

Overview of the Violet Grove CO₂ seismic monitoring project

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Background

- Alberta Department of Energy (ADOE) instituted a Royalty Credit Program (2004)
- Royalty reduction for using CO₂ in enhanced oil recovery
- UofC [CREWES] developed seismic monitoring program for one site.

CO₂ EOR sites

- Apache at Zama
- Devon Energy at Swan Hills
- Penn West at Pembina
- Anadarko at Enchants



October, 2005

Province touts \$1.5B CO₂ pipeline network

CANWEST NEWS SERVICE
AND THE CANADIAN PRESS
EDMONTON

Alberta Environment Minister Guy Boutilier said Tuesday the government is planning a massive \$1.5 billion project to establish a province-wide CO₂ pipeline network. The scheme would both revive declining oil wells and keep the greenhouse gas out of the atmosphere.

"It's just huge," Boutilier said. "Once it's captured and stored, then it's actually used as an energy to help actually push up even more oil. It's called enhanced oil recovery."

Although it is unclear how much gas would actually be prevented from going into the atmosphere, the project could help to significantly reduce Alberta's greenhouse gases — which are a target of the international Kyoto accord.

Boutilier stressed that the project is still in early stages, but he hopes funding will come from industry and the federal government as well as the province. Much of the captured CO₂ would come from oilsands emissions.

Successes at a project in Weyburn, Sask. have perhaps prodded Boutilier and the government in this plan. There, carbon dioxide sent 320 kilometres by pipeline from a synthetic fuels plant in Beulah, N.D. has been pumped into the oilfield. This form of CO₂ sequestering forces extra oil from pools where pressure has become too low.

"We're pursuing this aggressively," Boutilier said Tuesday. "I have never been accused of moving slowly."

Alberta Energy estimates that recovering just five per cent more oil would add \$31 billion to the provincial coffers over the life of the resource.

The use of water for enhanced oil recovery is very unpopular in many Alberta communities, and using CO₂ instead for extraction could also be well received in many political constituencies.

It's a win-win situation, says Boutilier, with serious environment benefits along with greater volumes of oil extraction.

"(The CO₂) is not going into the atmosphere, ultimately reducing greenhouse gases even further. It's an important technology."

Elements of a monitoring program

Baseline programs (prior to injection)

- Well analysis, well integrity
- Baseline geology and hydrogeology
- Observation well instrumentation
- Baseline seismic program
- Monitoring wells (groundwater)
- Soil and casing gas
- Core & reservoir fluids analysis
- Rock physics & well log suites

