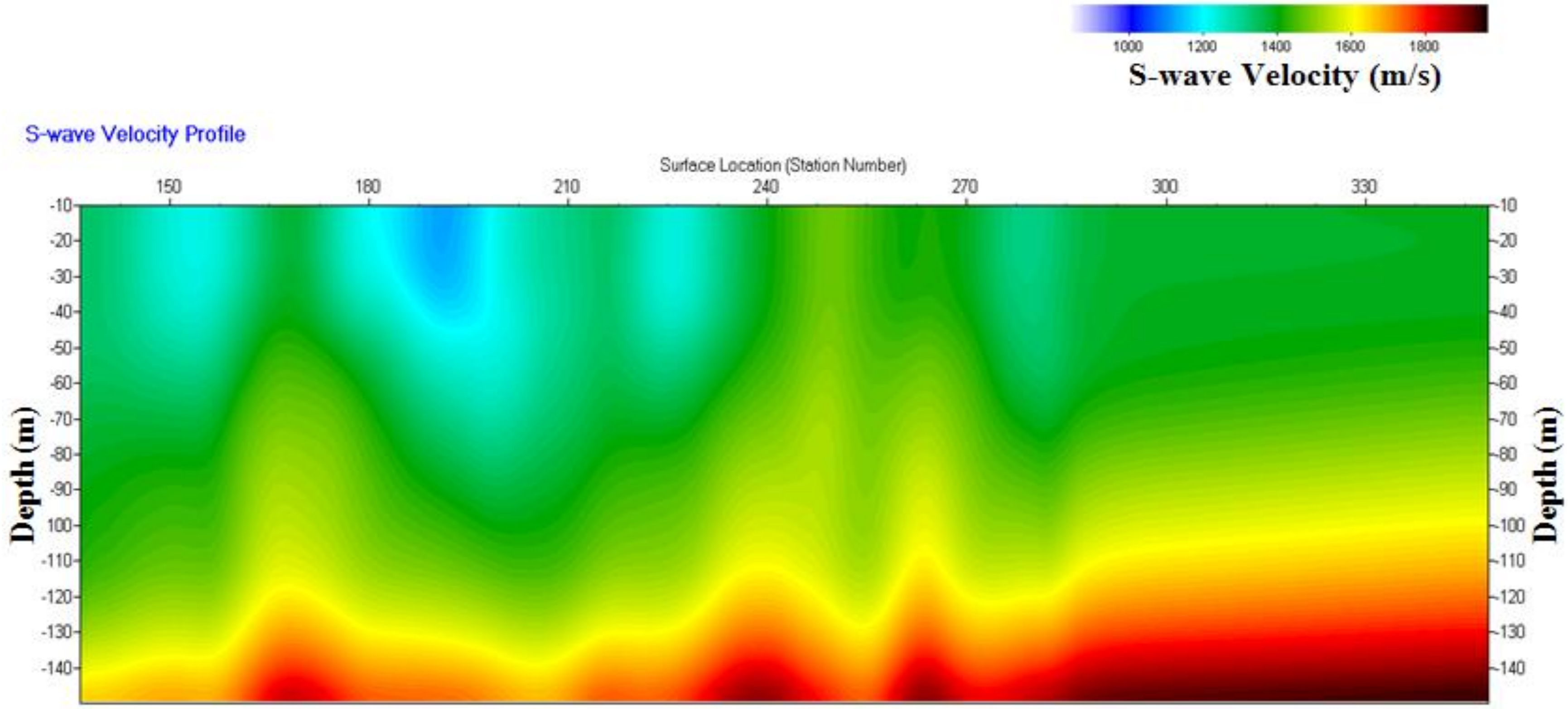
(2) Dispersion Image



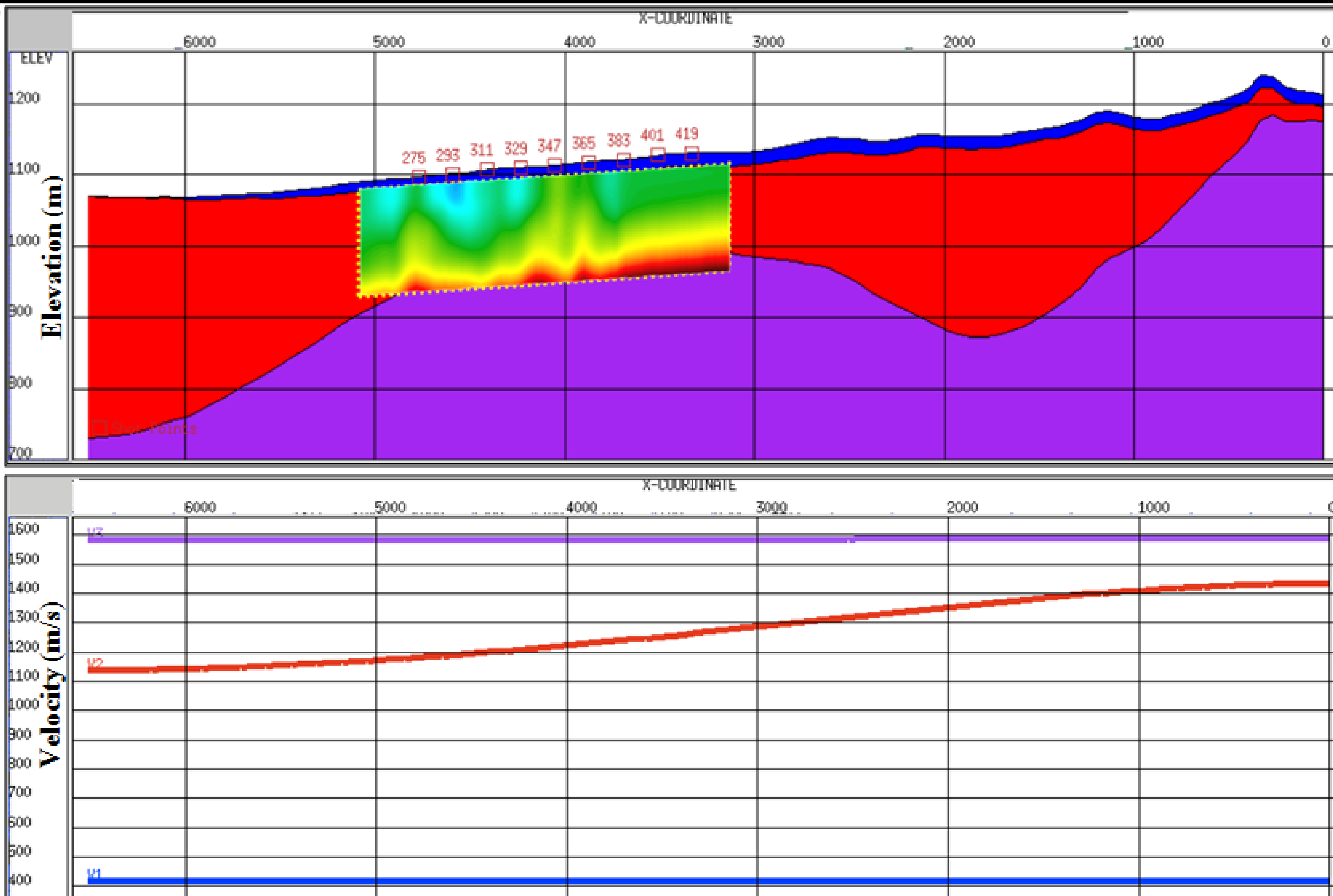
(3) Inversion for V_s



