A Massive 3D VSP in Milne Point, Alaska

Claire Sullivan, Allan Ross, James Lemaux, Dennis Urban, Brian Hornby, Chris West, and John Garing,

BP Exploration Alaska

Björn Paulsson, Martin Karrenbach, and Paul Milligan, Paulsson Geophysical Services, Inc. (P/GSI)

What we did:

- Acquired a 3 million trace 3D VSP with 4 wells, each instrumented with 80 3-component receivers recording simultaneously.

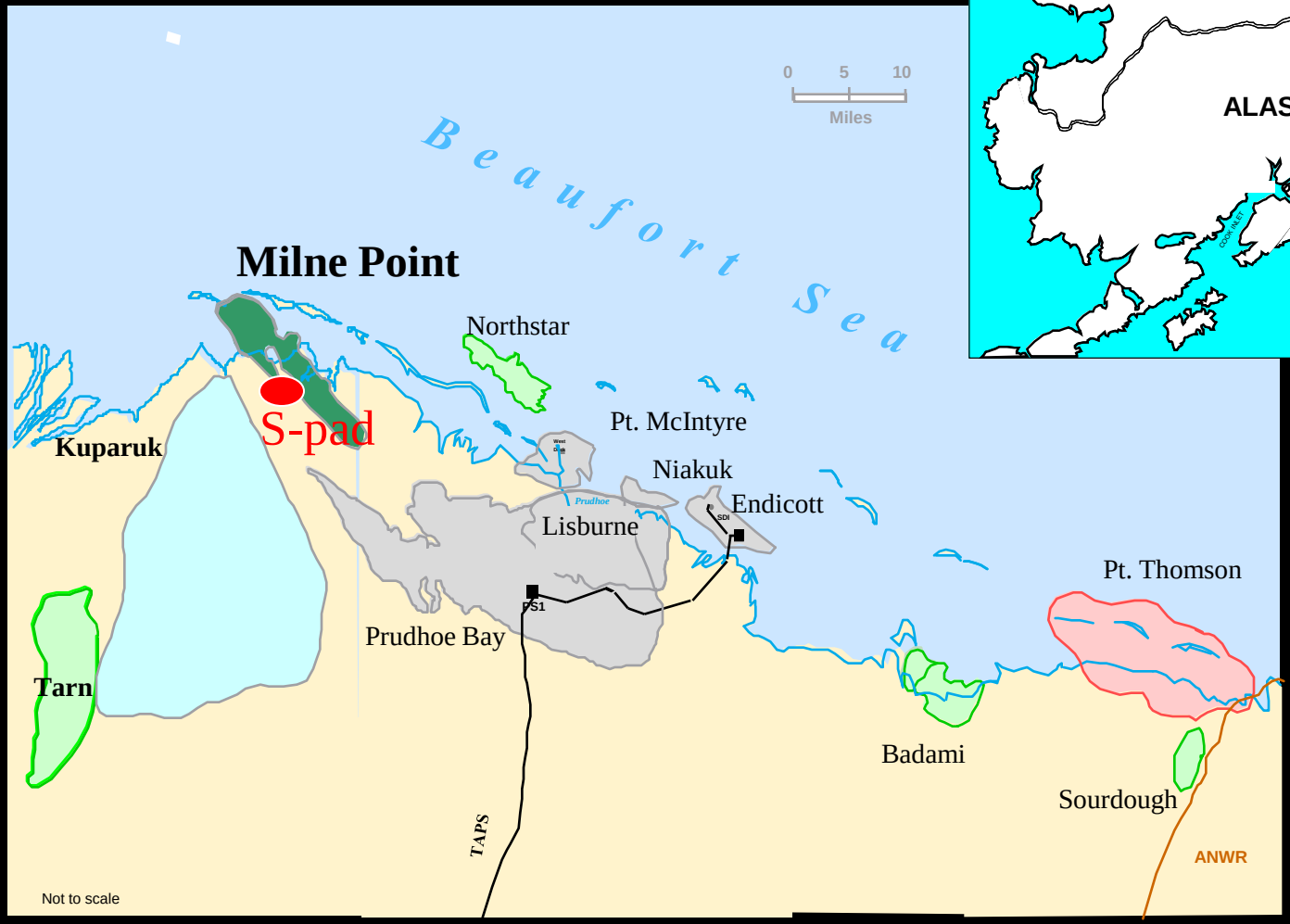
Why we did it:

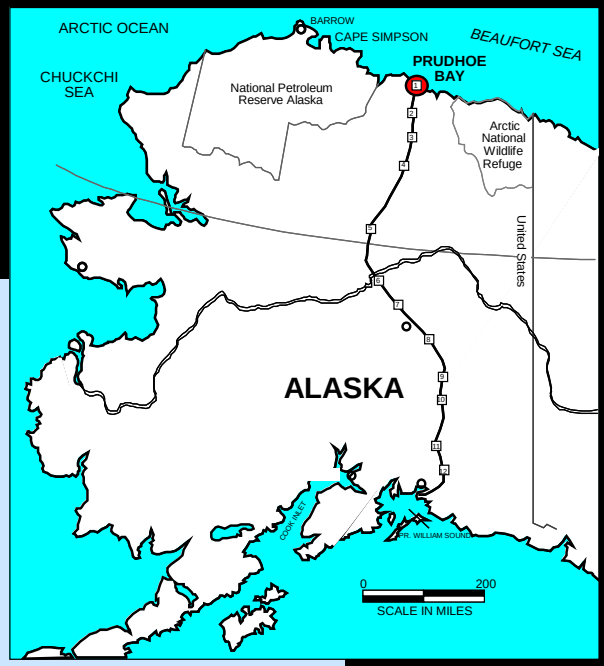
- High resolution data set for field development.
- Determine variation in permafrost velocities.

Outline

- Introduction
- Planning the VSP
- Acquisition
- The Data
- Conclusions

Milne Point Location

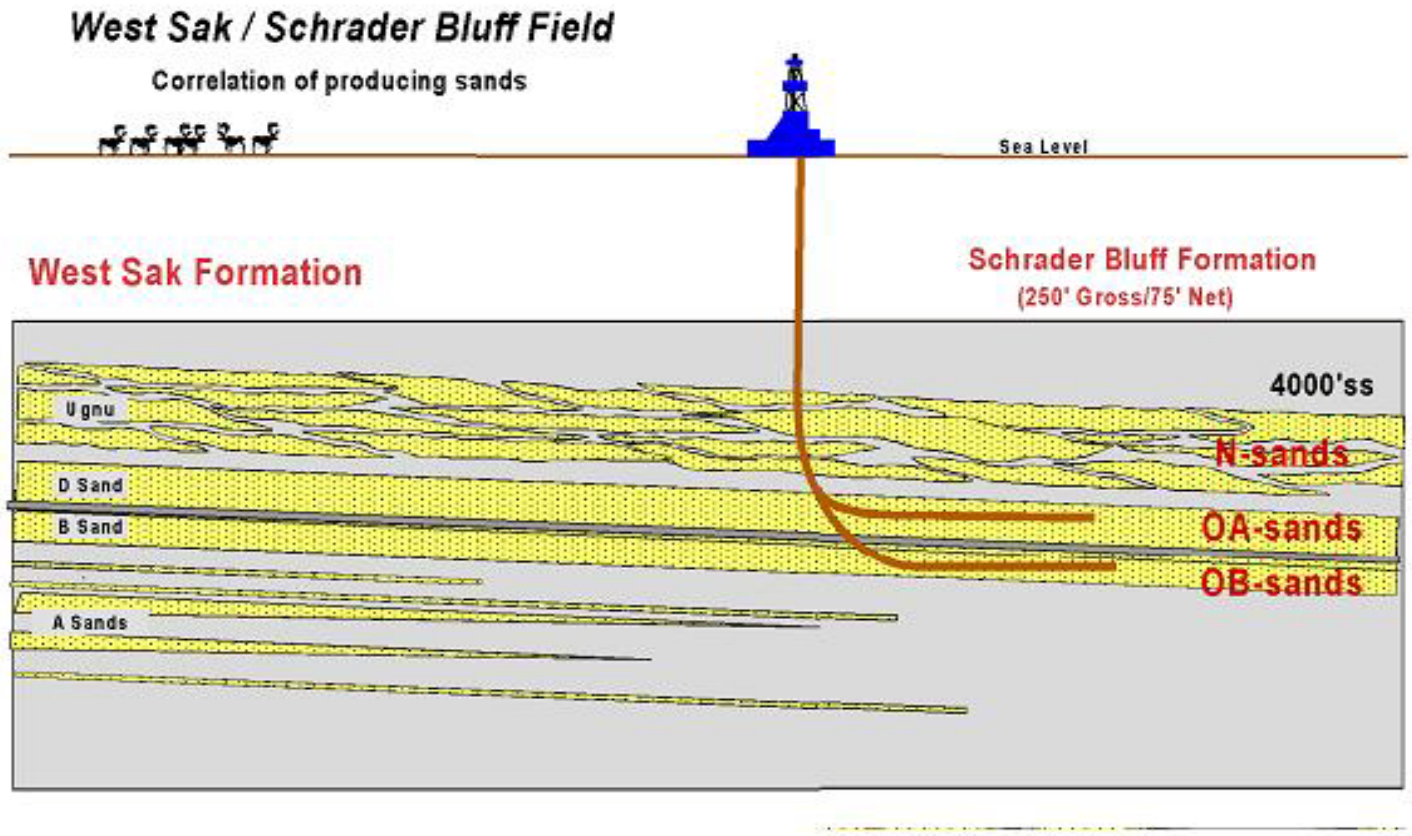




Schrader Bluff S-pad Highlights

- 53 mmbo recoverable
- Reservoir depth = 4000 ft.
- Viscous Oil – *API 14-24, biodegraded, low temperature*
- Economic breakthrough with multi-lateral drilling design.
- Success depends on accurate placement of laterals in the reservoir and elimination of drilling sidetracks.

Schrader Bluff Geology

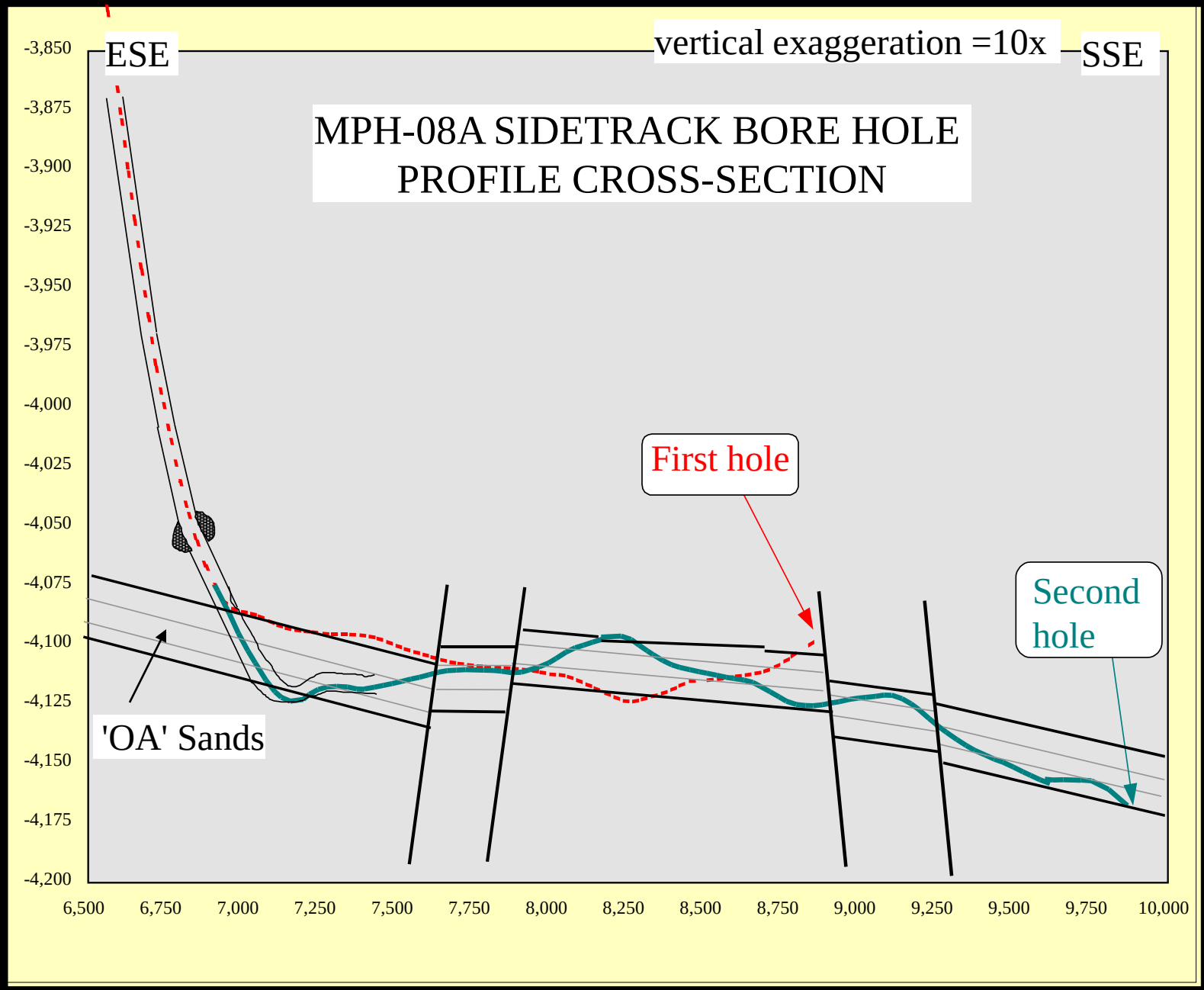


Multiple, stacked sands

Main reservoirs are O & N at Milne Point

Motivation for the 3D VSP

- Current seismic data was low fold (4-6).
- Thin sands (20-30 ft) with sub-seismic faulting.
- Need a high resolution data set to steer development drilling and avoid sidetracks.



Depth

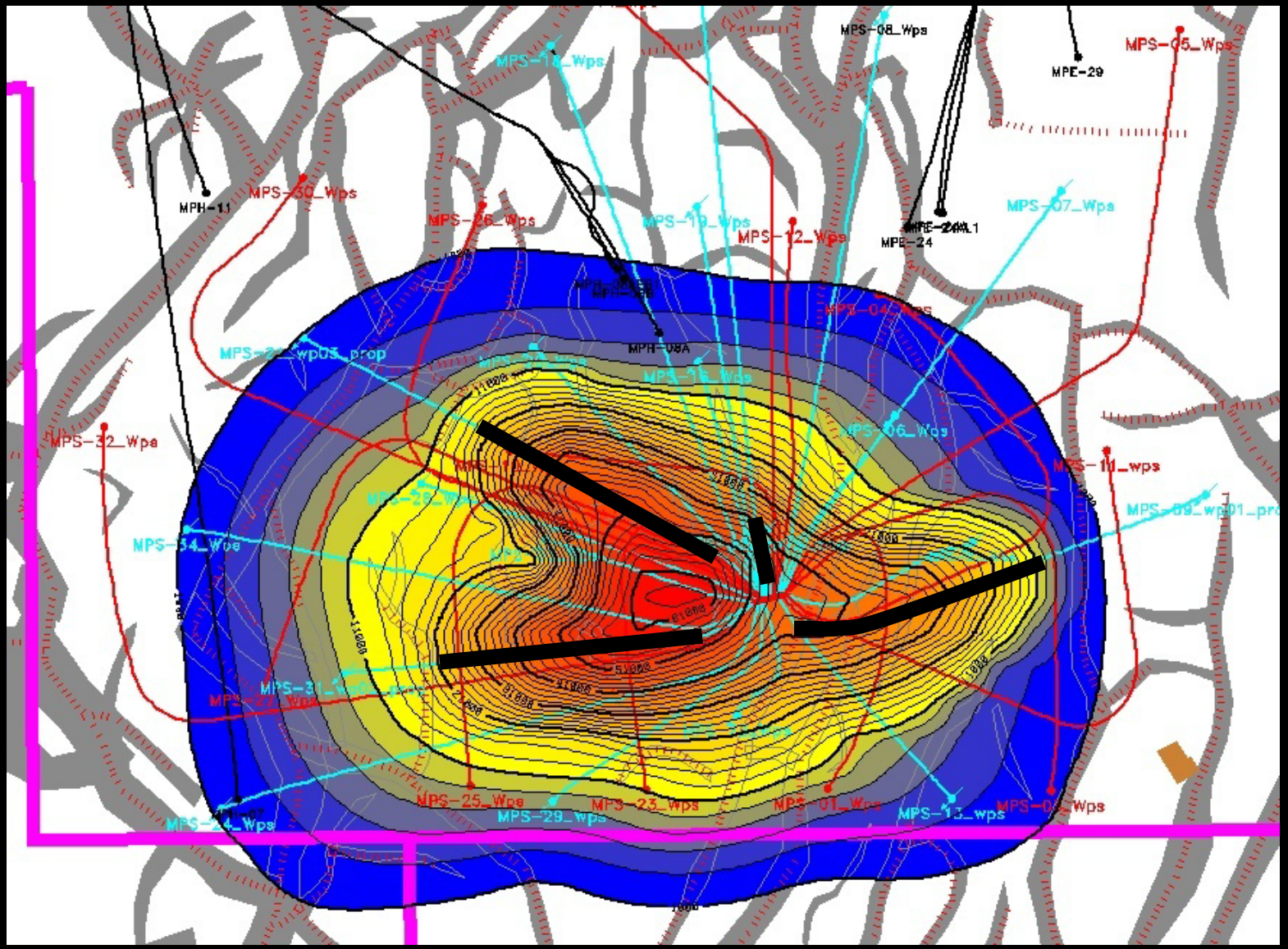
Feet from surface location

Planning the Survey

Image coverage modeling

- P/GSI Illumination modeling.
- Various scenarios were simulated:
  - single well and combined deviated wells
  - different shot spacing and coverage
  - varied placement of geophone arrays in borehole
  - designed trajectory of borehole
- Complete 3D volume of hit counts computed.