Elements of a monitoring program

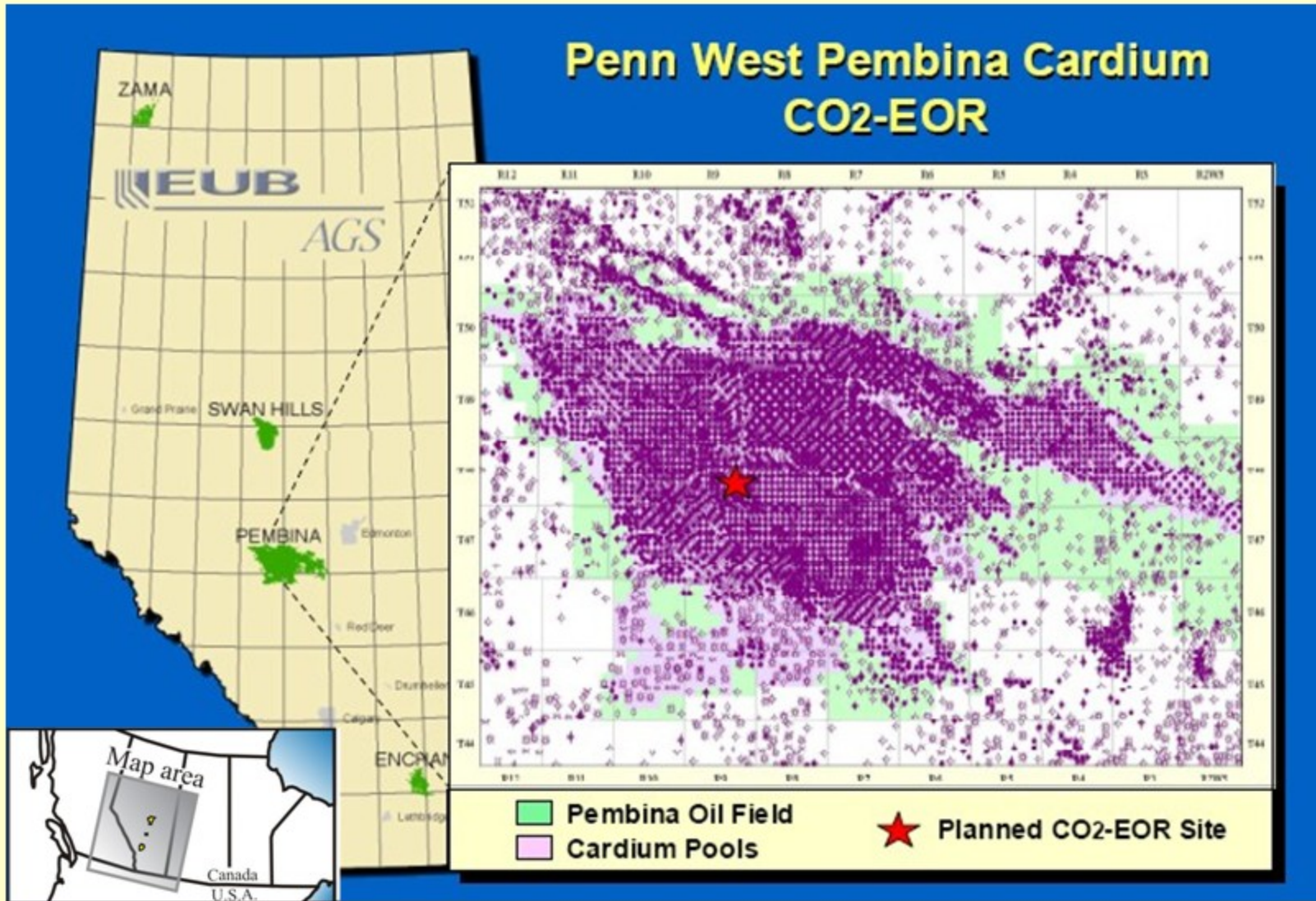
Discrete monitoring

- Timelapse seismic programs
- Timelapse geochemistry (observation and shallow monitor wells)
- Well testing and tracers

Continuous monitoring

- Geochemistry at production wells
- Pressure/temperature at observation well
- Passive seismic program