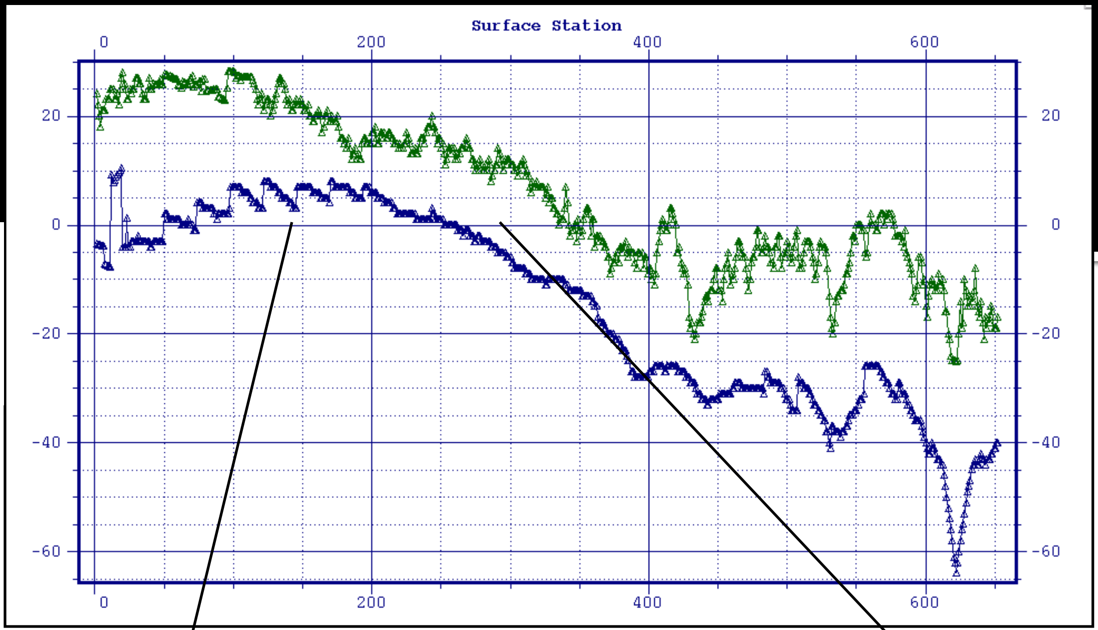
MASW S-wave Velocity Model



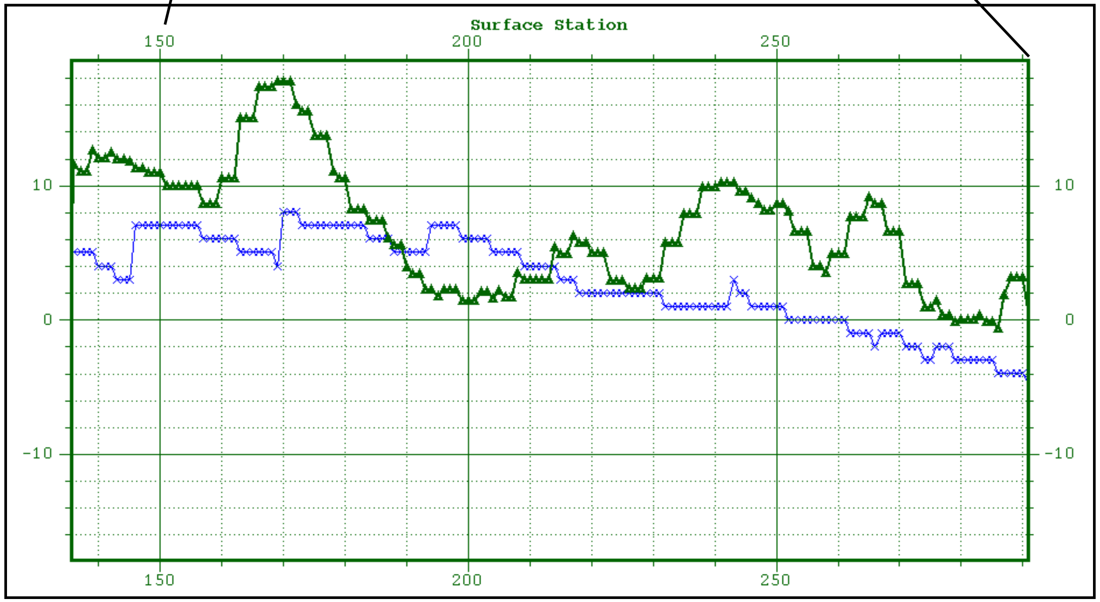