Modeled illumination at 4000 feet with 320 receivers placed in 4 wells.



# of hits

1000-8000

10,000-30,000

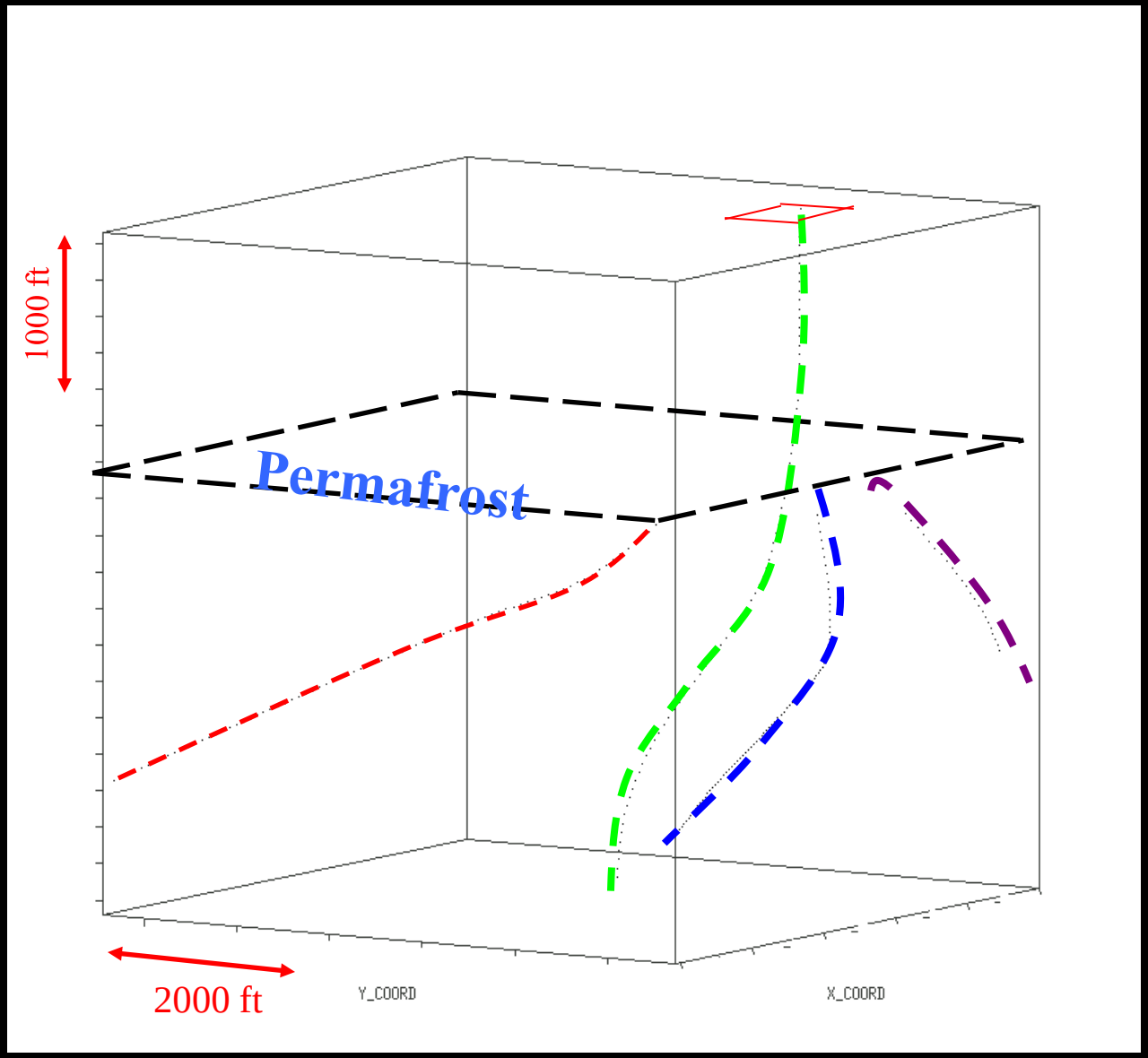
30,000- 60,000

Receiver locations

One mile

Contour interval = 200 hits

Placement of geophone arrays



4 geophone arrays

Each array has 80 levels spaced 50 ft apart.

Length of array is 4000 ft.

Total of 320 multi-component geophones

Receivers in deviated wells are placed below permafrost.

Acquisition of the Survey

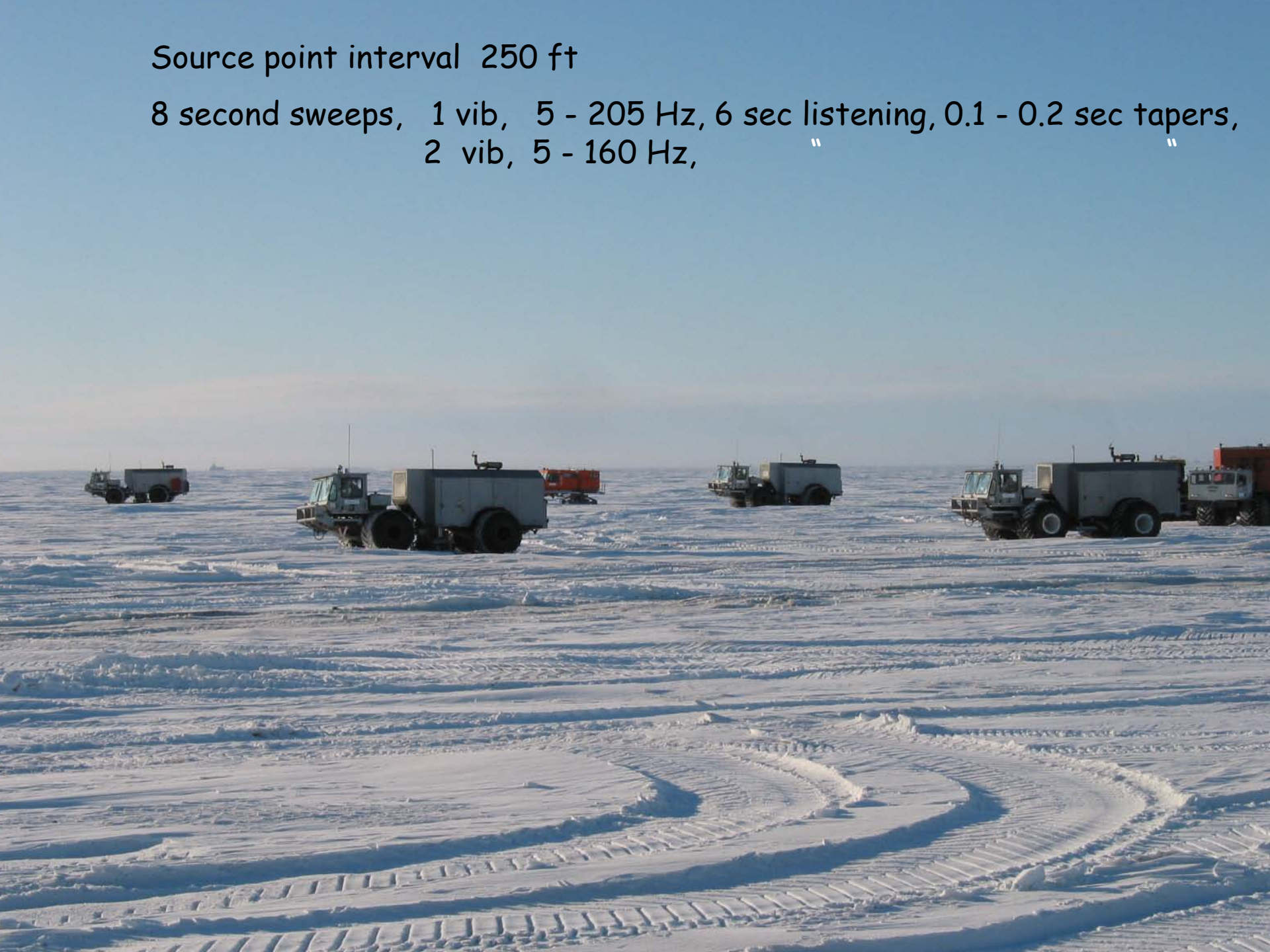

EXIT


bp
EXIT

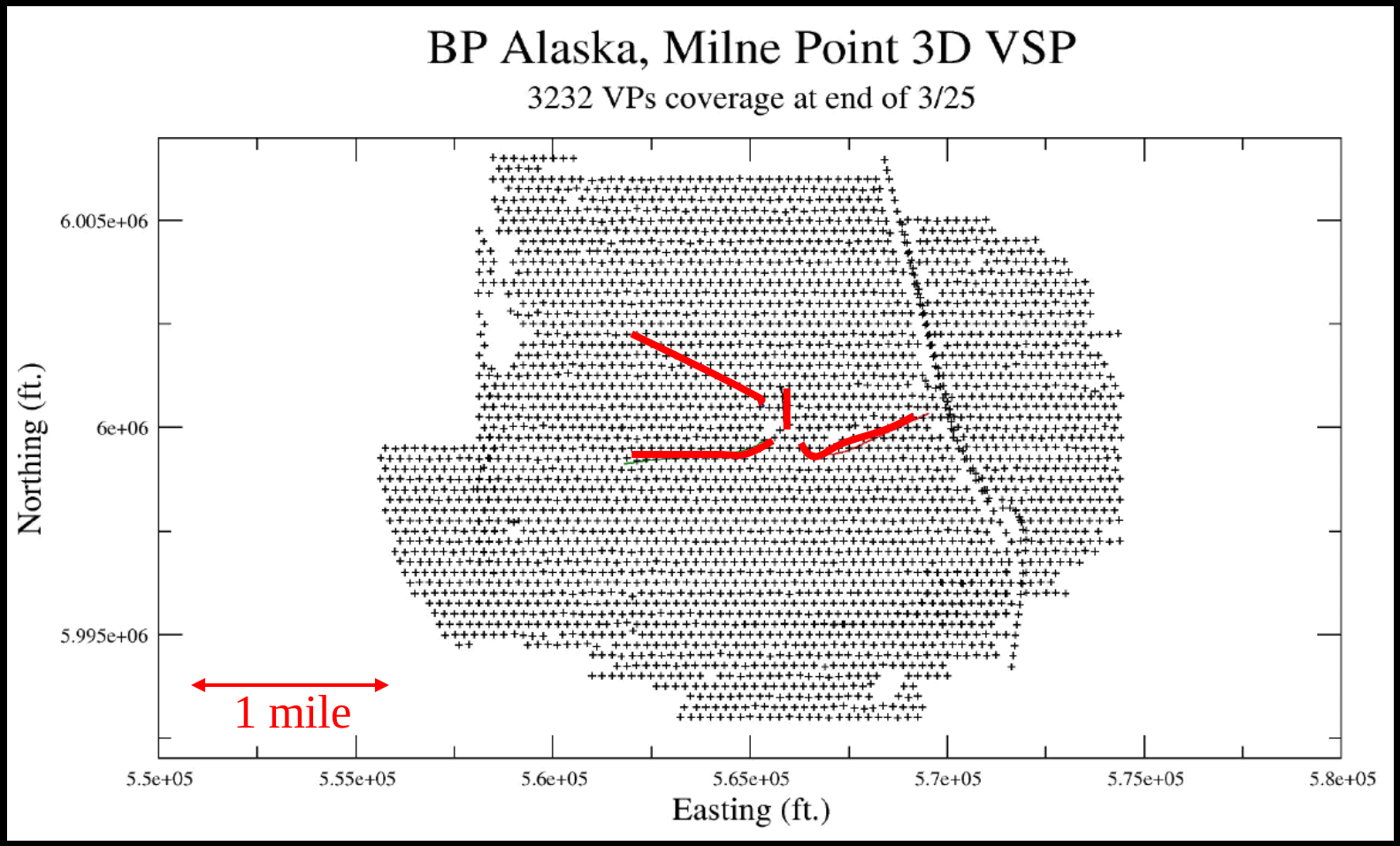

SWACO-DSR

Source point interval 250 ft

8 second sweeps, 1 vib, 5 - 205 Hz, 6 sec listening, 0.1 - 0.2 sec tapers,
2 vib, 5 - 160 Hz, " "