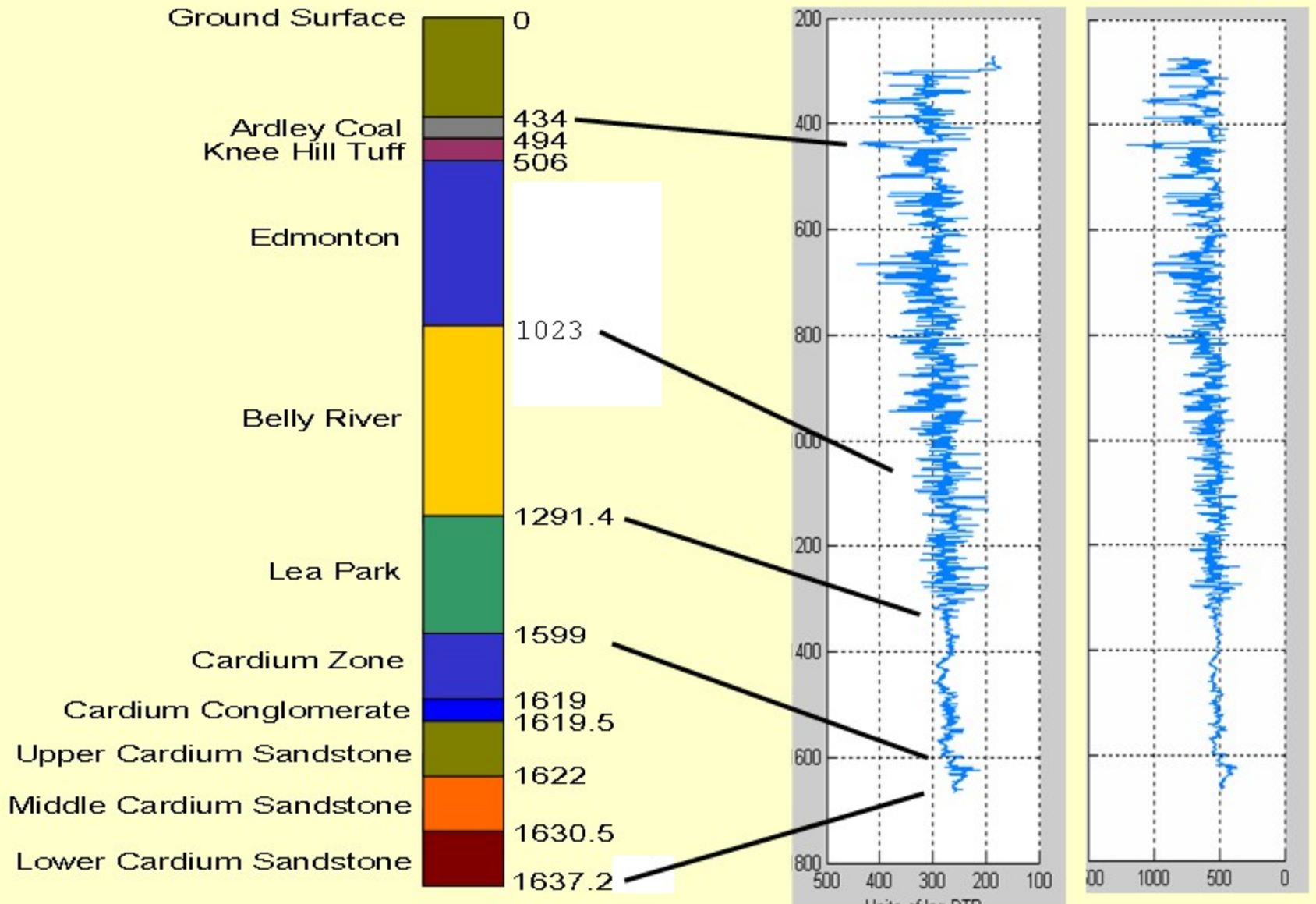
Penn West Petroleum CO₂-EOR Pilot



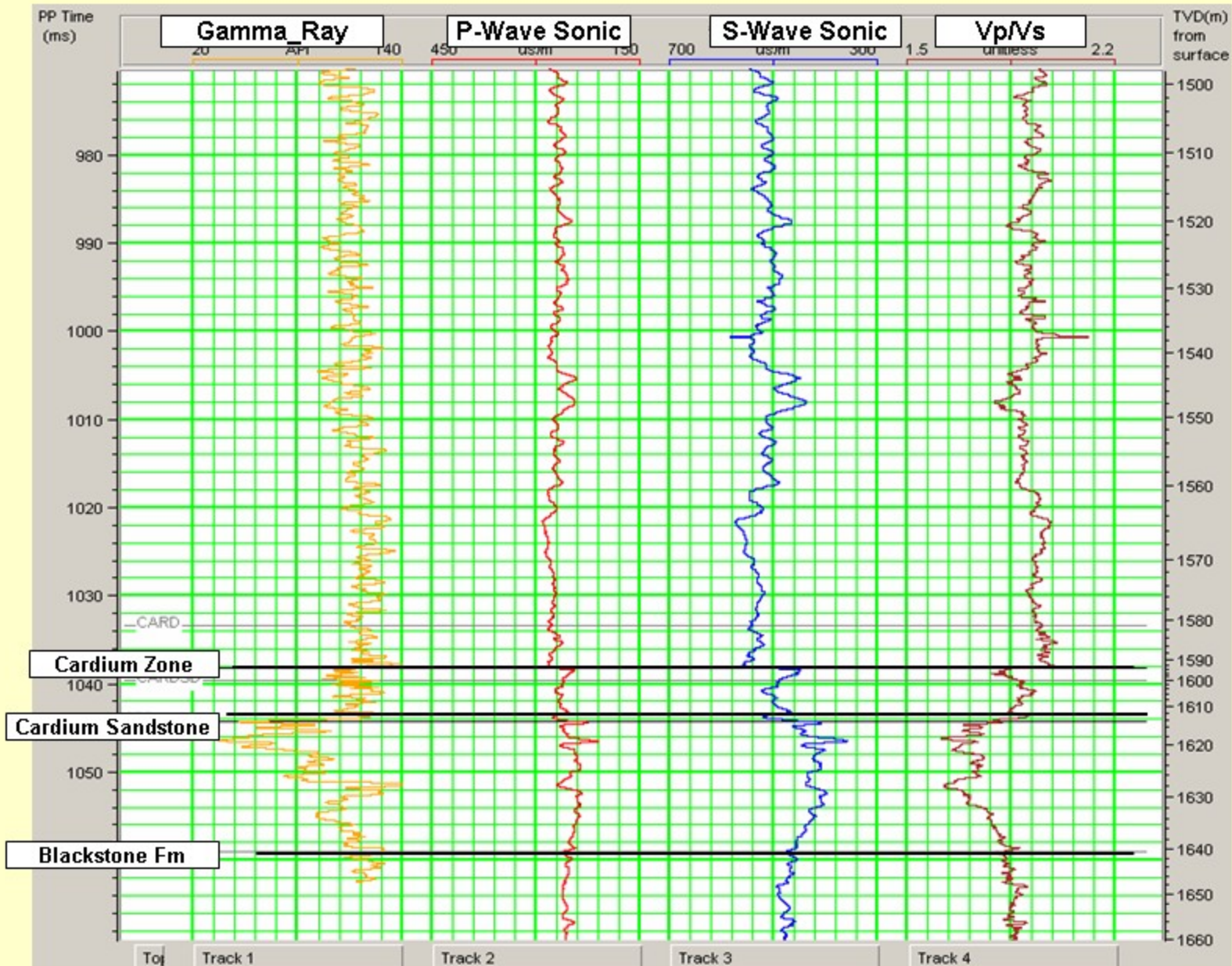
Geology

P-wave sonic

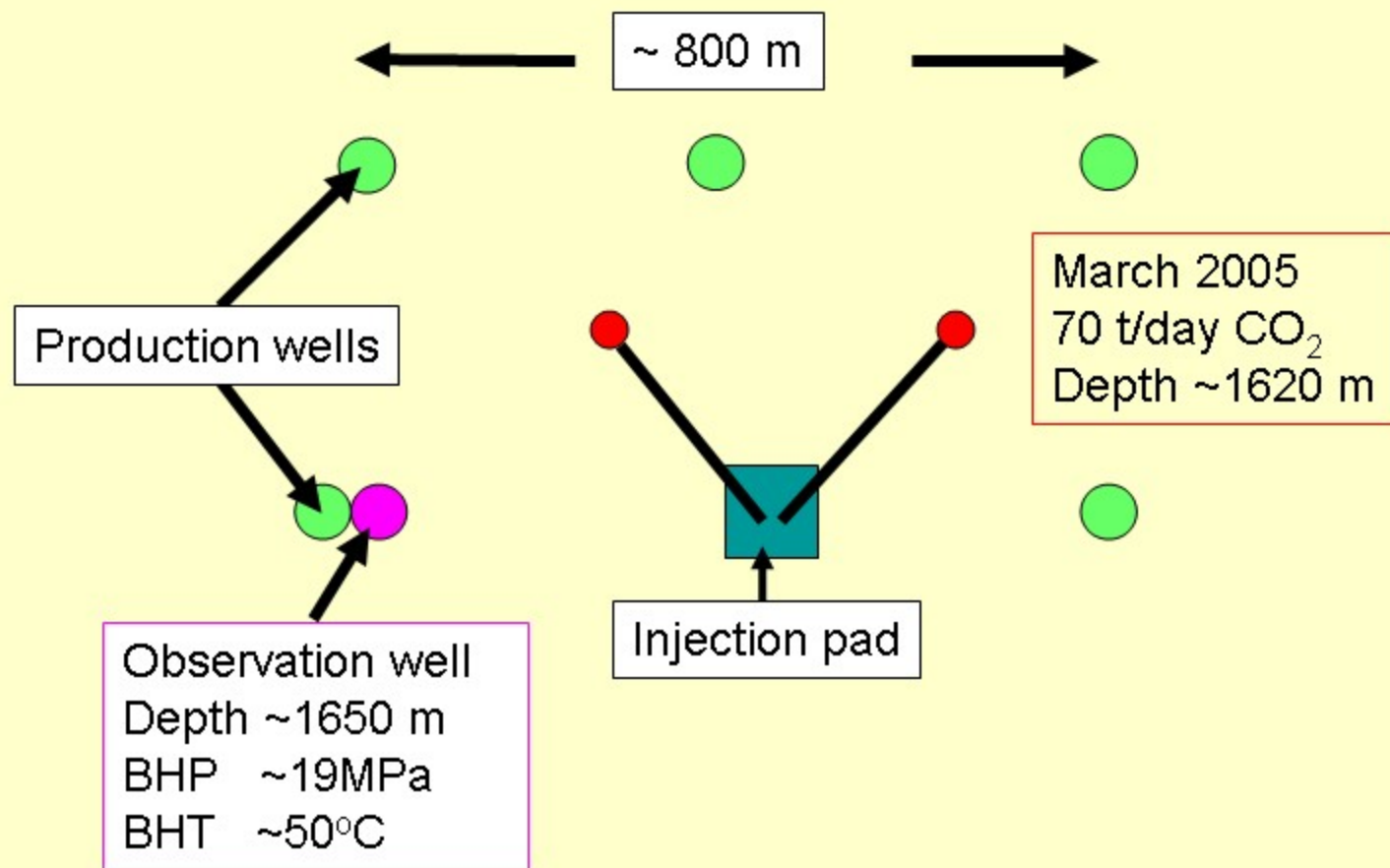
S-wave sonic



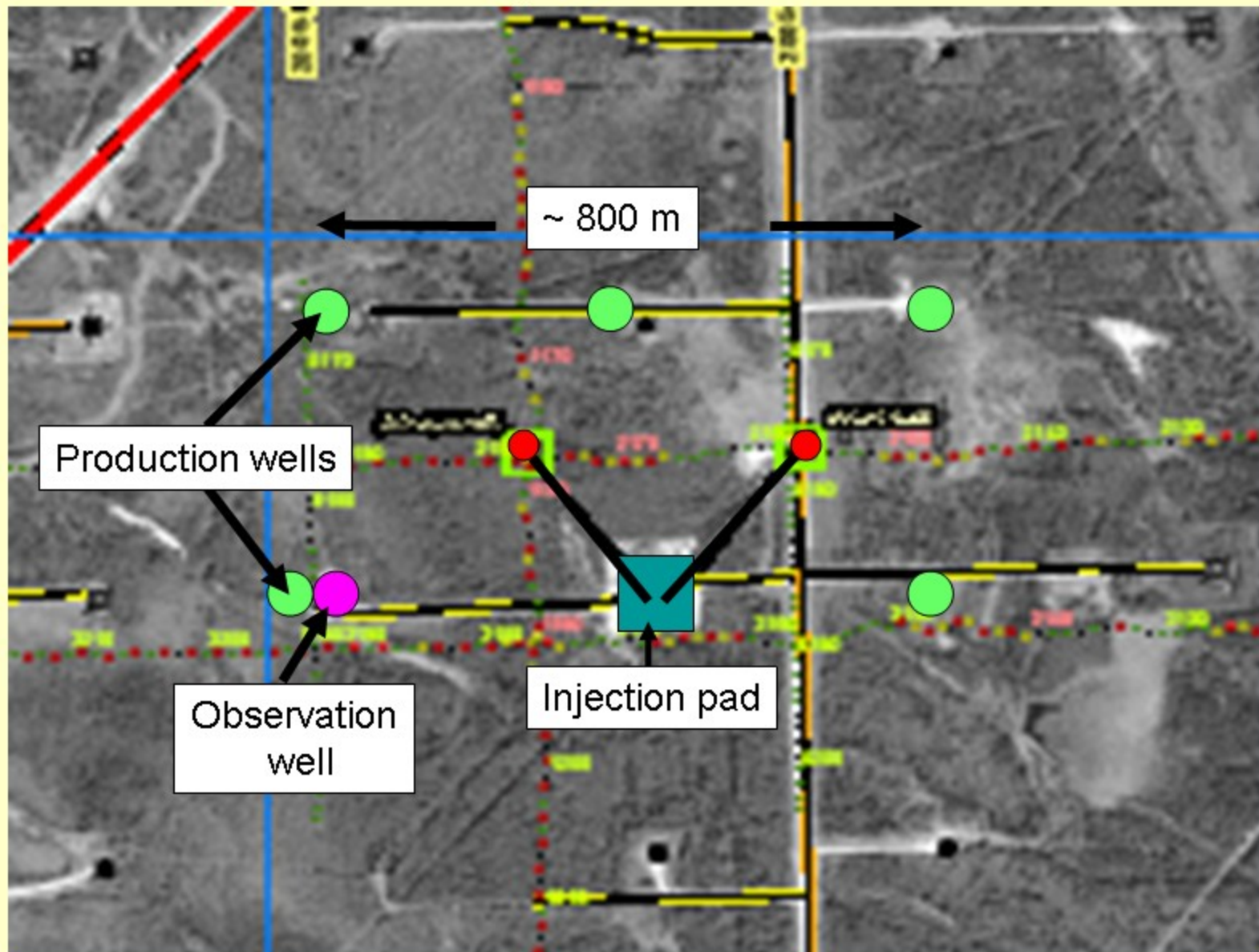