S-wave velocity from MASW and refractions at Spring Coulee



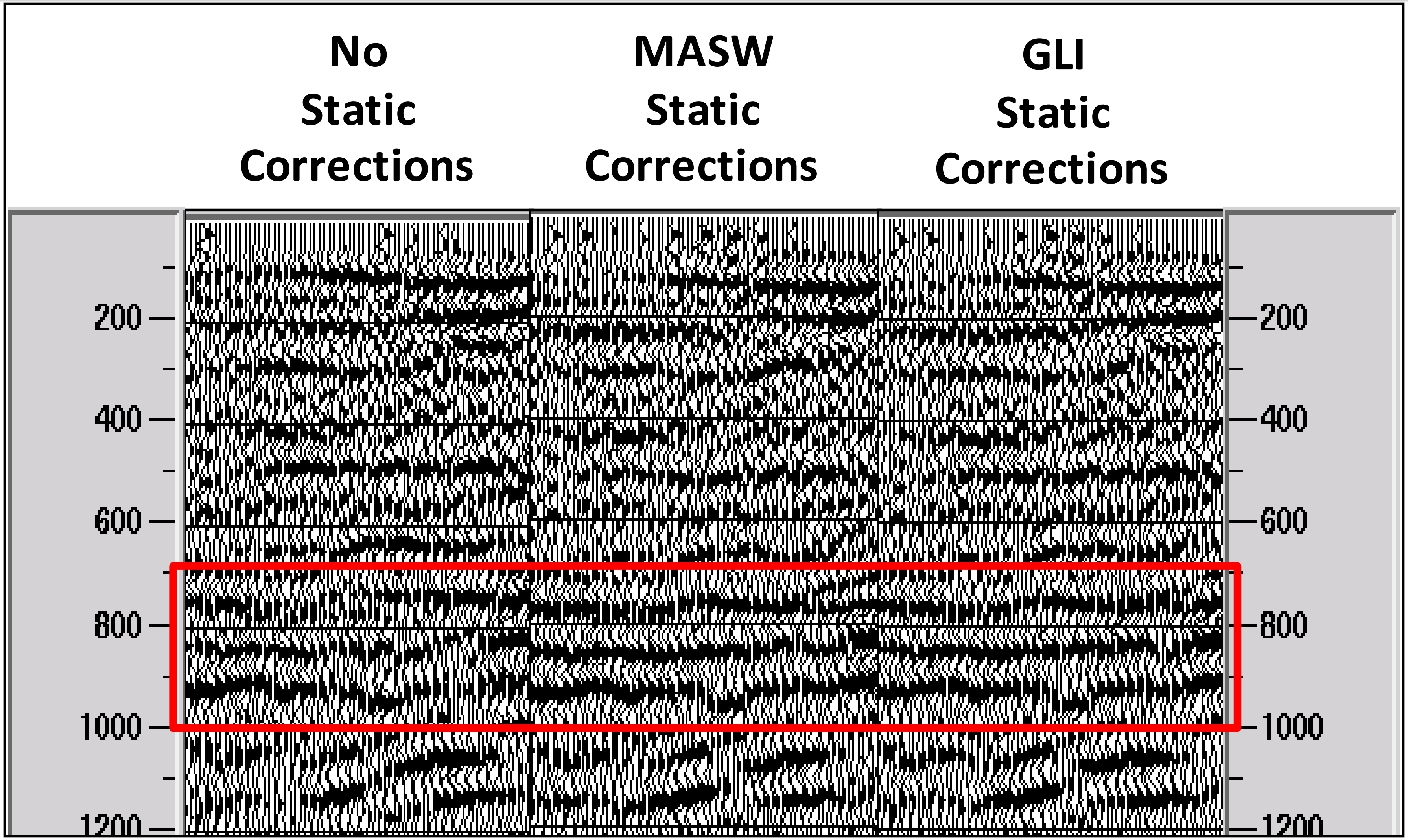
P- and **S**-wave Statics from GLI Model