VP coverage and active receiver wells map

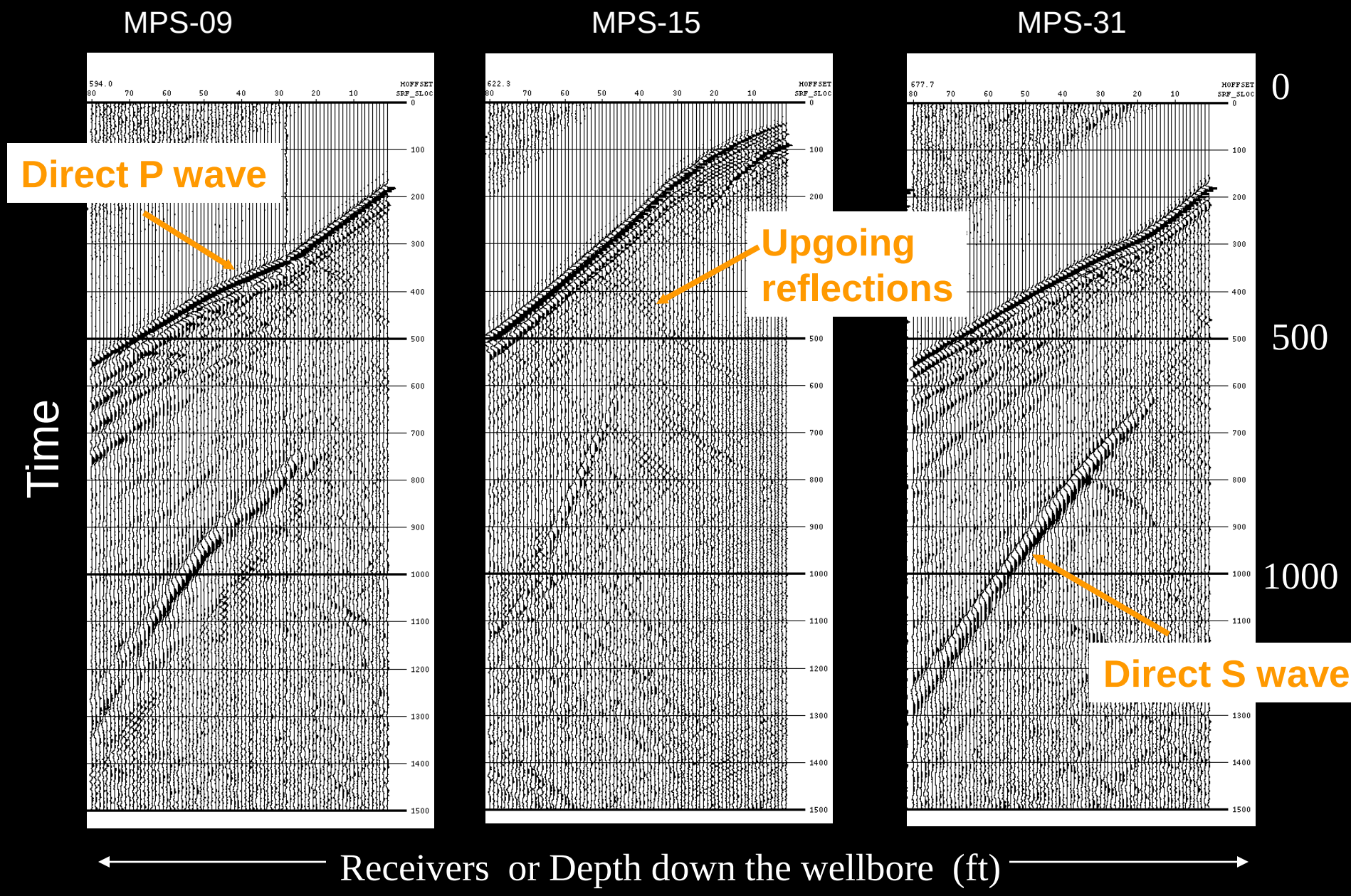


3232 VPs into 4 wells, 80 three-component geophone levels, 960 channels, 3 million traces.

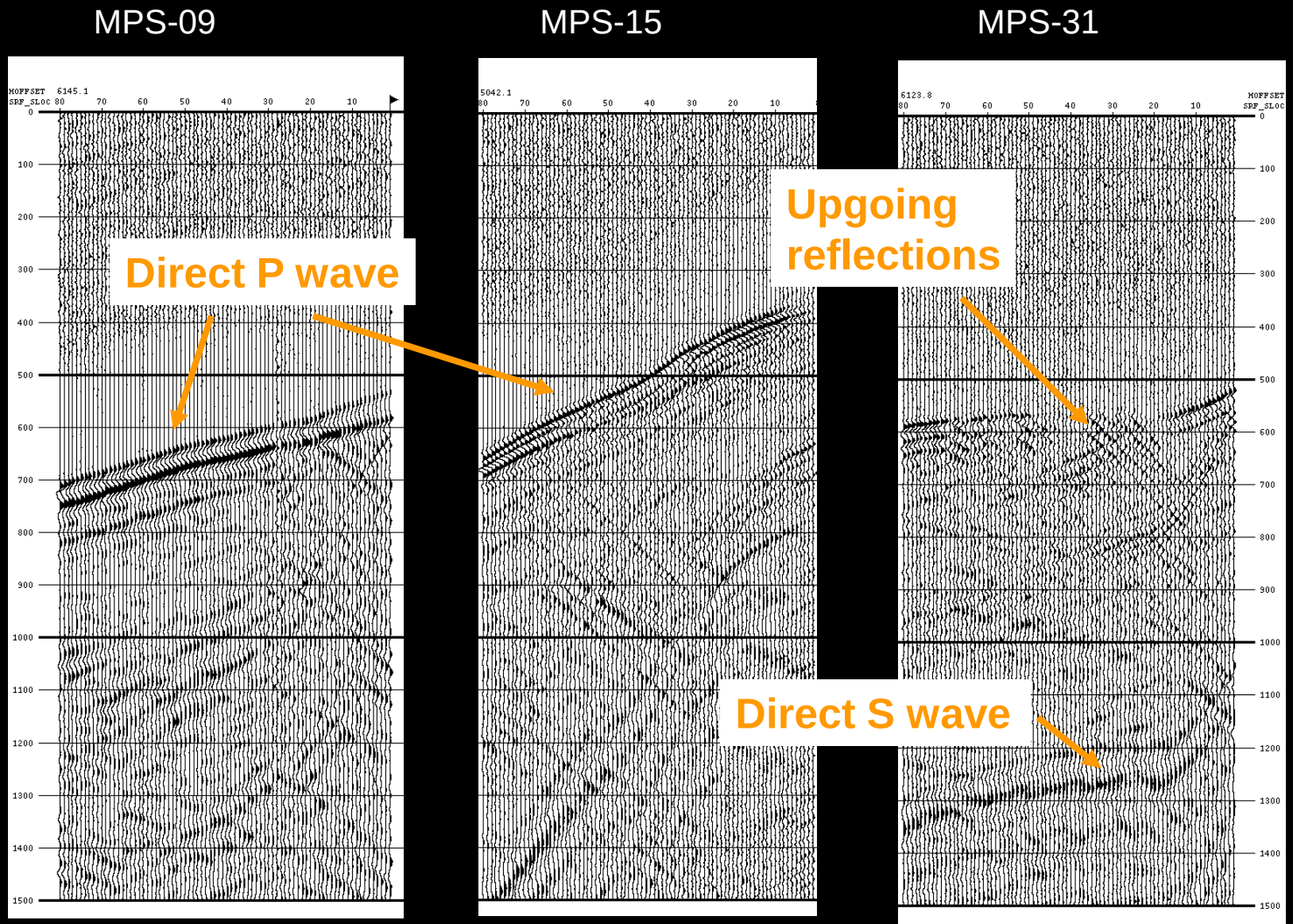
4 walk-above lines at 50 ft source interval to aid in 3C geophone orientation.

A Look at the Data

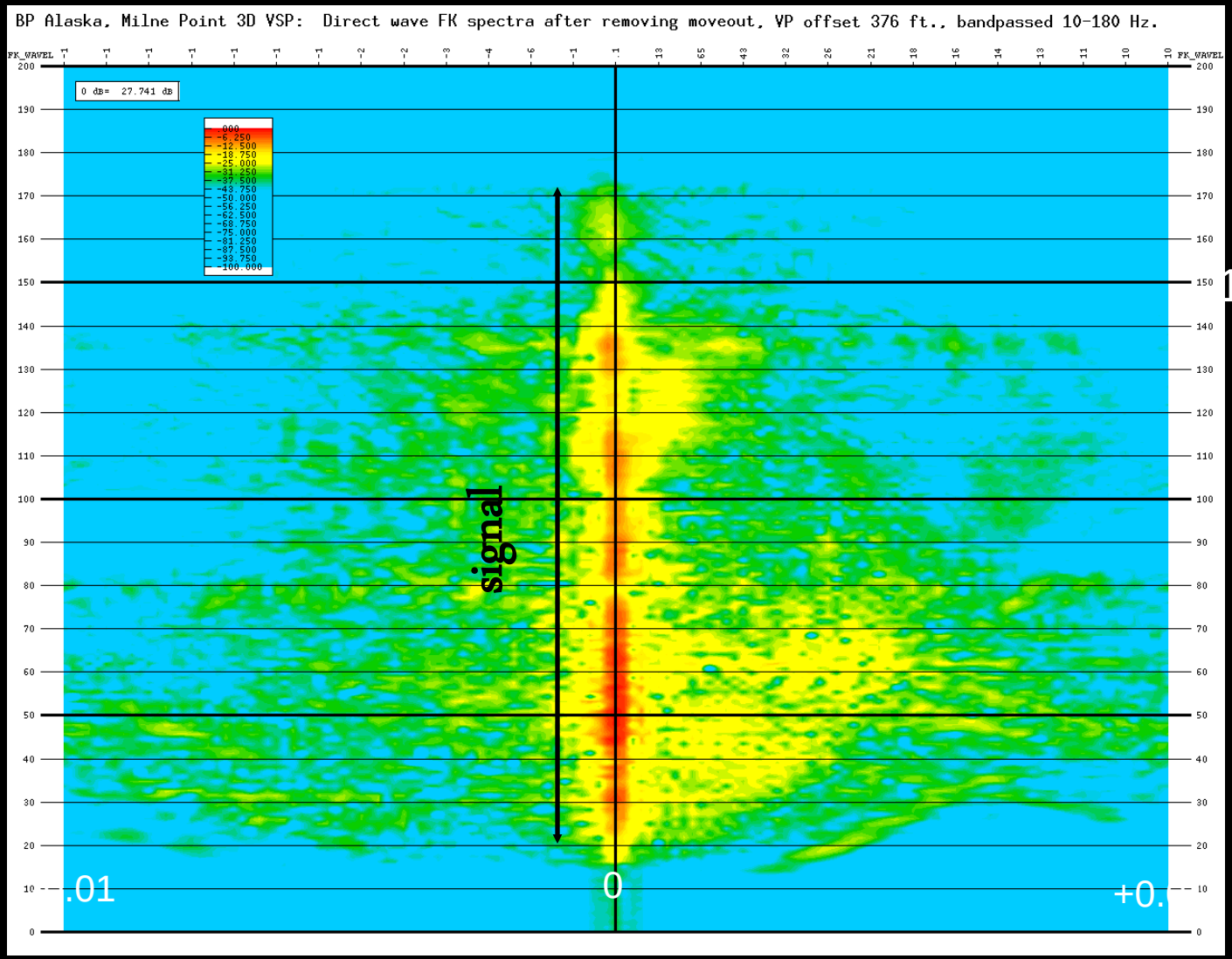
Raw records: near offset (500 - 670 ft)

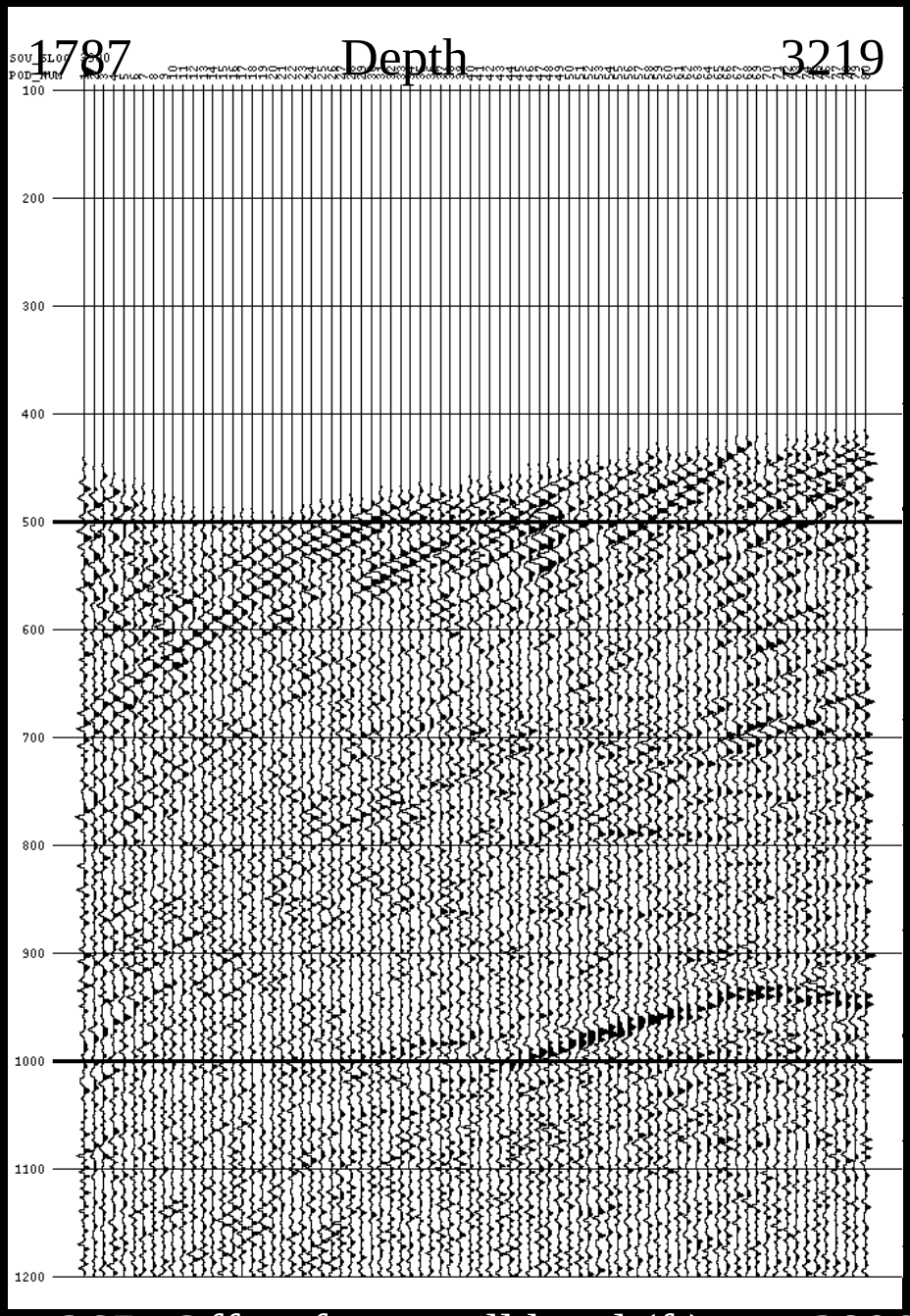


Raw records: far offsets (5000 - 6200 ft)



Direct wave spectral analysis
Near offset – 376 ft 10-170Hz bandpass





Common Source Gather

Raw axial data

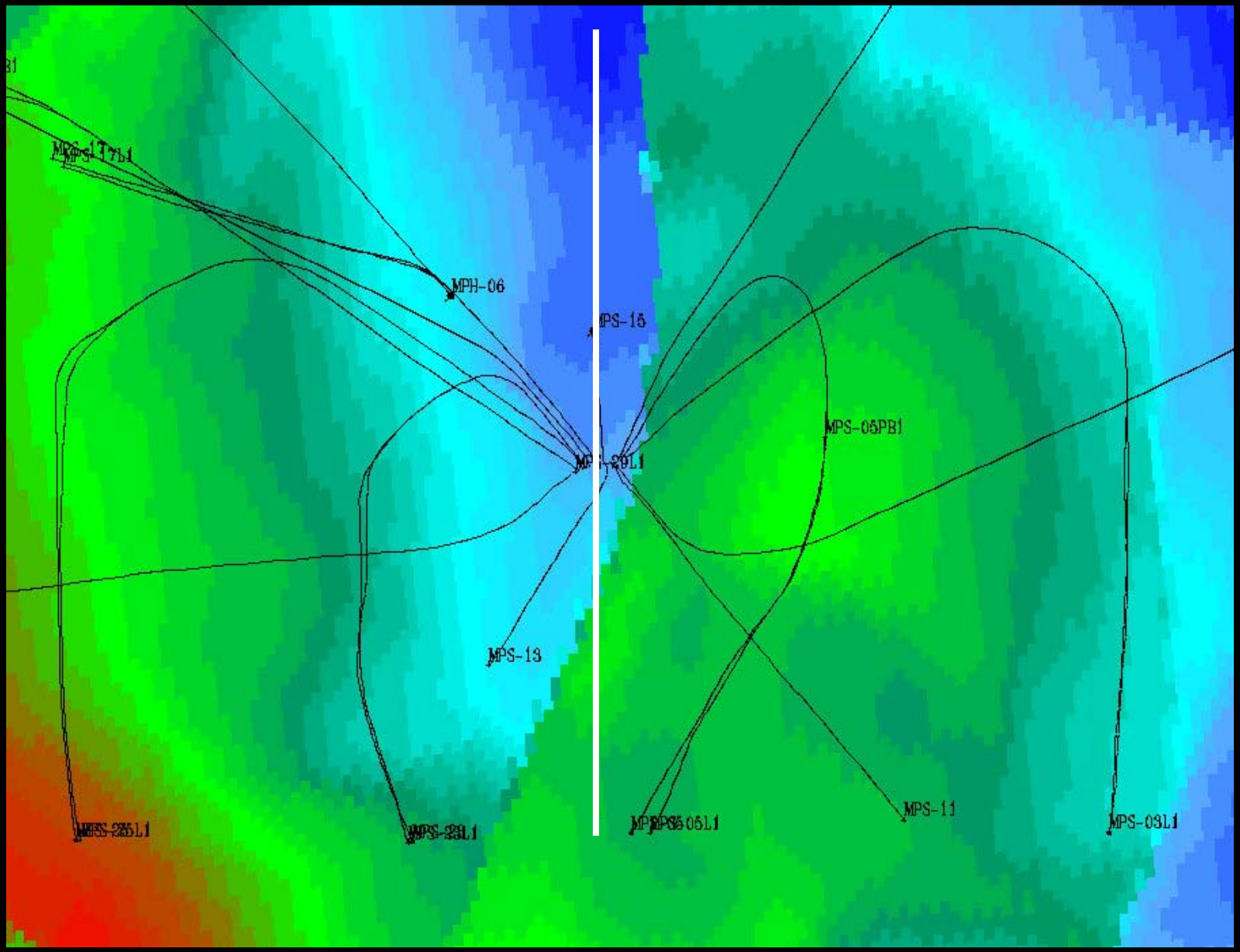
Data rotated towards source.