Log suites



Penn West CO₂- EOR injection pilot



Penn West CO₂- EOR injection pilot



Seismic applications in CO₂ storage

GOAL

Reservoir characterization

geometry
impedance ($I = \rho V$)
petrophysical properties
(λ, μ, ρ)



high effort 3D surveys
(expensive)

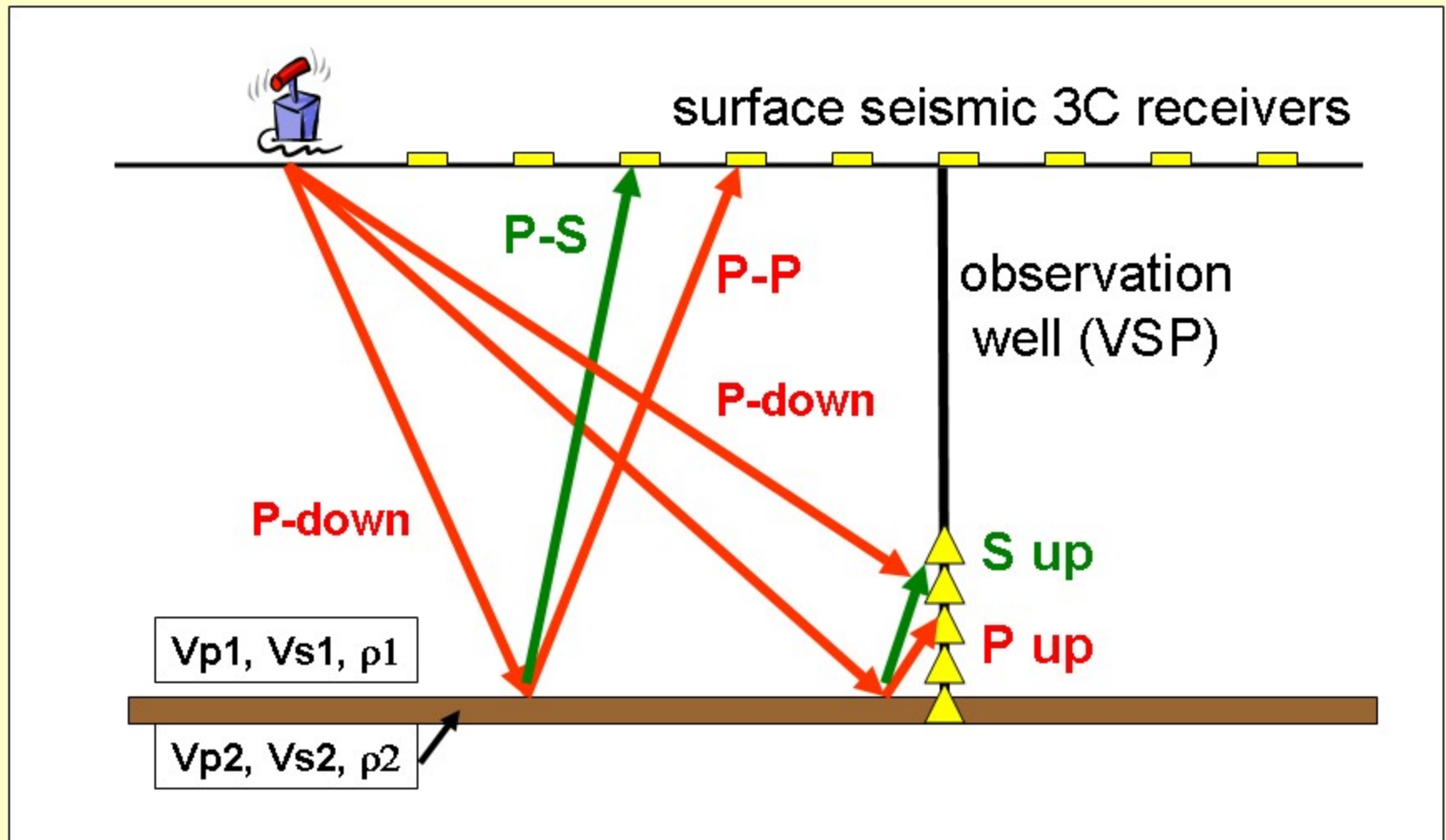
Reservoir monitoring

fluid substitution
pressure changes
 $\Delta I = (\Delta V \Delta \rho)$
 $\Delta \lambda, \Delta \mu, \Delta \rho$