S-wave Statics from GLI and MASW models



Effect of S-wave static corrections



Summary: S-wave statics from ground roll

- S-wave statics are usually important & may be difficult to estimate
- Ground roll may be inverted for S-wave velocity
- The multi-channel analysis of surface waves (MASW) and GLI S-wave near-surface models of Spring Coulee show some correlation
- Rayleigh-wave inversion is a very promising technique for near-surface S-velocity estimation

Dispersion Image:
Transformation method of Park, et al. (1998)

- A shot gather: $u(x,t)$
- Fourier transform: $U(x,\omega) = \int u(x,t) e^{i\omega t} dt$
- In terms of phase, $P(x,\omega)$, and amplitude spectra, $A(x,\omega)$:

$$U(x,w) = A(x,w)\,P(x,w)$$

$$U(x,\omega) = A(x,\omega) e^{-i.\phi.x}$$

, where $\phi = \frac{\omega}{c_\omega}$ and c_ω is the phase velocity.

- Integral transformation:

$$S(\omega,\theta) = \int e^{i\theta x}\left[\frac{U(x,\omega)}{|U(x,\omega)|}\right]dx = \int e^{-i(\phi-\theta)x}\left[\frac{A(x,\omega)}{|A(x,\omega)|}\right]dx$$

$\phi = \theta = \frac{\omega}{c_\omega}$, and c_ω can be estimated at peak.

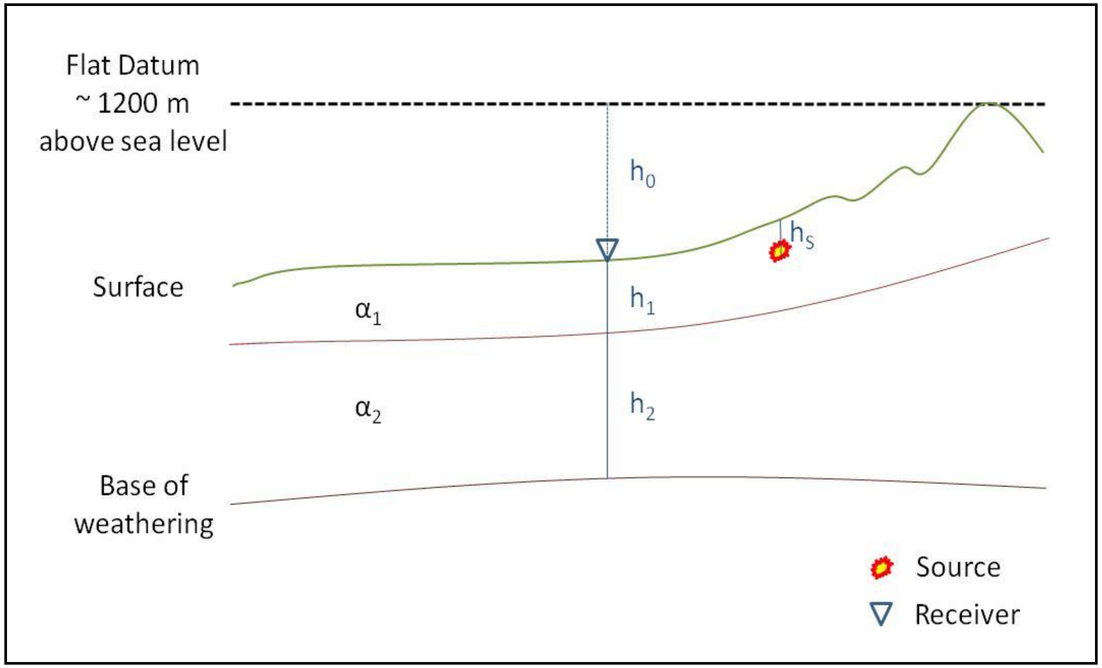
Calculation of Static Corrections

- For each source and receiver location:
  - low-velocity layer (LVL) component
  - Elevation correction