Data rotated towards reflectors

Data after wavefield separation – upgoing P wave

Source point is 2400 ft SW of lowest receiver

North – South example line through center of S-pad



Depth

-4350

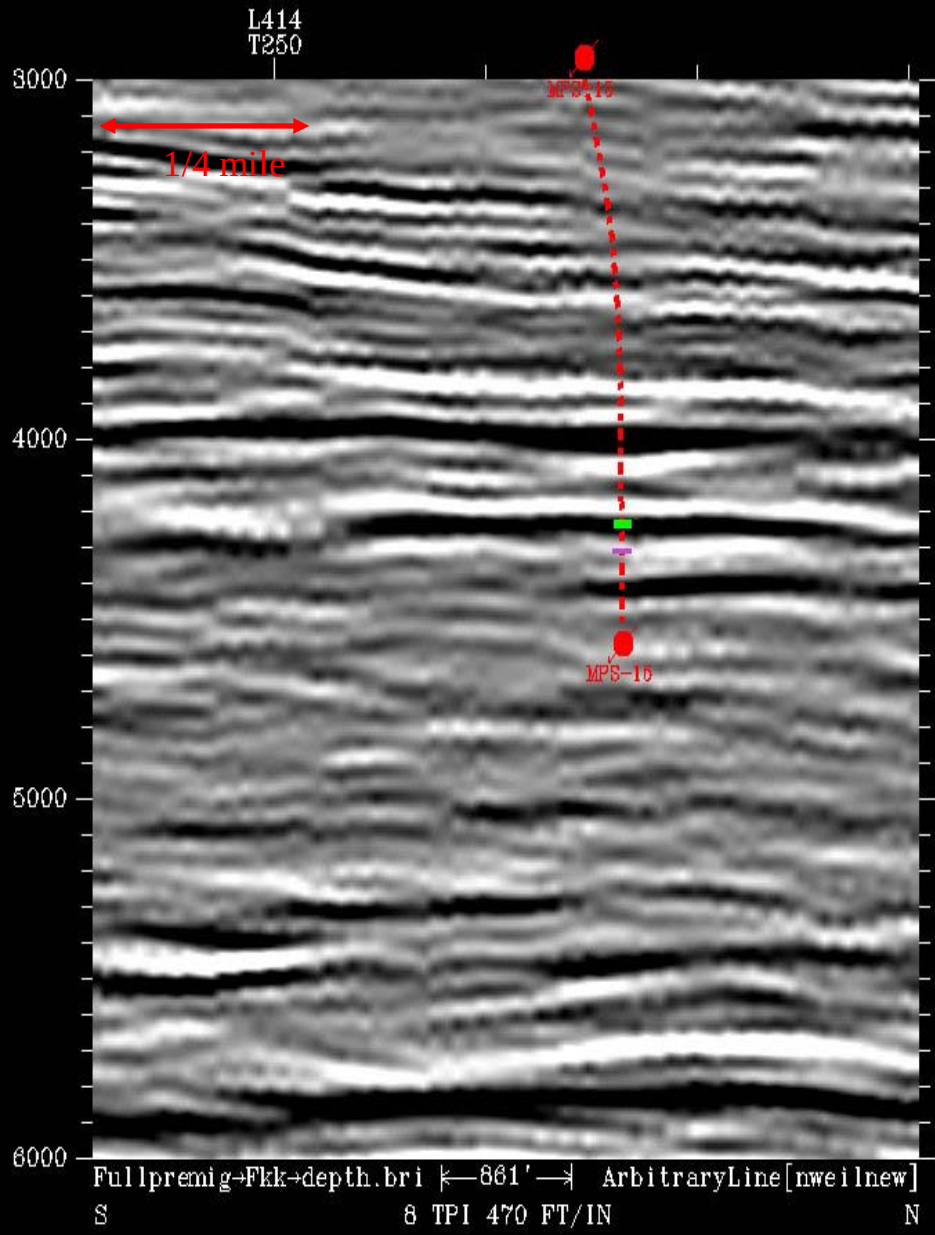
-4150

-4050

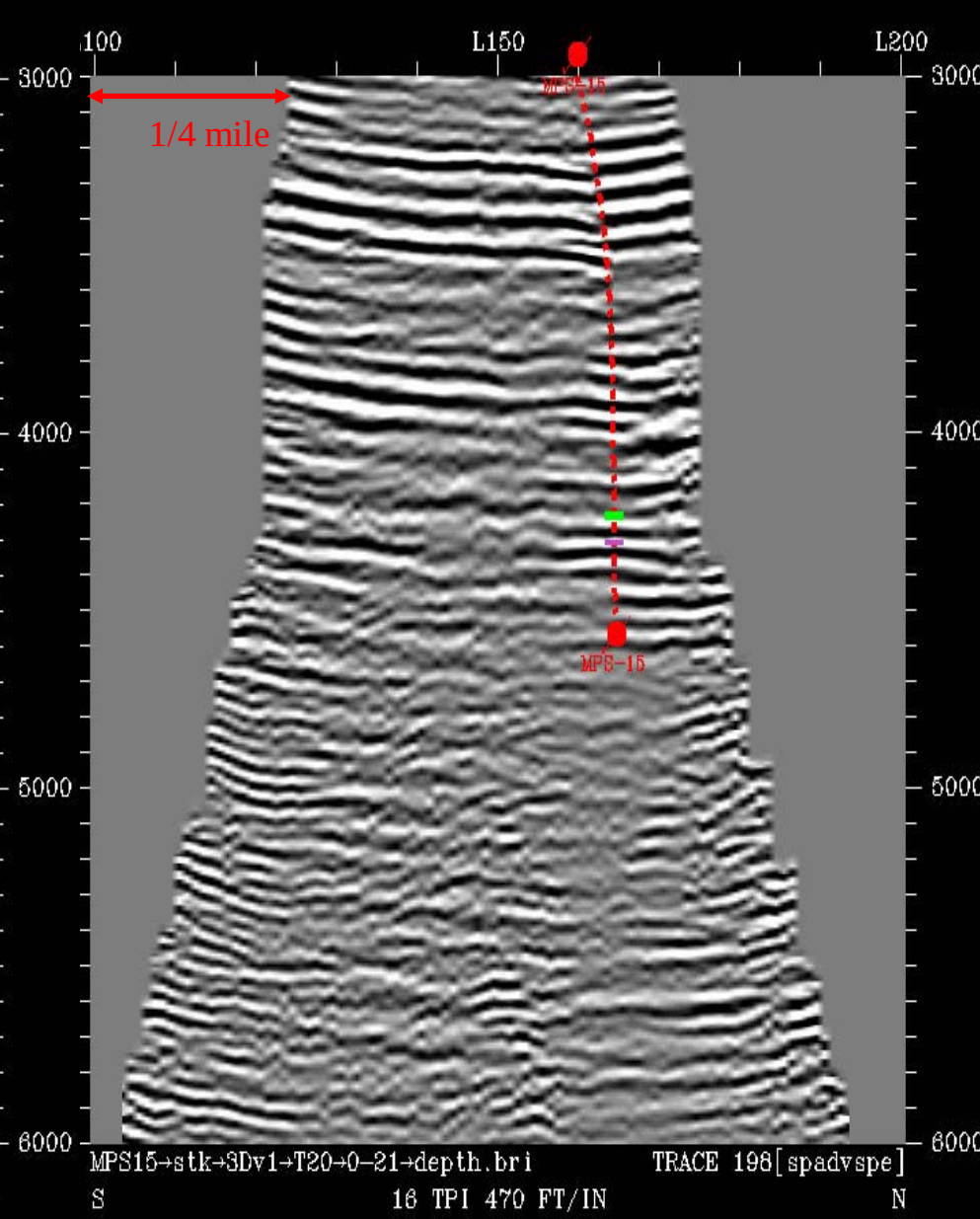
-3950

¼ mile

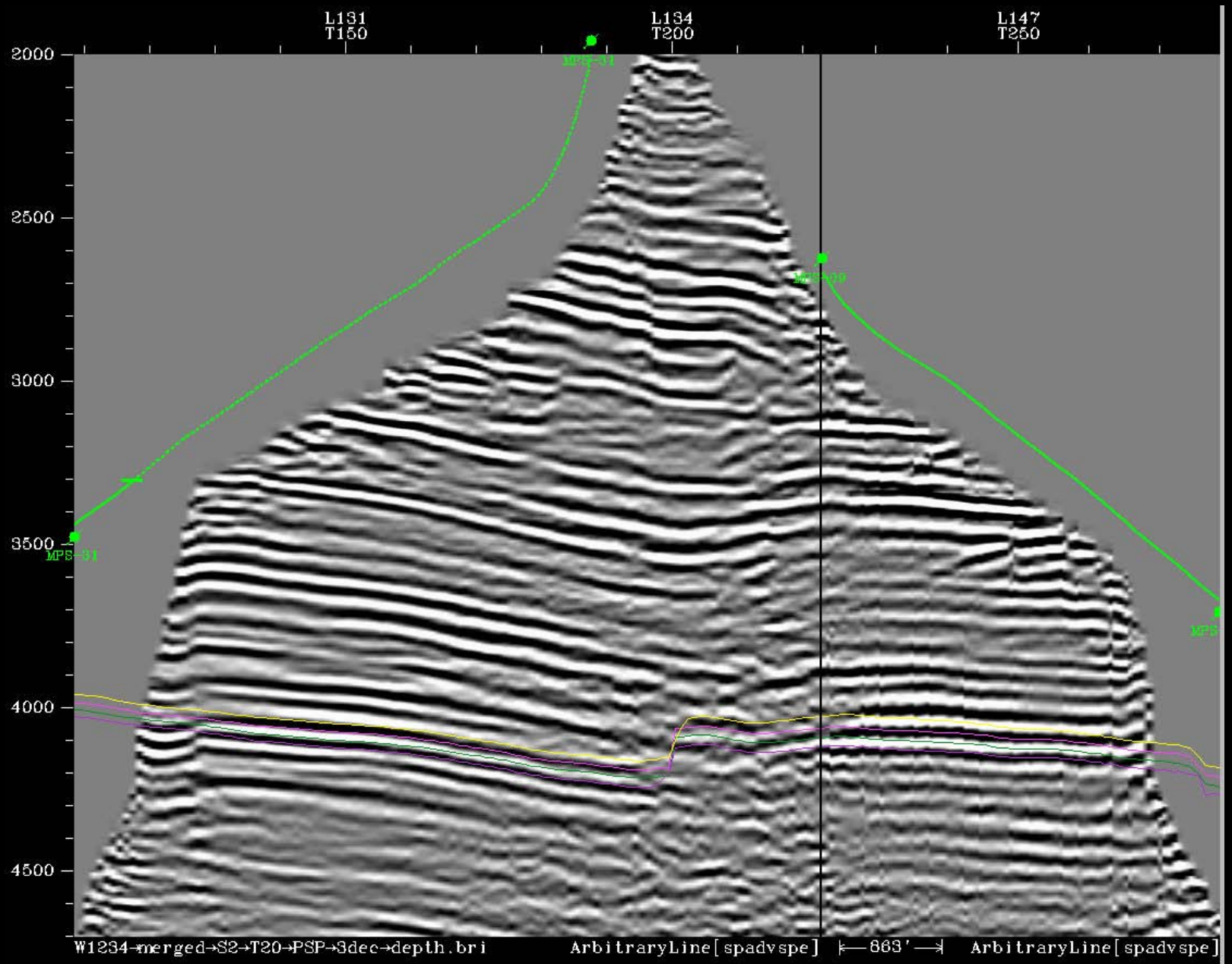
Reprocessed Surface Seismic



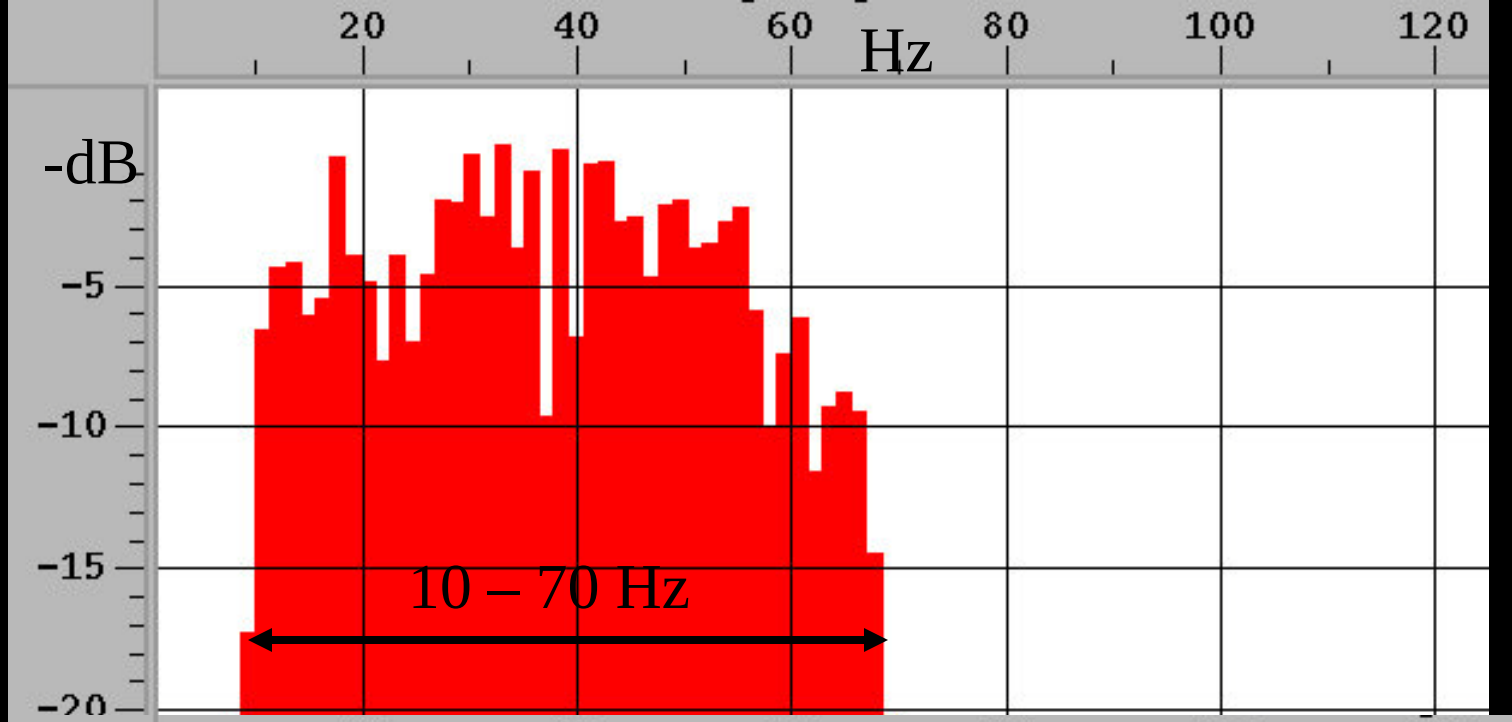
Preliminary VSP



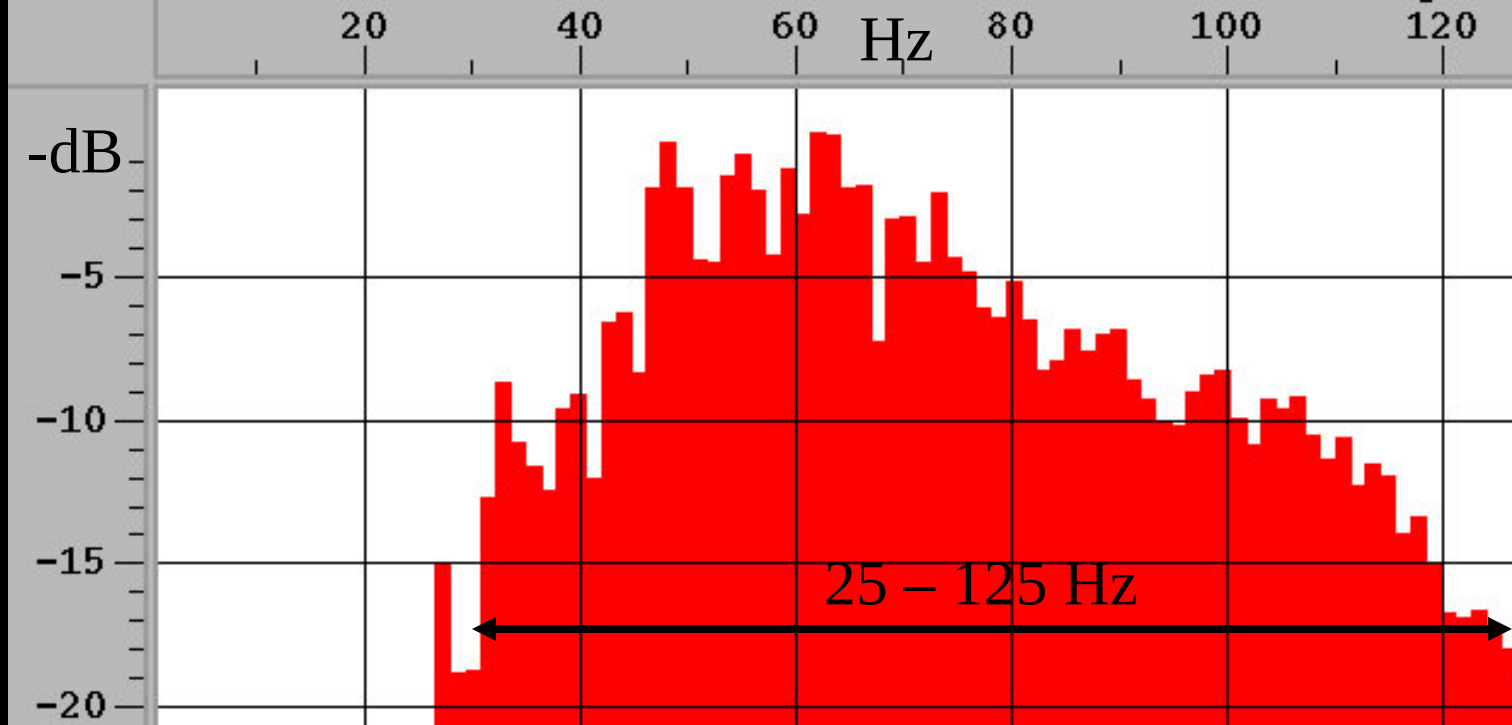
Massive 3D VSP / W-E Profile