2D, 2.5D or
low effort 3D surveys
(cheaper)

Multicomponent surface seismic and vertical seismic profile (VSP)



Geology and well completion

2 downhole fluid sampling ports

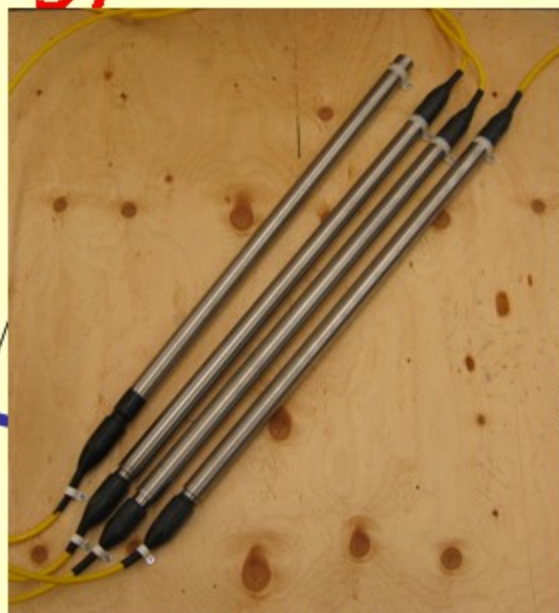
8 geophone nodes at 20m

3 pairs pressure/temperature gauges

Ground Surface 0

Ardley Coal
Knee Hill Tuff
Edmonton

434
494
555
1023



on for Obs Well (1007-11-48-9W5)

ing tubing, gauges, and
run to surface. From surface to
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on strapped to 2" tubing string.

op at

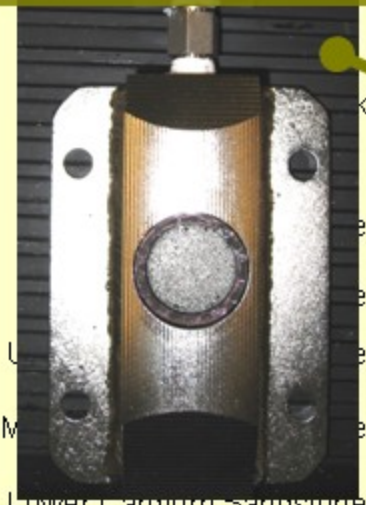
g Port #1
Port located within
rk zones where
%



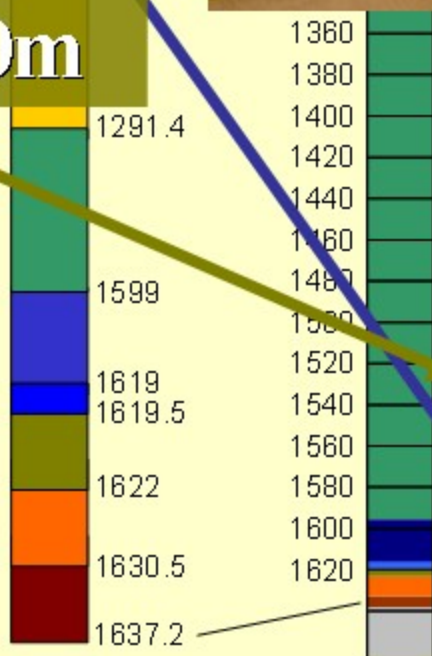
Two (2) pressure gauges at 1702



Two (2) pressure/temp. gauges at 1610 mD. In the middle of the Cardium Zone.



Lower Cardium Sandstone



8 Geophone String. Bottom phone at 1640 mD and phone spacing is 20 m.

Fluid Sampling Port #2 at 1622 mD. Port located within Upper/Middle Cardium SST

Two (2) pressure/temp. gauges at 1621 mD.