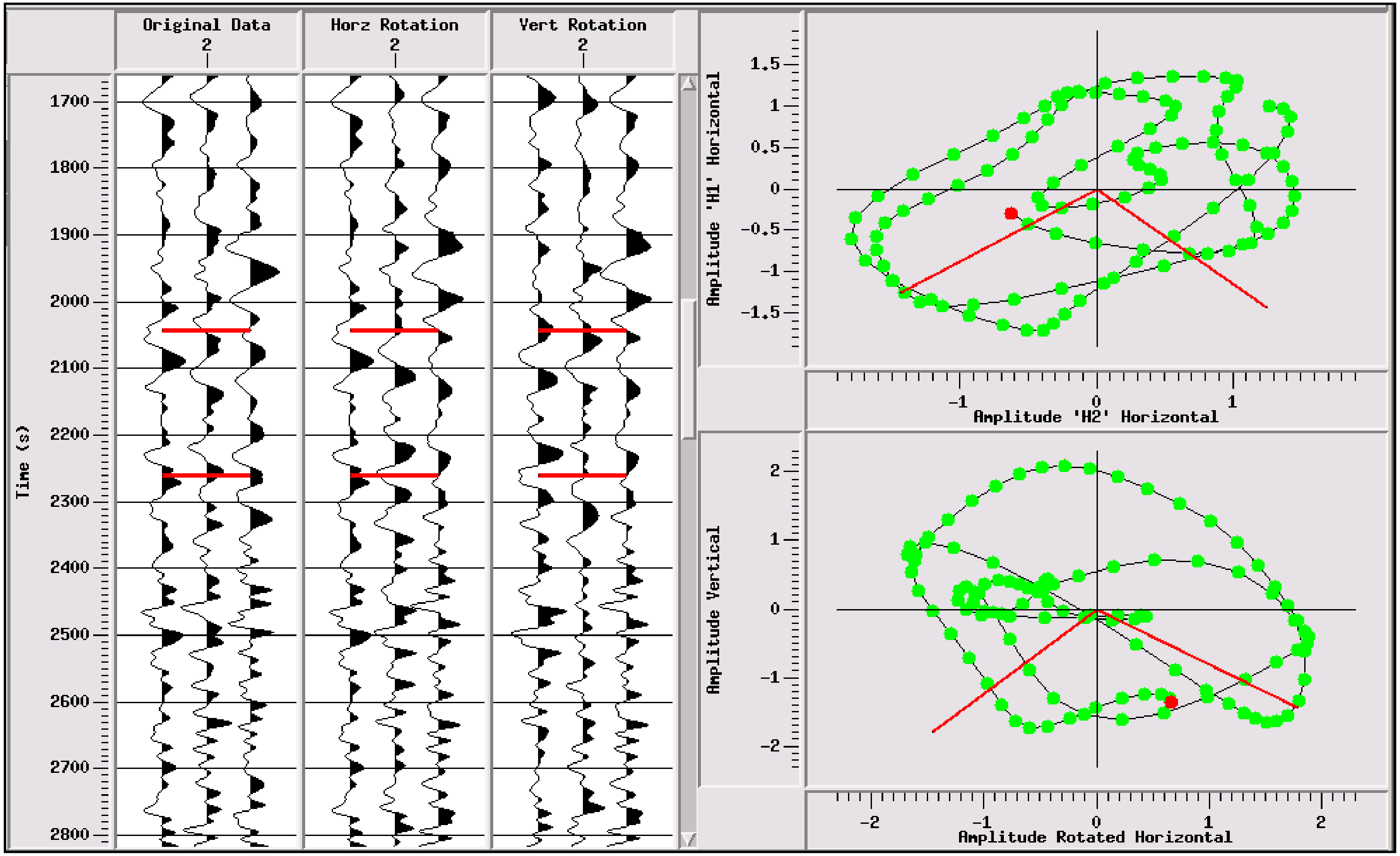
$$t_{LVL} = -\left(\frac{h_1}{\alpha_1} + \frac{h_2}{\alpha_2}\right)$$

$$t_E = \frac{h_0 + h_1 + h_2}{V_{rep}}$$

$$t_{Datum} = \frac{h_0 + h_1 + h_2}{V_{rep}} - \left(\frac{h_1}{\alpha_1} + \frac{h_2}{\alpha_2}\right)$$



Rayleigh-wave Hodogram



Can we use ground roll to estimate S-wave statics?

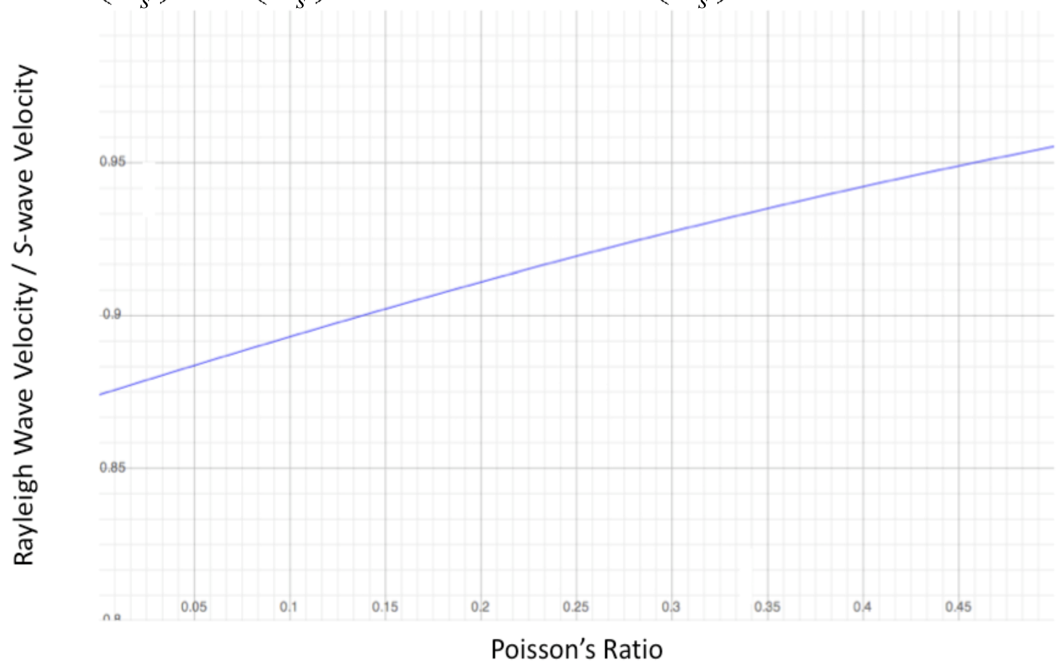
Problem – Receiver statics are often significant in PS imaging & difficult to resolve