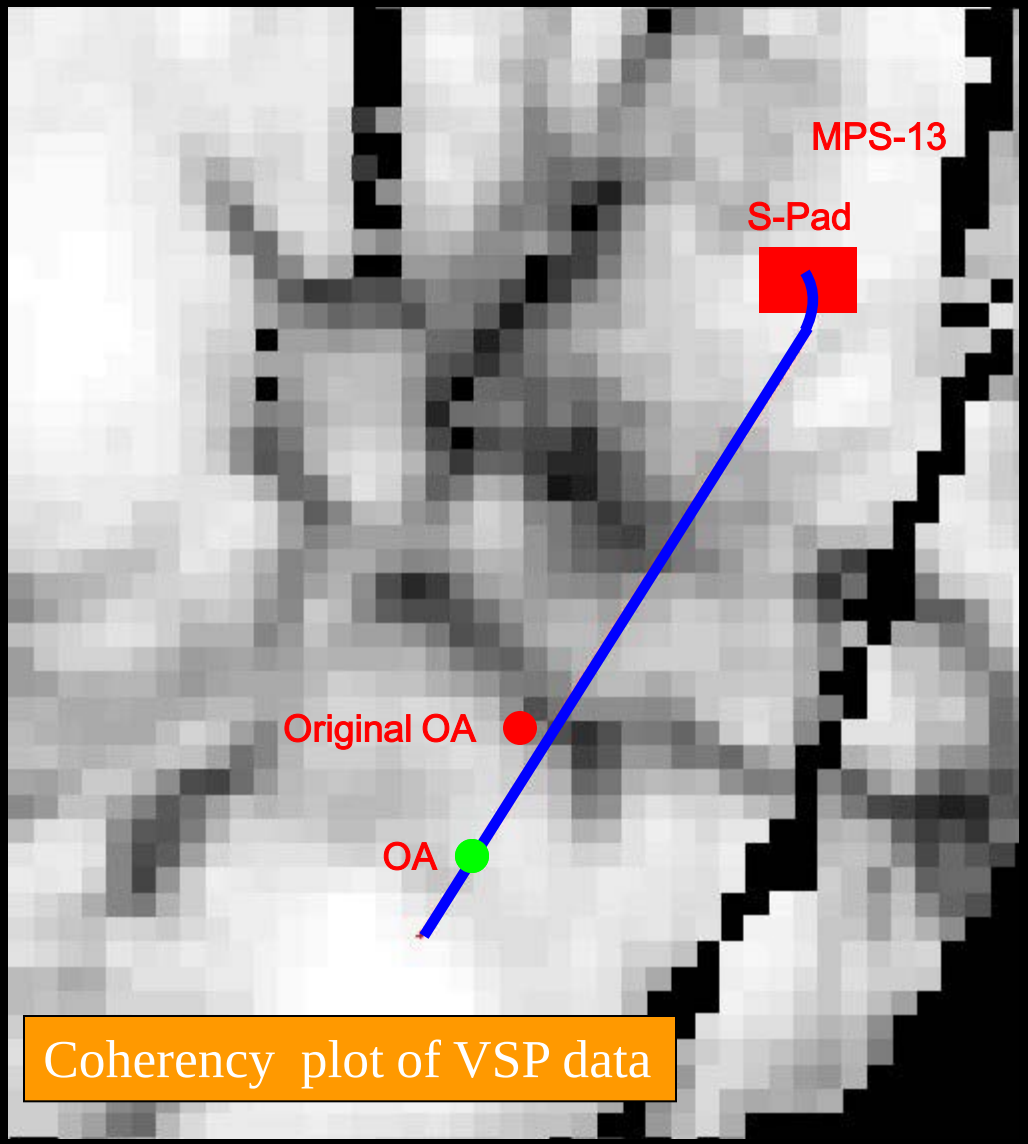
Reprocessed Surface Seismic



Preliminary 3D VSP



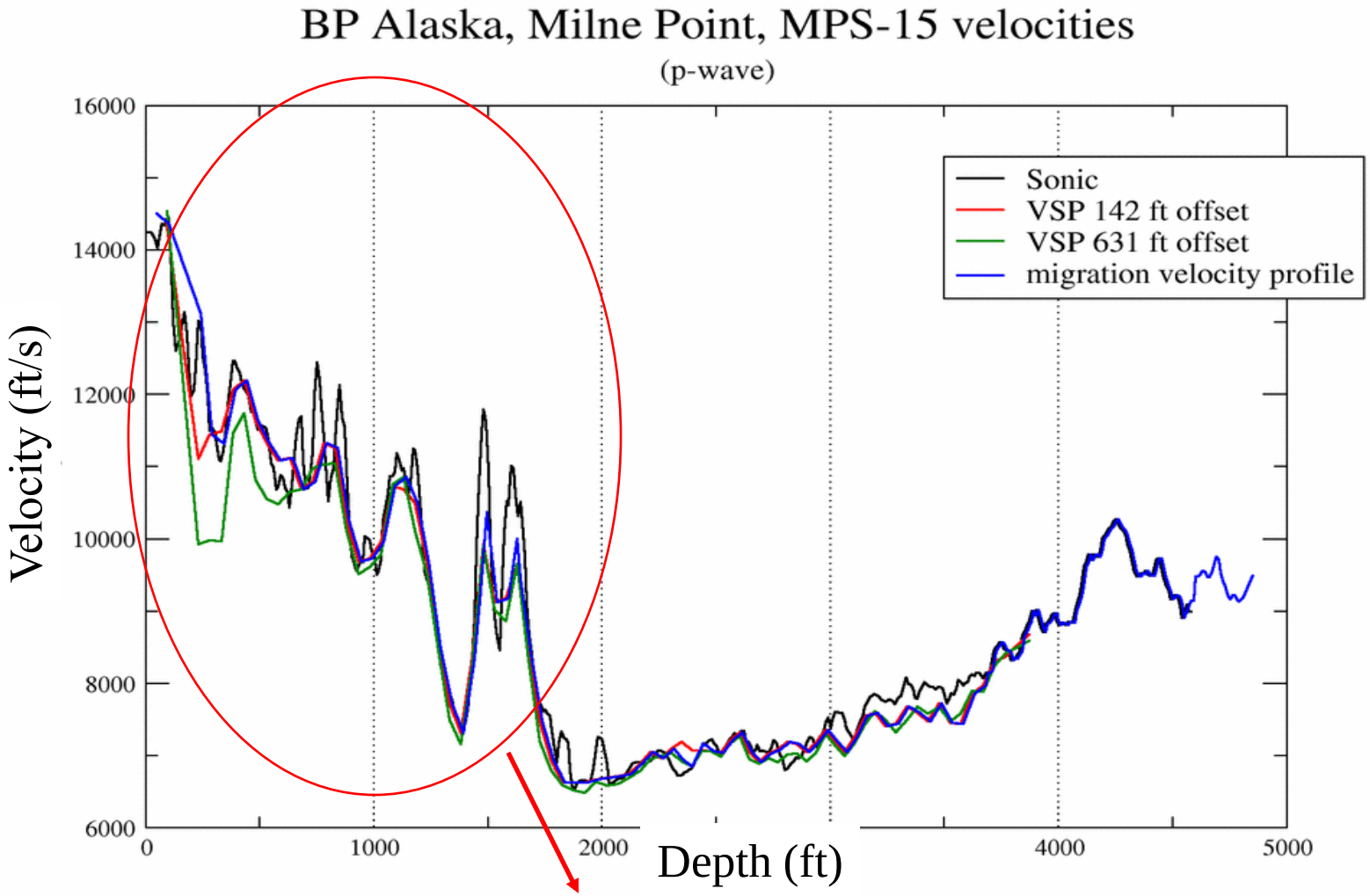
Well Planning Impact



- The MPS13 injection well was moved 400 ft to the SW avoiding a faulted zone.

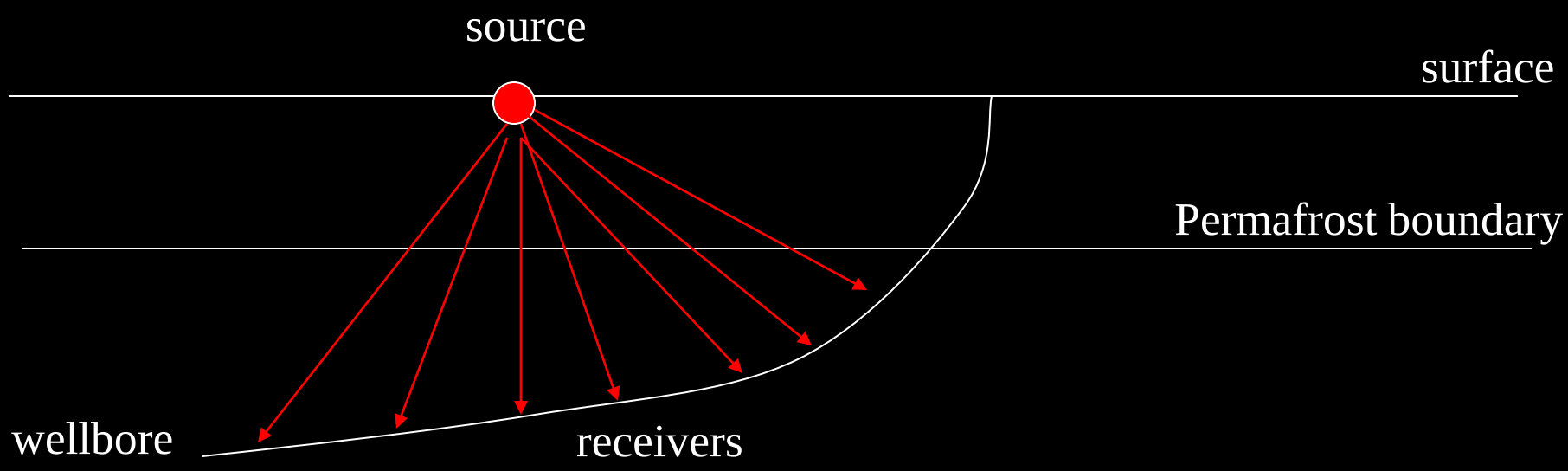
Velocity issues

Correlation between sonic data, offset VSP's and 1D migration velocity

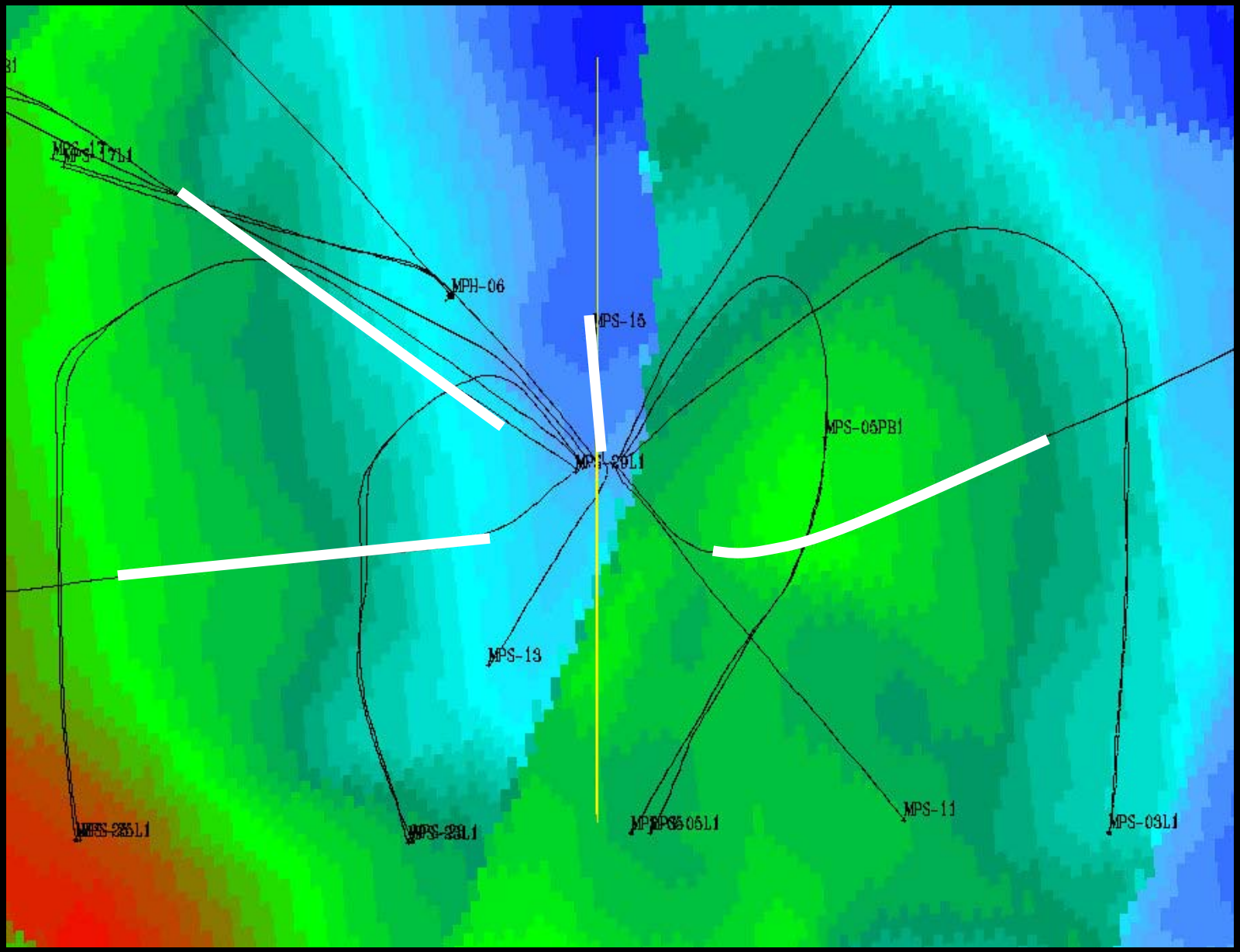


First Break Tomography

- Direct arrivals from surface to deviated wellbores are used to determine local shallow velocity variations