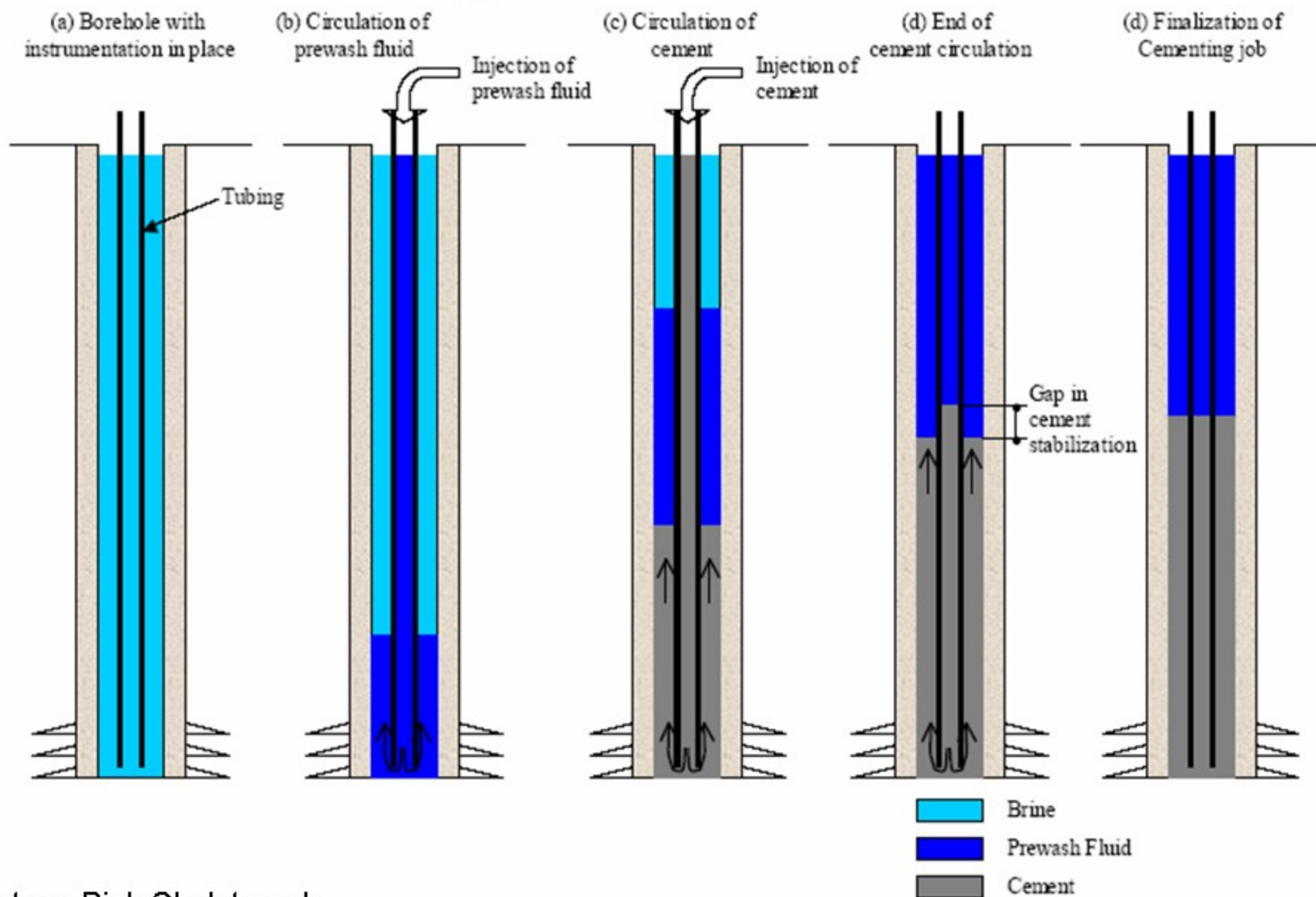


BRANDETTE

72 hours later



Cementing the Observation Well