- Phase velocity and group velocity:

$$C = V\left[1 - \frac{f}{C}\frac{dC}{df}\right]$$

- Phase velocity: function of frequency and 4 earth parameters (P-wave velocity, S-wave velocity, density, and layer thickness)

$$\left(\frac{V_R}{V_s}\right)^6 - 8\left(\frac{V_R}{V_s}\right)^4 + \left(24 - 16\frac{1-2\sigma}{2-2\sigma}\right)\left(\frac{V_R}{V_s}\right)^2 + 16\left(\frac{1-2\sigma}{2-2\sigma} - 1\right) = 0$$



Multichannel analysis of surface waves (MASW) (using the KGS' Surfseis)

Read SEG-Y file in *SurfSeis 2.05*

Mute first breaks

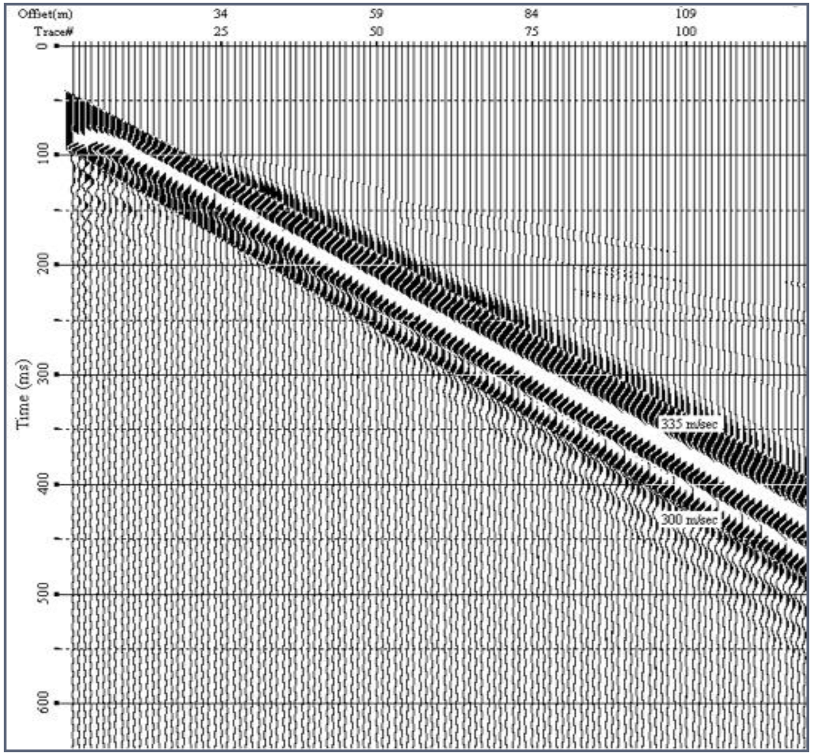
Create dispersion image of the Rayleigh waves

Pick the fundamental mode dispersion curve

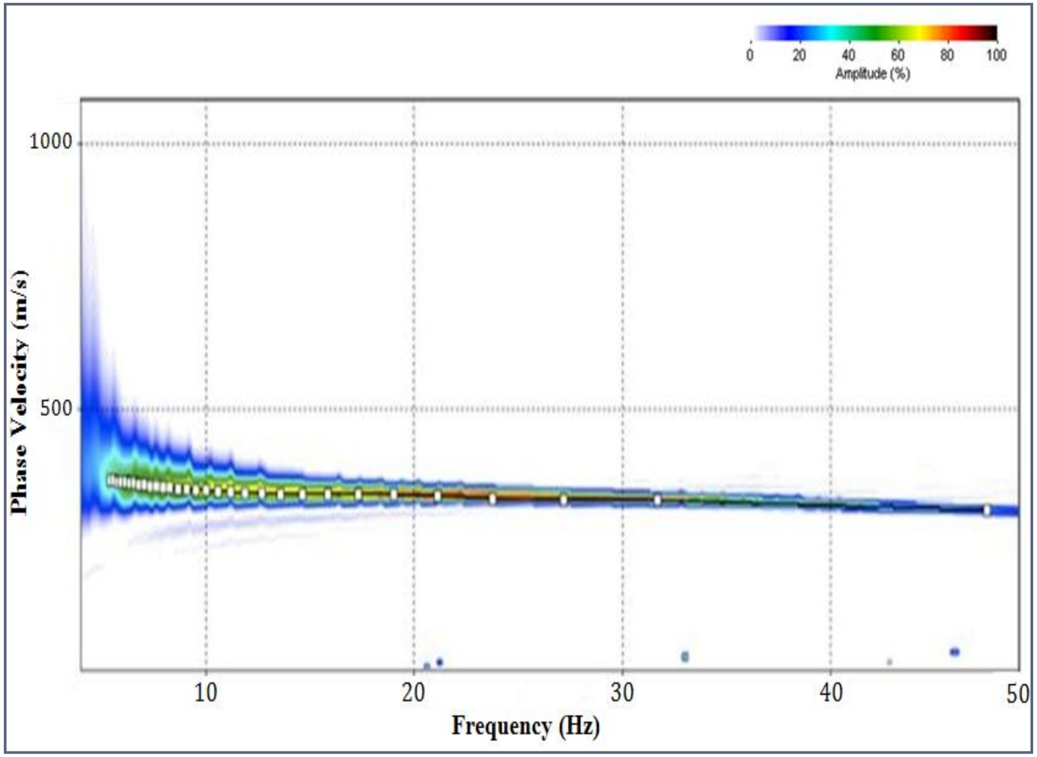
Invert for S-wave velocities using 2 initial models:

- 1) based on the P-wave model derived earlier using the refraction method and a constant Poisson's ratio
- 2) Created from the dispersion curve.

(1) Shot Gather

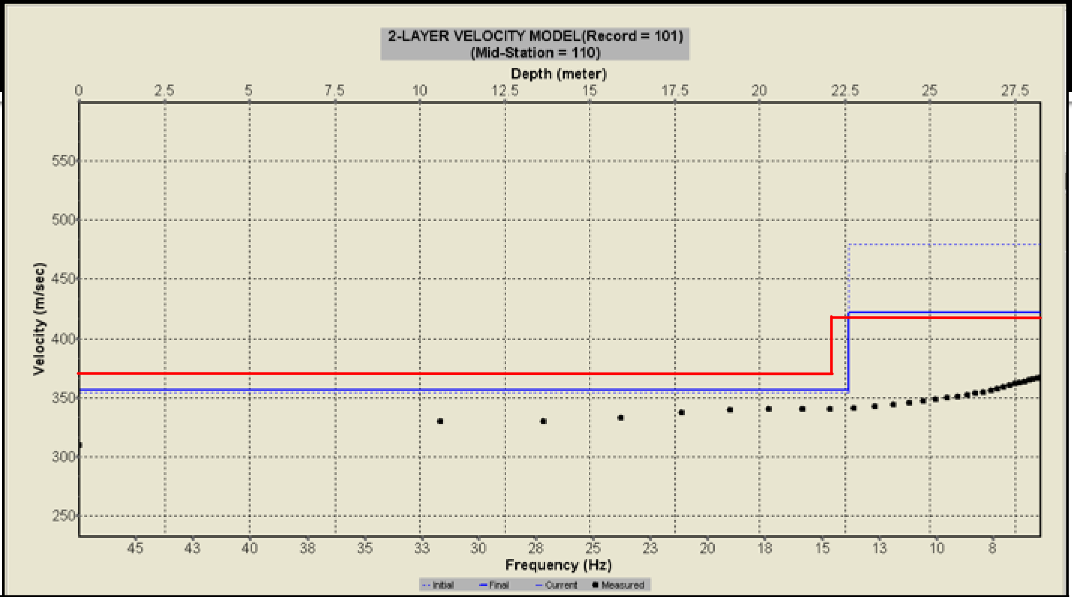


(2) Dispersion Image

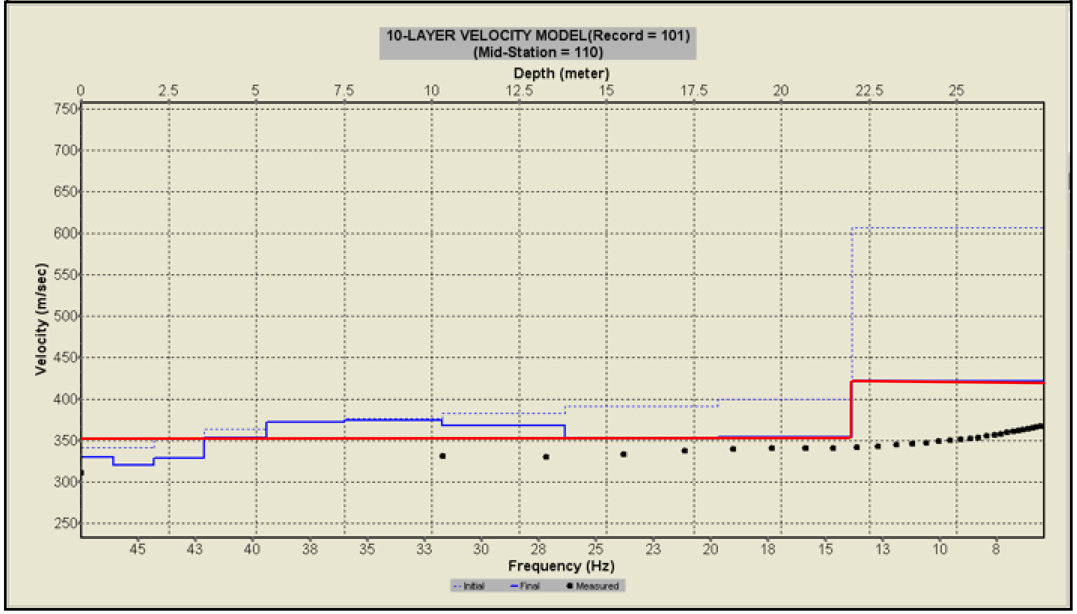


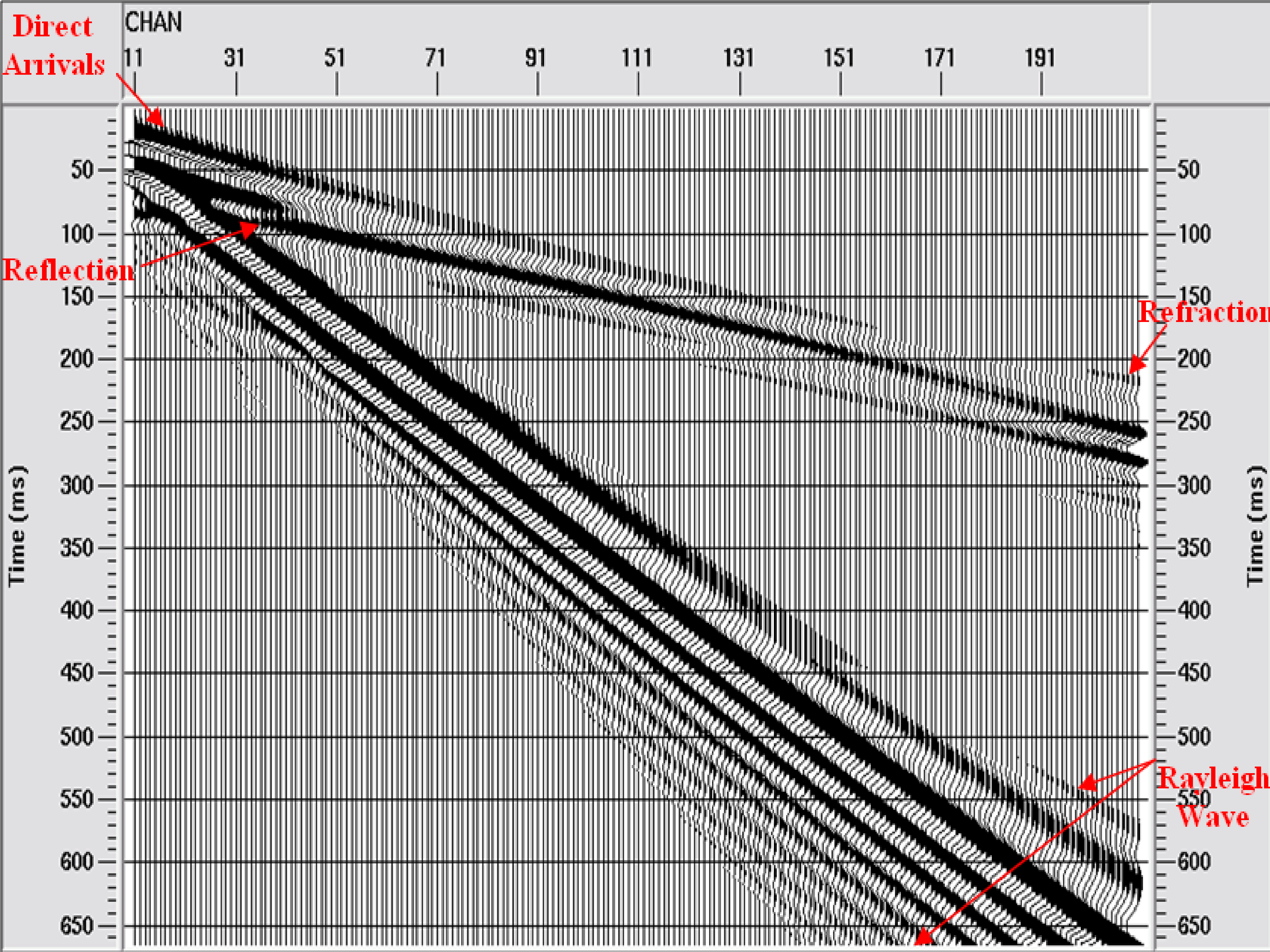
Inversion

- Based on P-wave velocities from refraction analysis and constant Poisson's ratio (~0.4)
- V_{s1} ~ 357 m/s
- V_{s2} ~ 422 m/s
- Thickness ~ 22.6 m
- Compared to 370 m/s, 420 m/s, and 22 m.



- Initial Model (B):
  - Created from dispersion curve by SurfSeis
  - V_{s1} ~ 360 m/s
  - V_{s2} ~ 420 m/s
  - Thickness ~ 22 m
  - Compared to 370 m/s, 420 m/s, and 22 m.





Direct Arrivals
CHAN
11
31
51
71
91
111
131
151
171
191
Reflection
Refraction
Rayleigh Wave
Time (ms)
50
100
150
200
250
300
350
400
450
500
550
600
650

S-wave Hodogram