North – South example line through center of S-pad



Depth

-4350

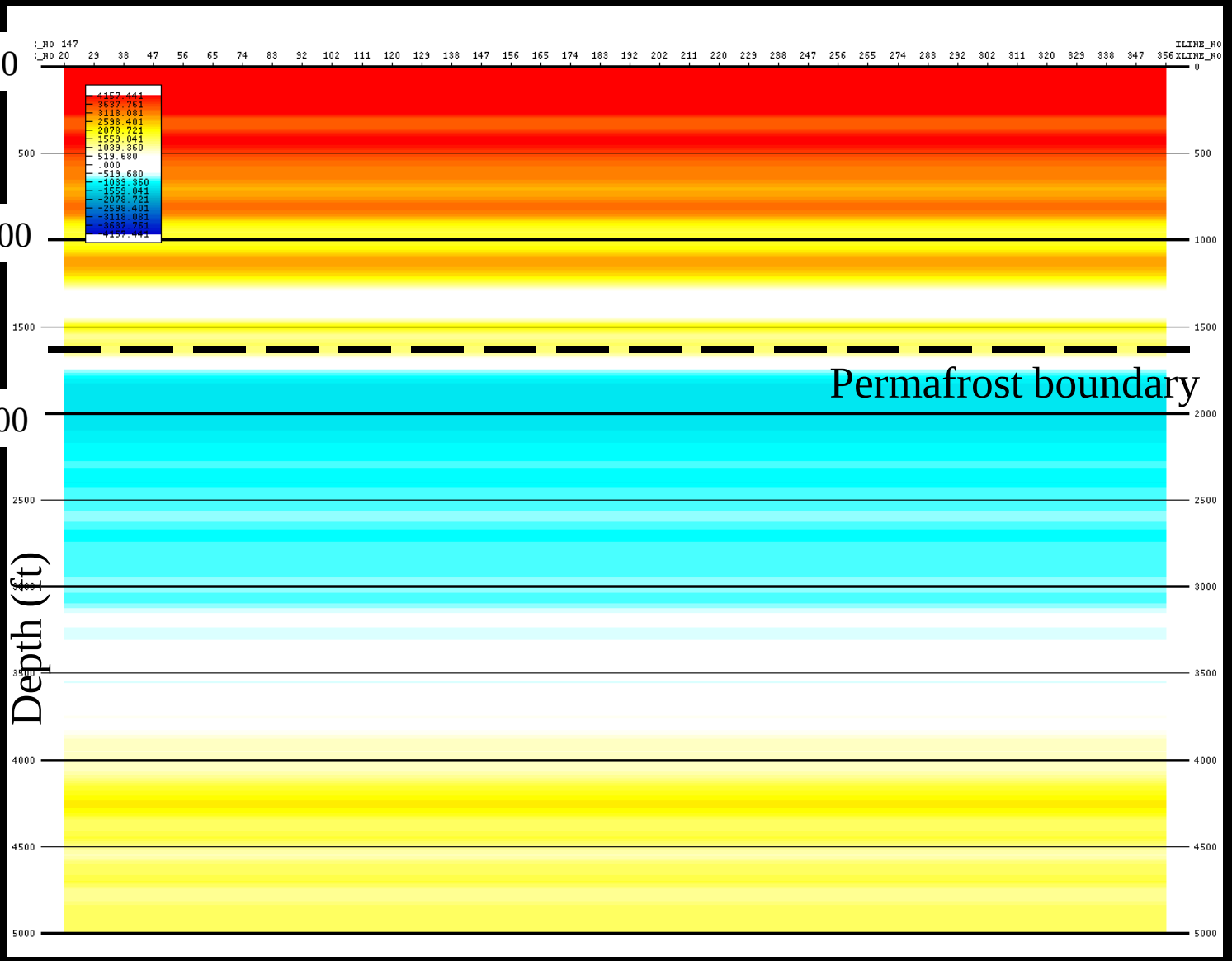
-4150

-4050

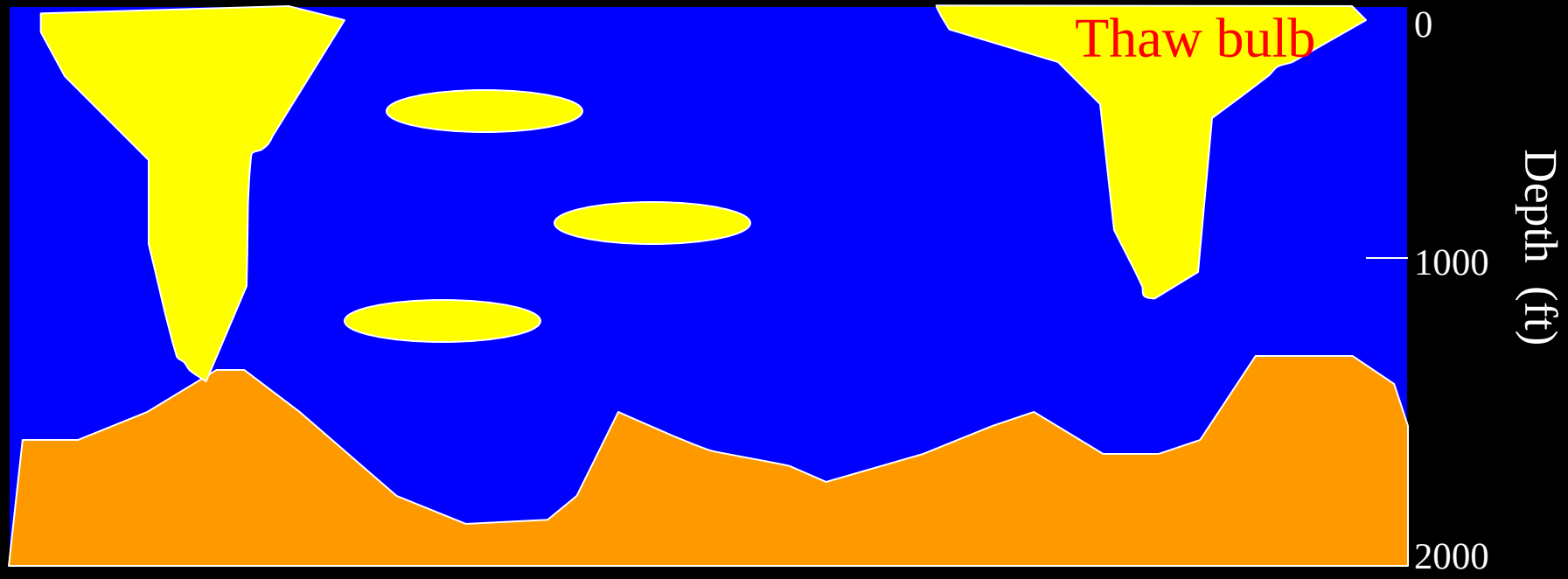
-3950

¼ mile

Original 1D velocity model



What does the permafrost really look like?

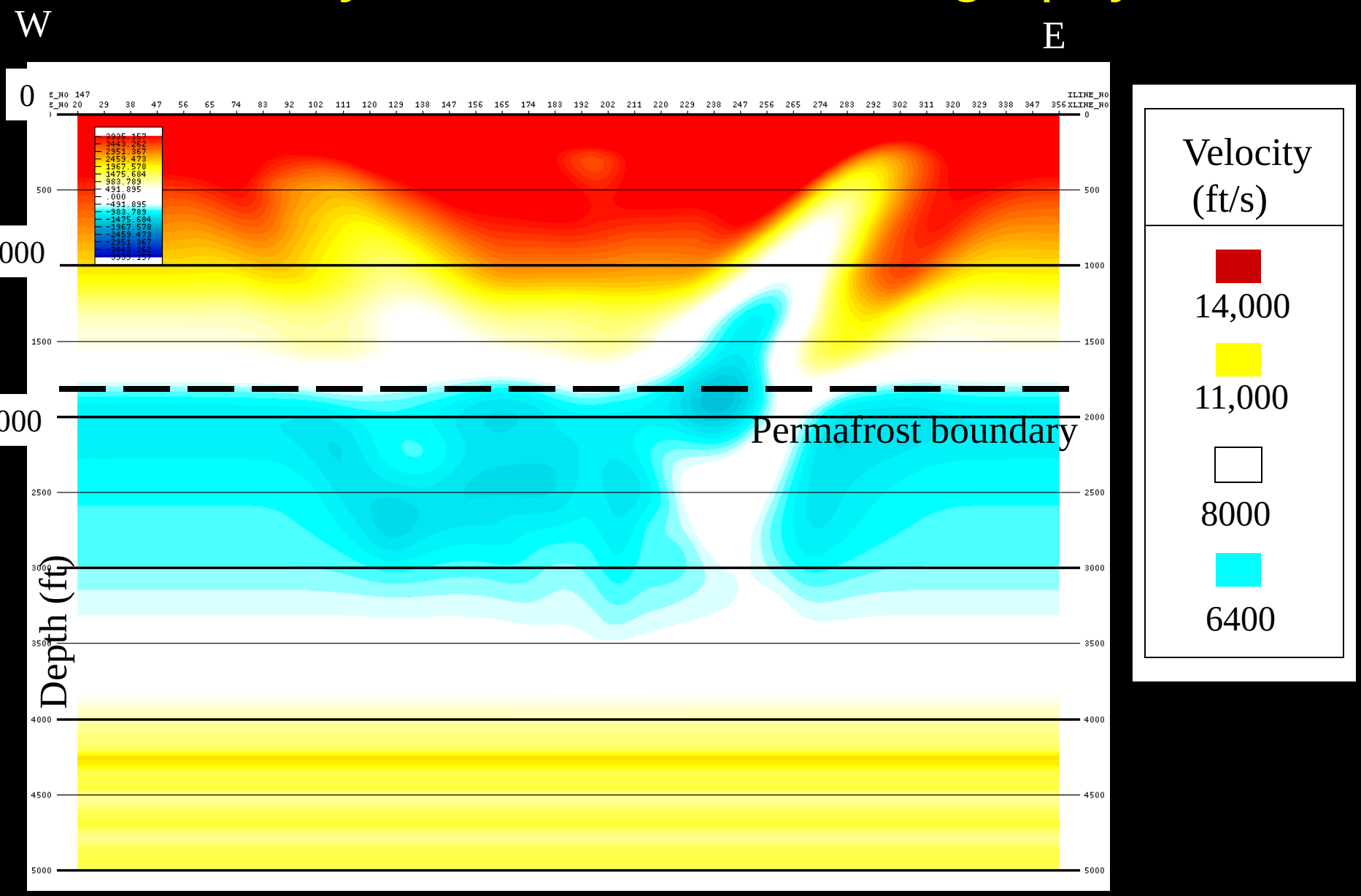


11,000 – 15,000 ft/s

6000 – 9000 ft/s

7500 ft/s

3D velocity model from FB tomography



Conclusions

- VSP data supported first phase of field development.
- No sidetracks were required.
- Production started Sept. 1, 2002 with 8000 bopd.
- VSP data provides twice the frequency of surface seismic.
- First break tomography identifies permafrost velocity variations.
- Processing is ongoing and survey will be used for reservoir management and identification of deeper Kuparak targets.

Acknowledgements

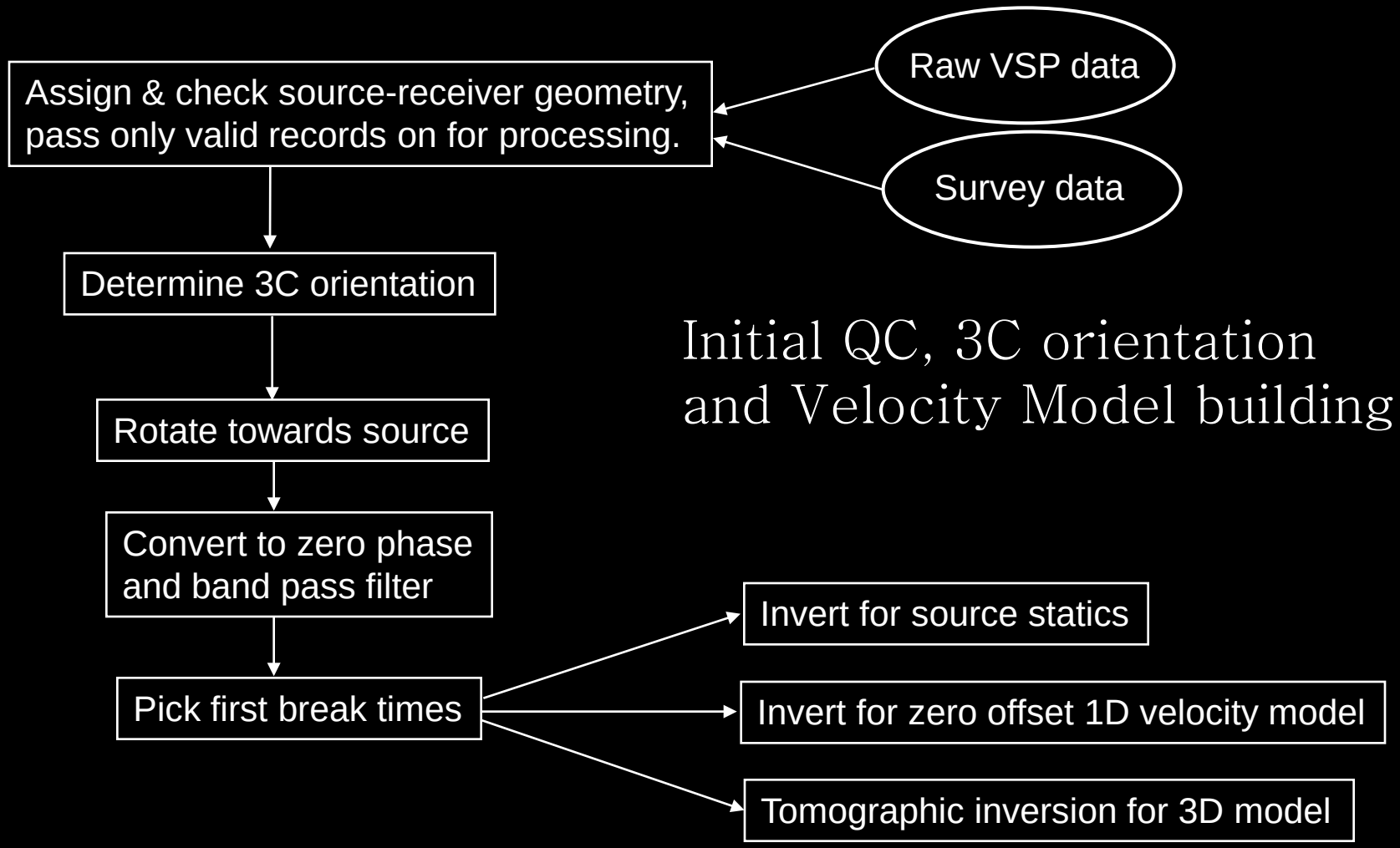
Thanks to the S-pad development team, BP Exploration Alaska, for the opportunity to work on and present this project.

Thanks to Grunde Ronholt, READ Well Services, Sue Raikes, BP Sunbury, and Jonathon Woolley, a summer intern from the Colorado School of Mines. Trace Geophysical recorded the data.

Equipment used for this survey was funded under a DOE grant, # DE-FC26-01NT41234.

Back-up slides

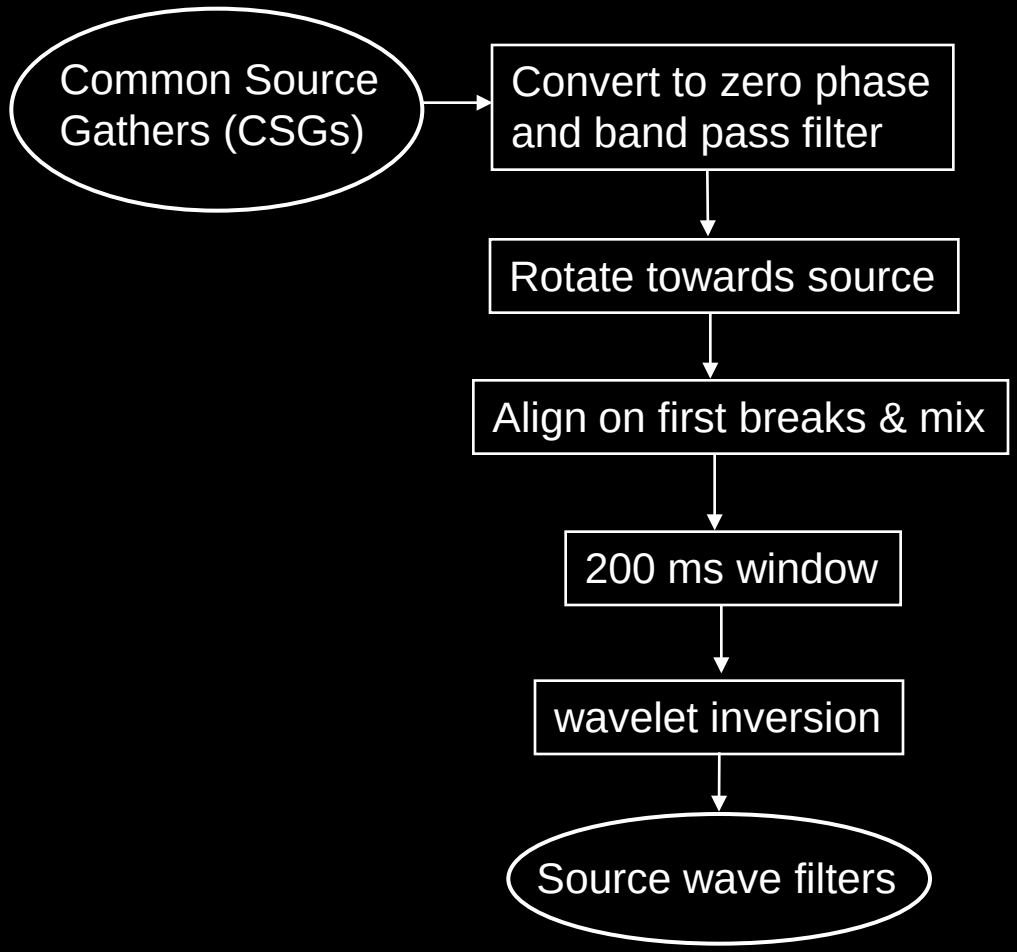
Data processing sequence (1):



Initial QC, 3C orientation and Velocity Model building

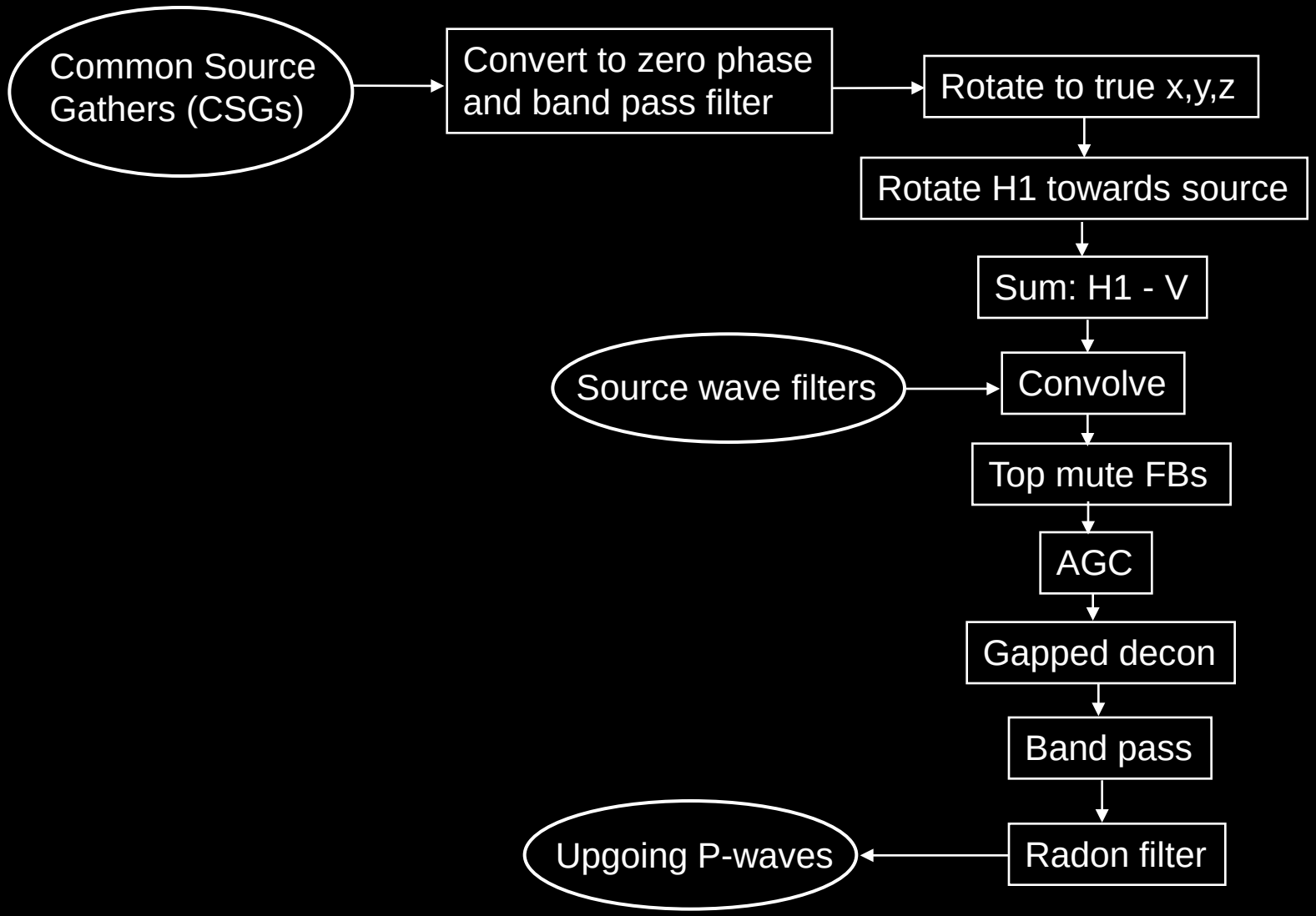
Data processing sequence (2):

Create source wavelet inversion filters



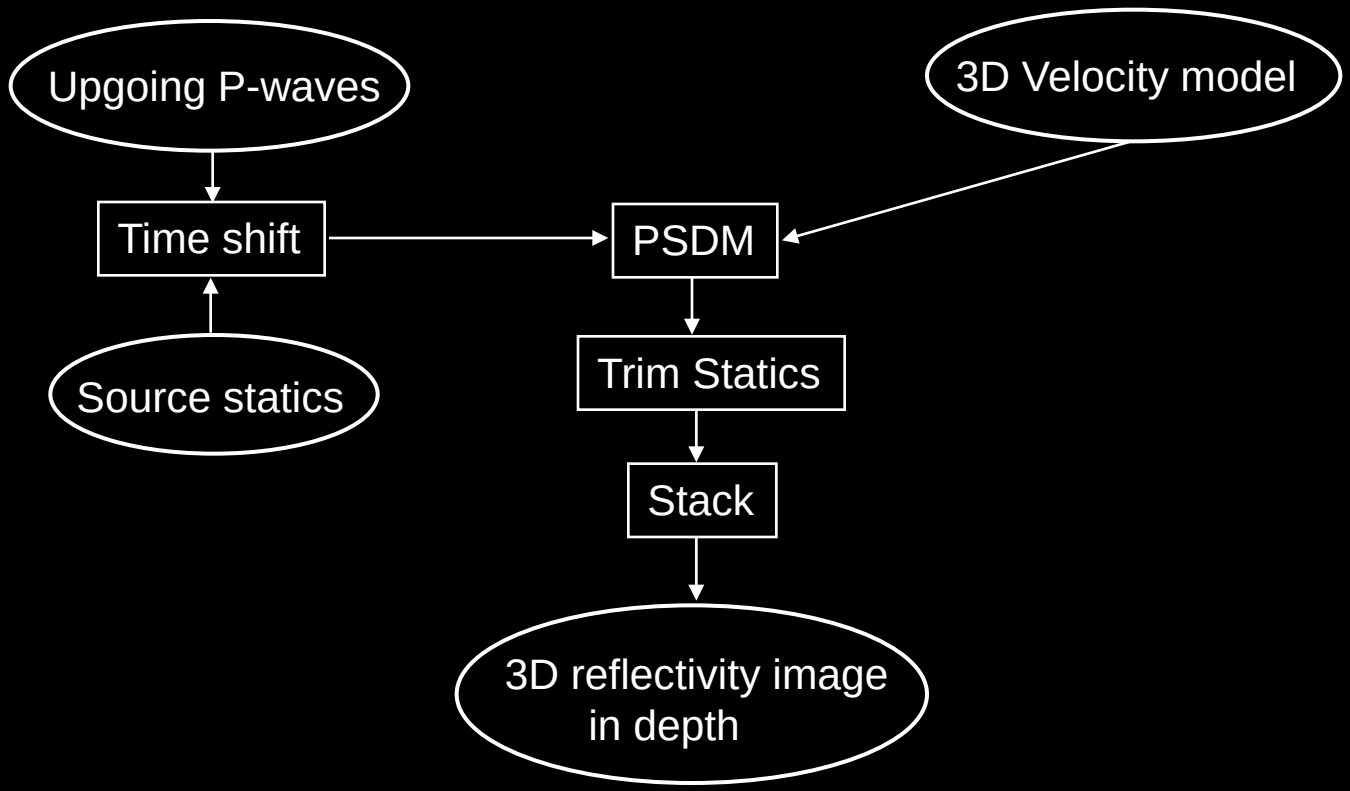
Data processing sequence (3):

3C upgoing wavefield separation



Data processing sequence (4):

Prestack Depth Migration & Stacking

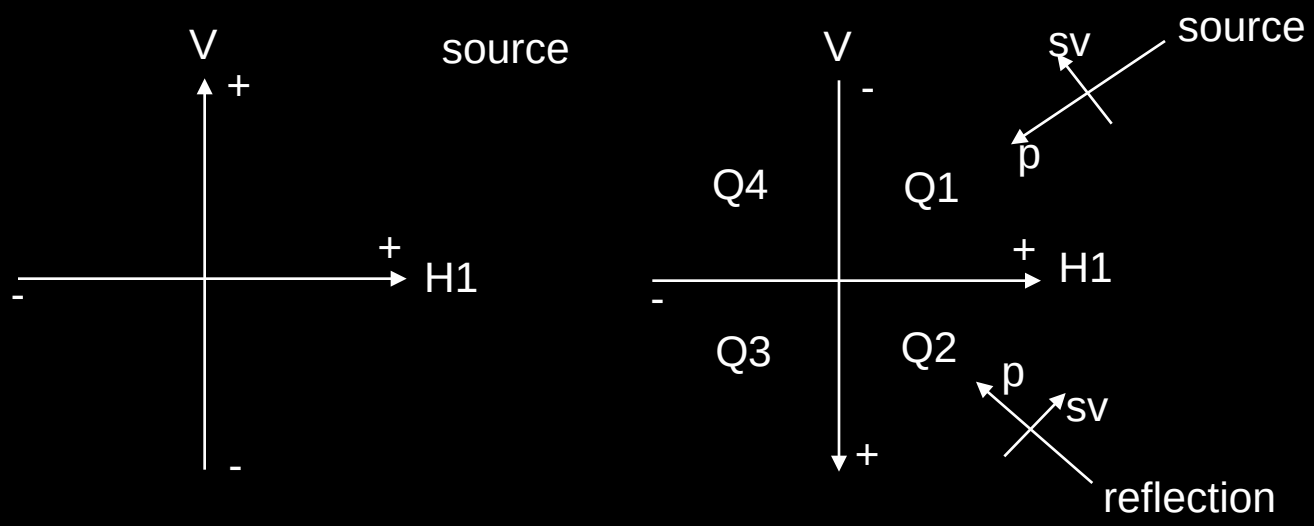


Multi component summing:

1) Rotate H1 (azimuth only) towards source

2) Reverse V polarity

3) Sum: -V + H1

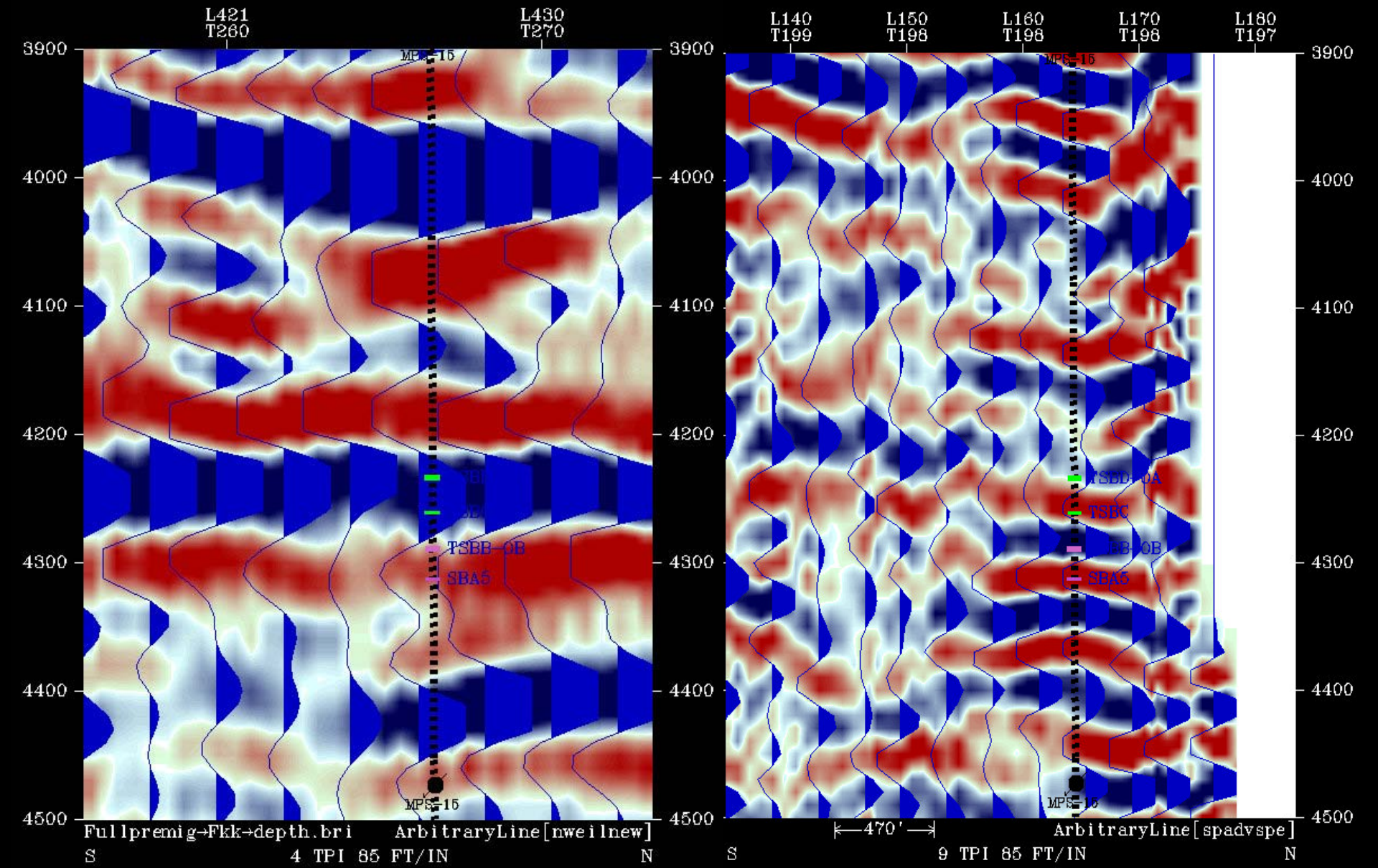


Results:

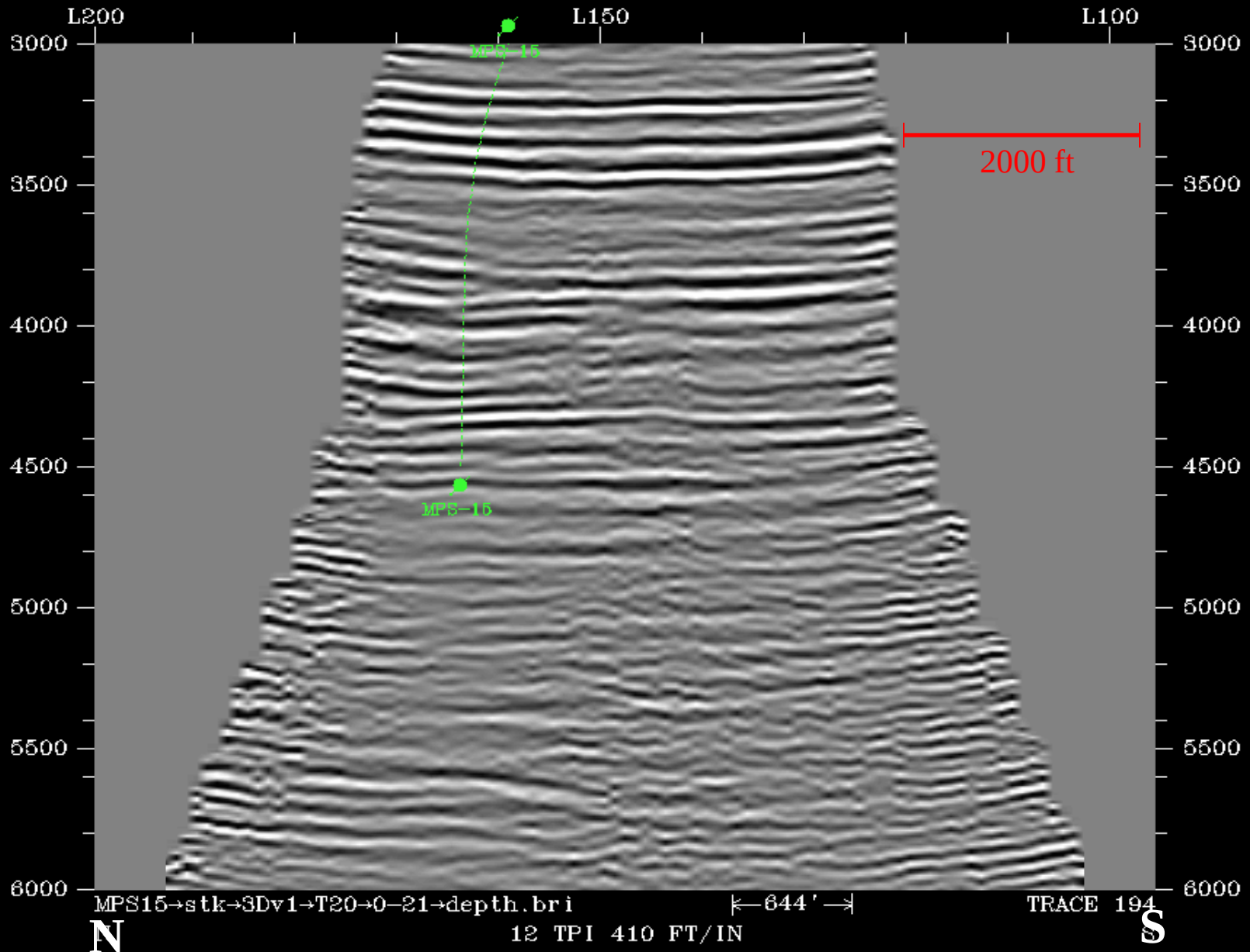
- Downgoing p-waves are attenuated with a dipole response in the Q1 quadrant.
- Downgoing s-waves are amplified with an isotropic response in the Q1 quadrant.
- Upgoing p-waves are amplified with an isotropic response in the Q2 quadrant.
- Upgoing s-waves are attenuated with a dipole response in the Q2 quadrant.

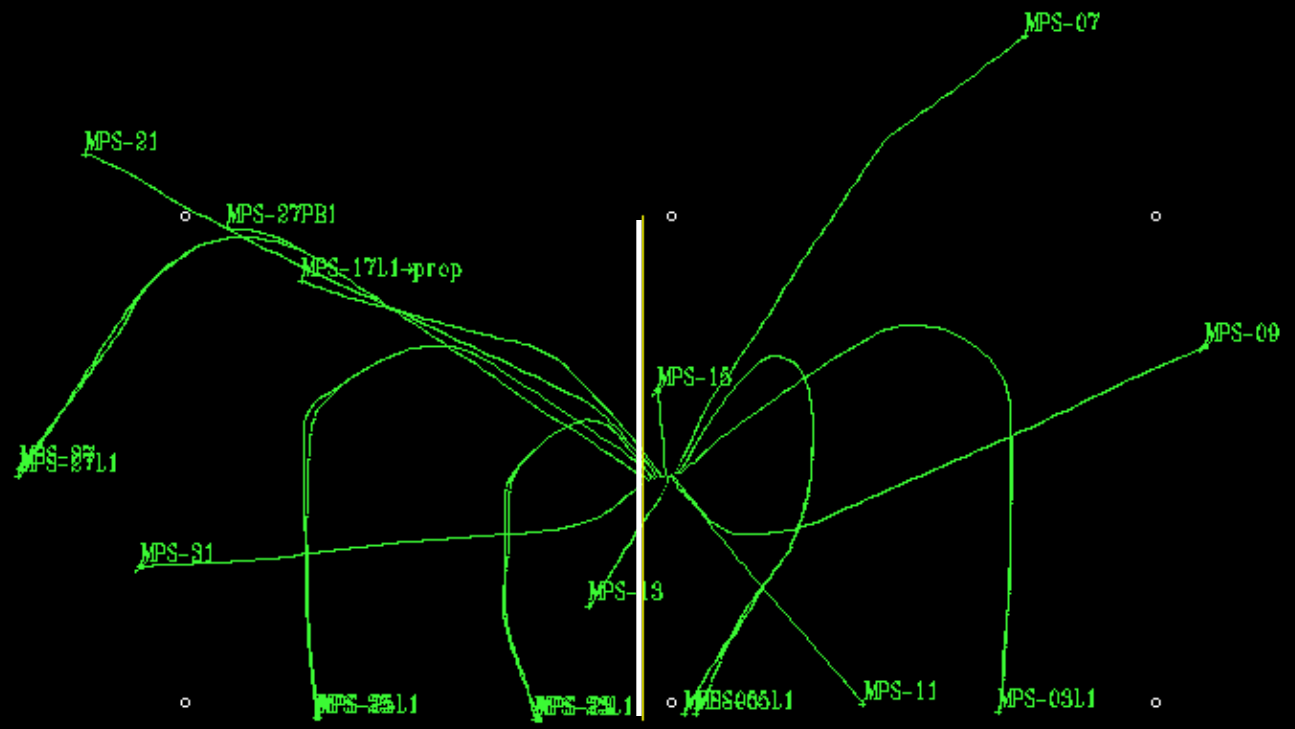
Reprocessed Surface Seismic

Preliminary VSP



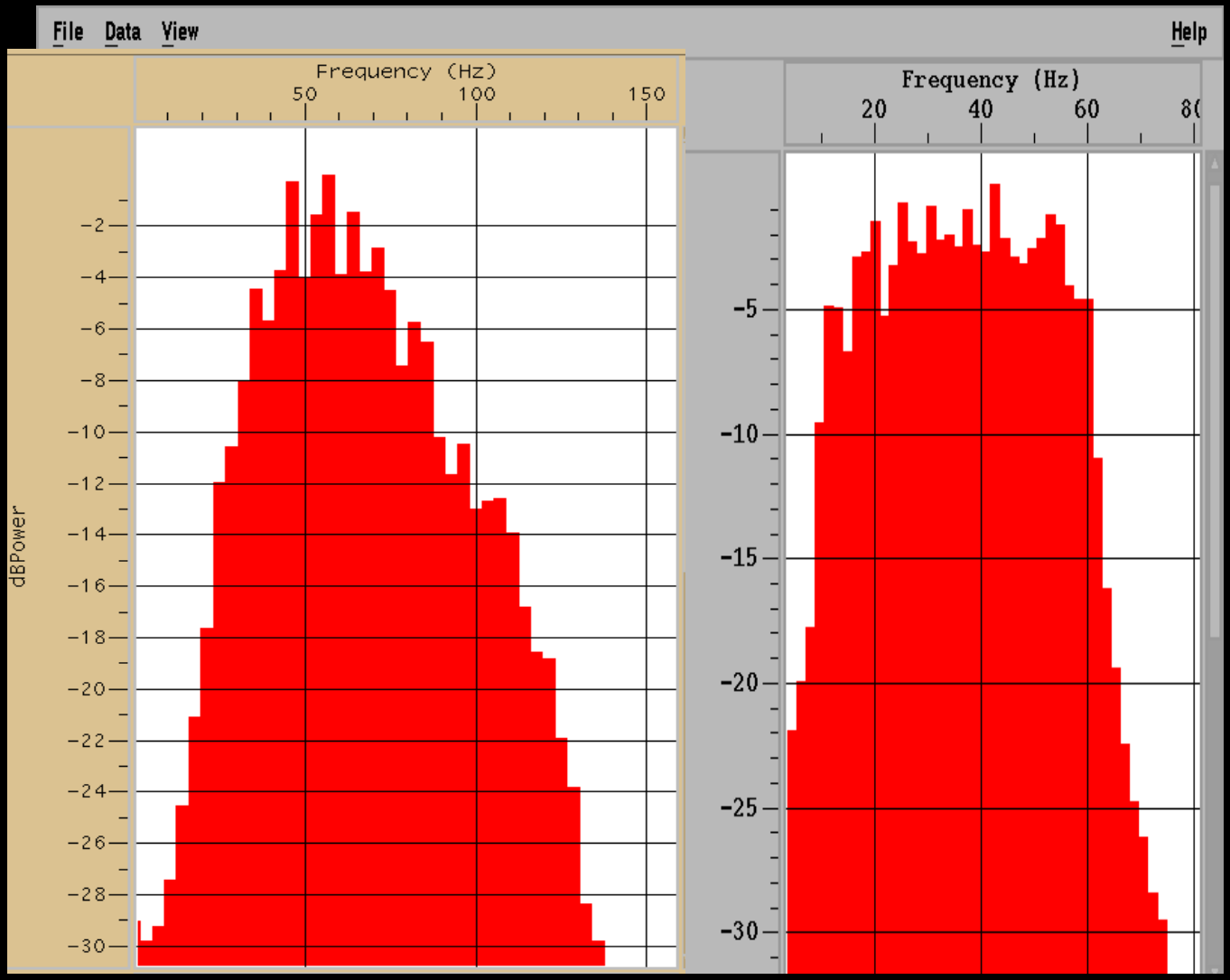
N-S line from MPS15 volume: preliminary 3D velocity model





North – South example line through center of S-pad

Frequency spectrum



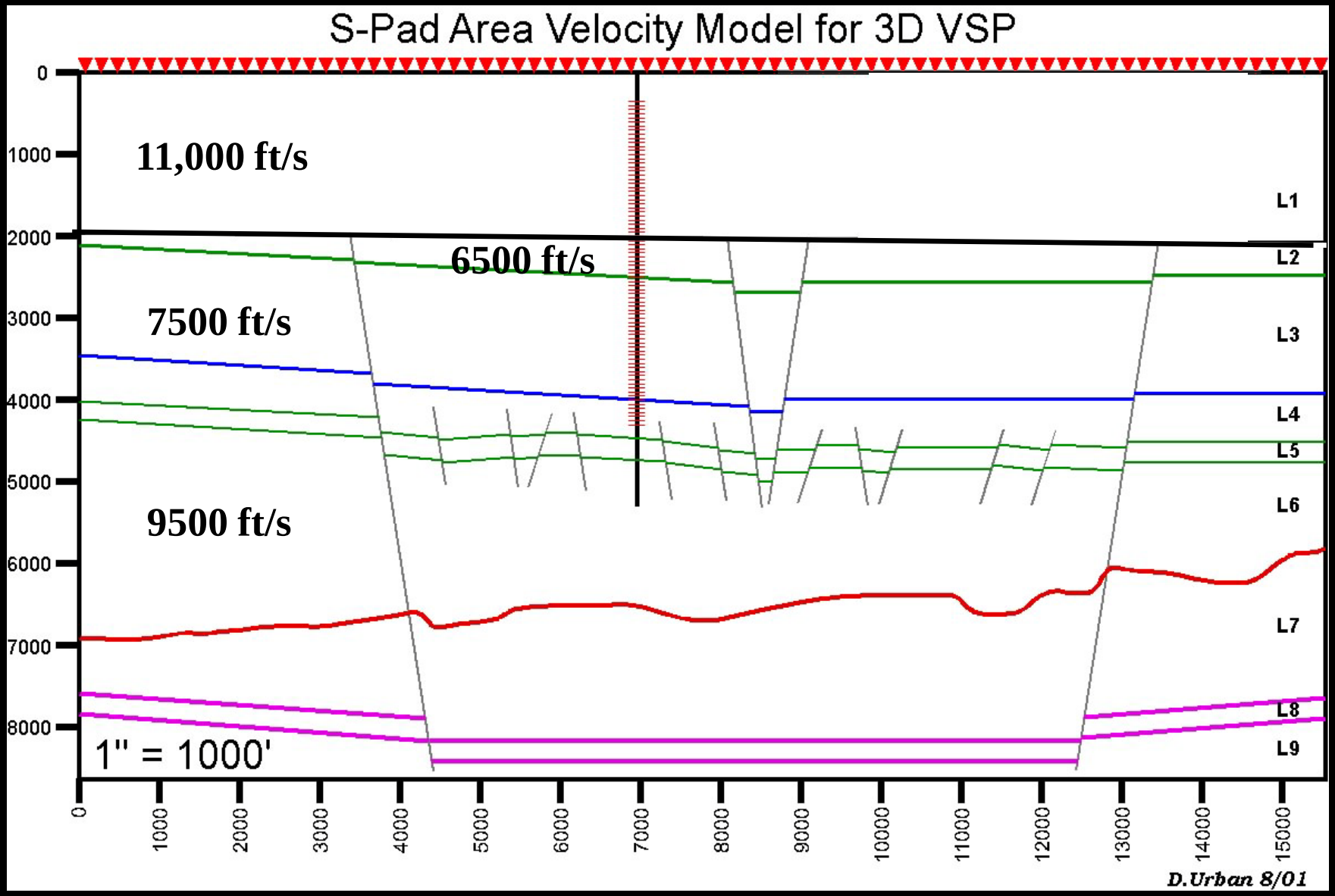
VSP

20-125 Hz (-20dB)

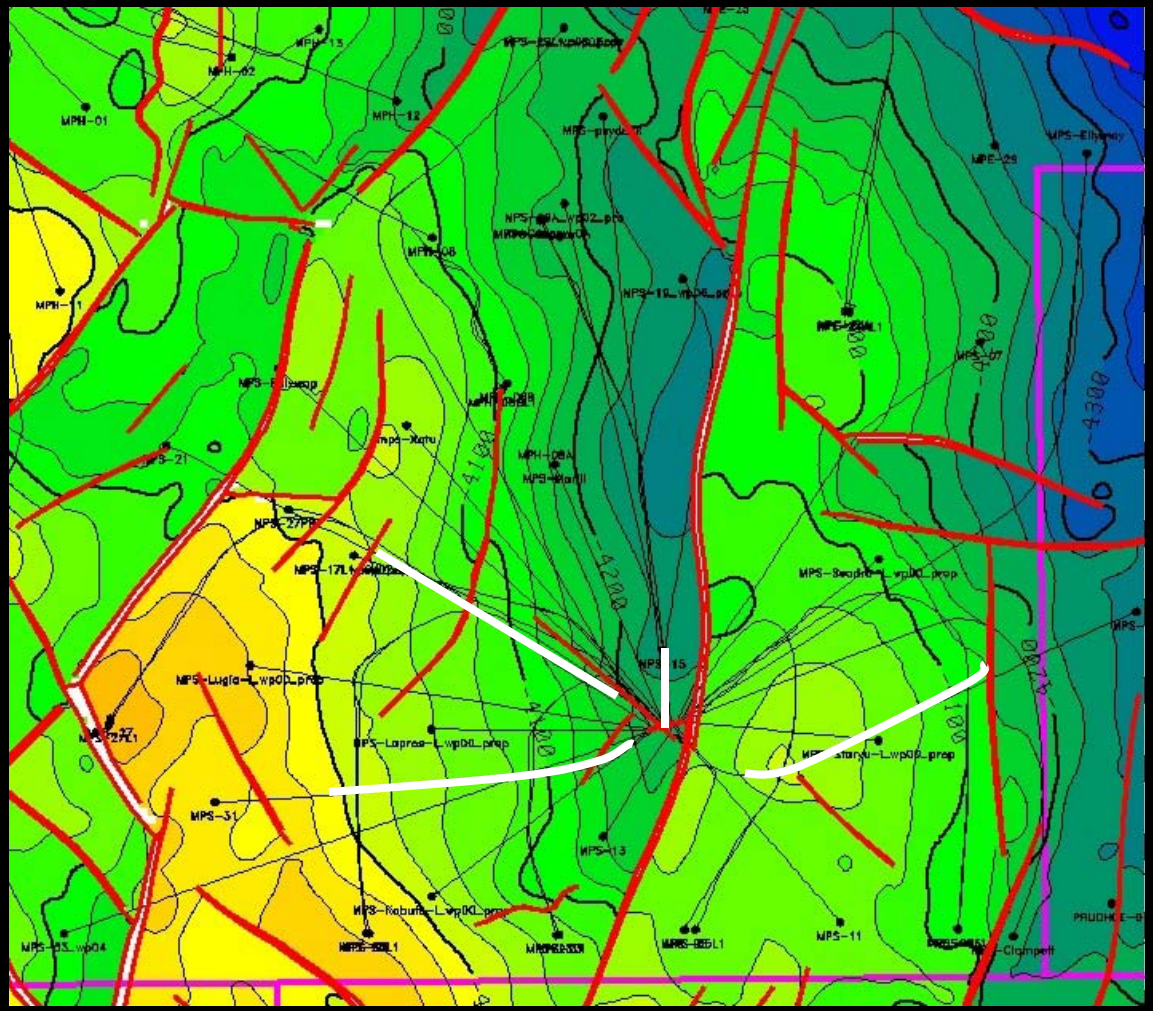
Surface Seismic

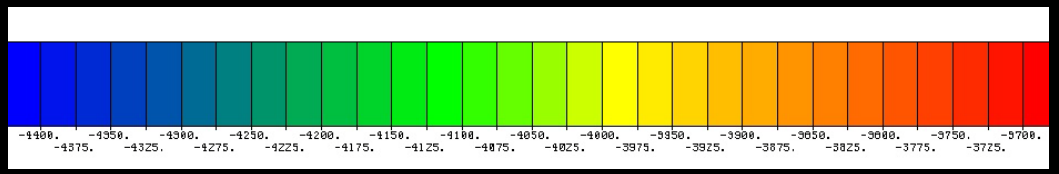
10-65 Hz (-20dB)

Velocity model



Schrader Bluff Structure Map





-4300 -4000 -3700

The central well in the VSP program is located in a narrow graben. It is the only well in the area with log data.

The velocities are anomalous at this well.

Original 1D velocity model was based on zero offset VSP at this well.

1 mile