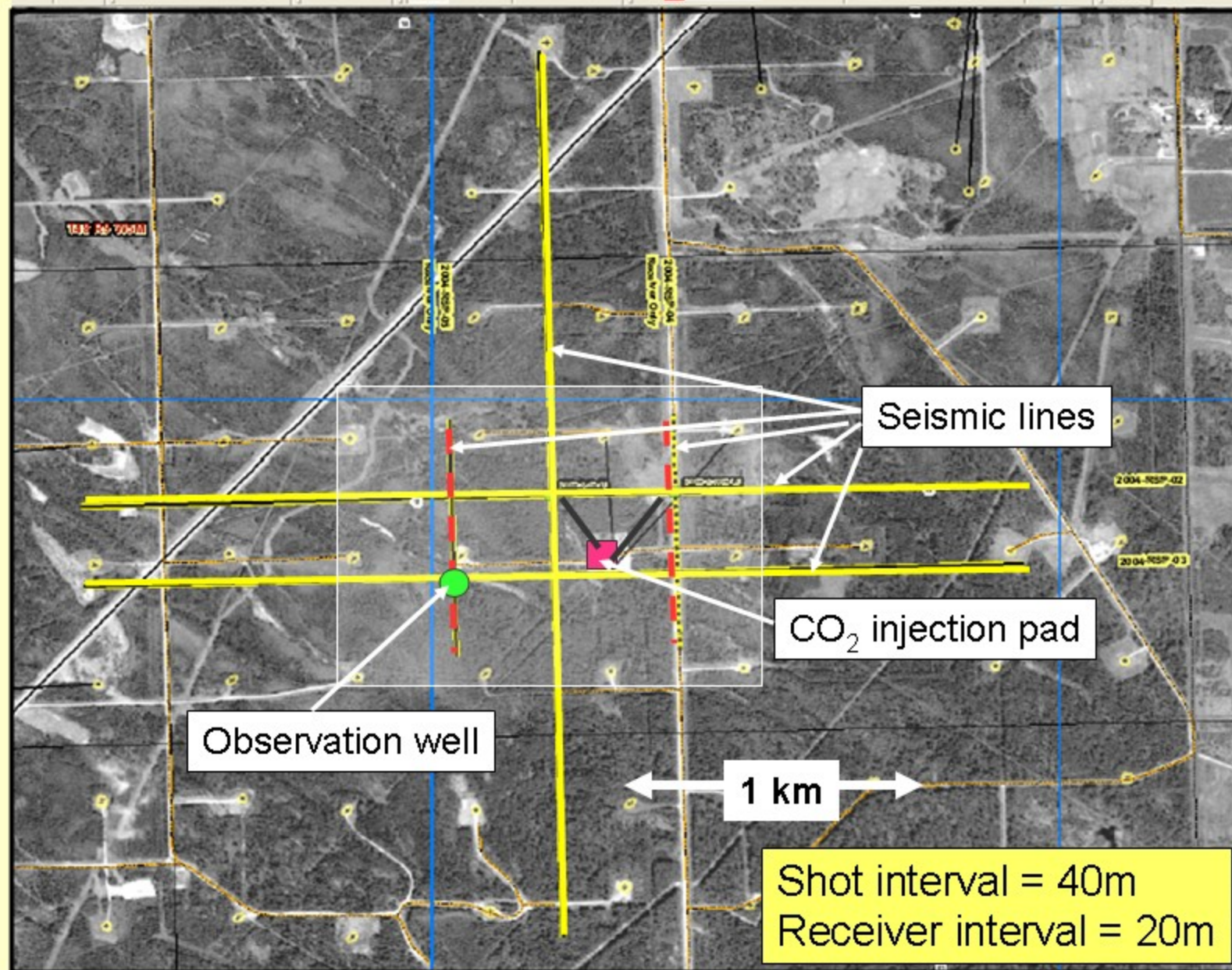




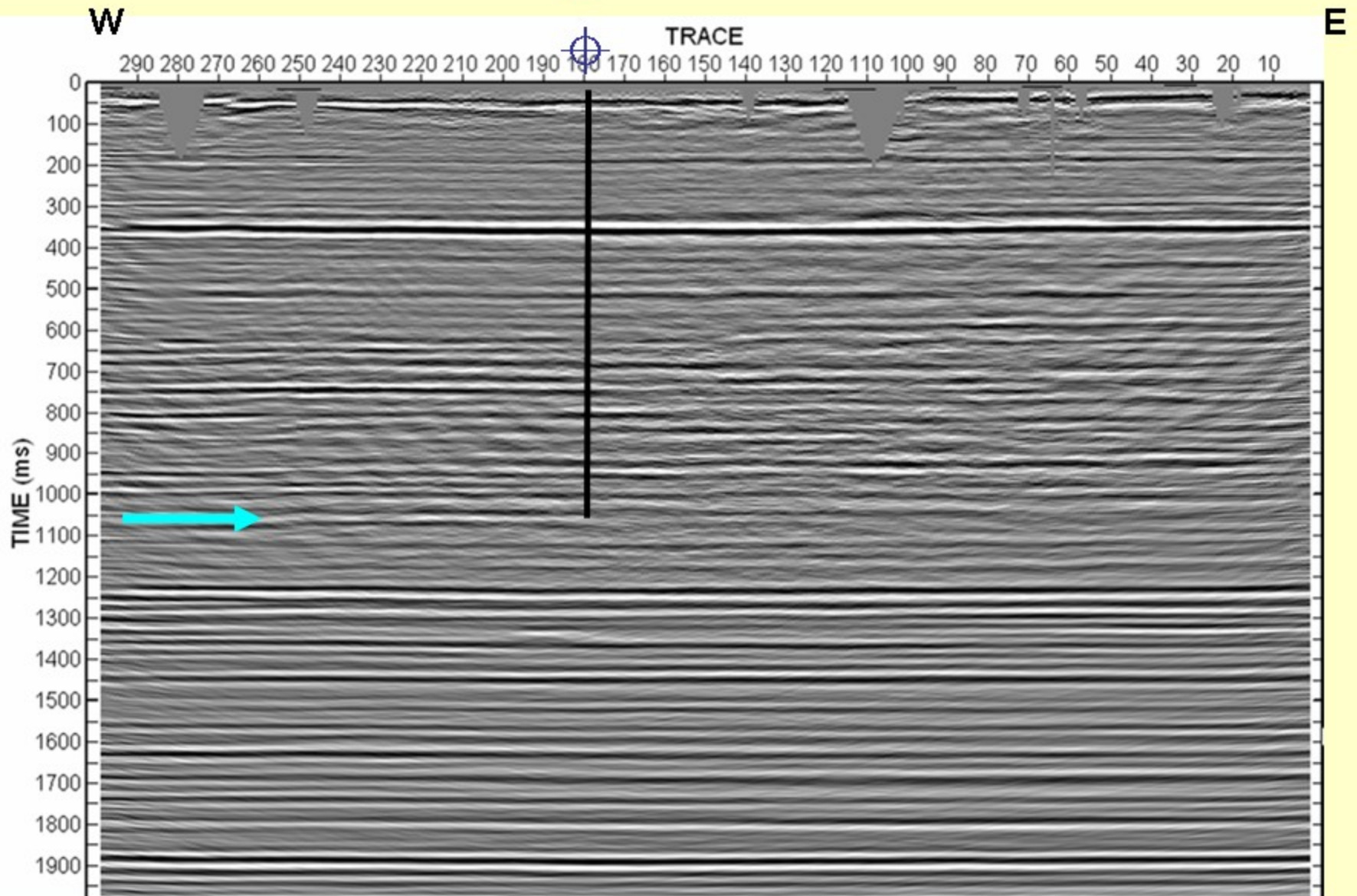




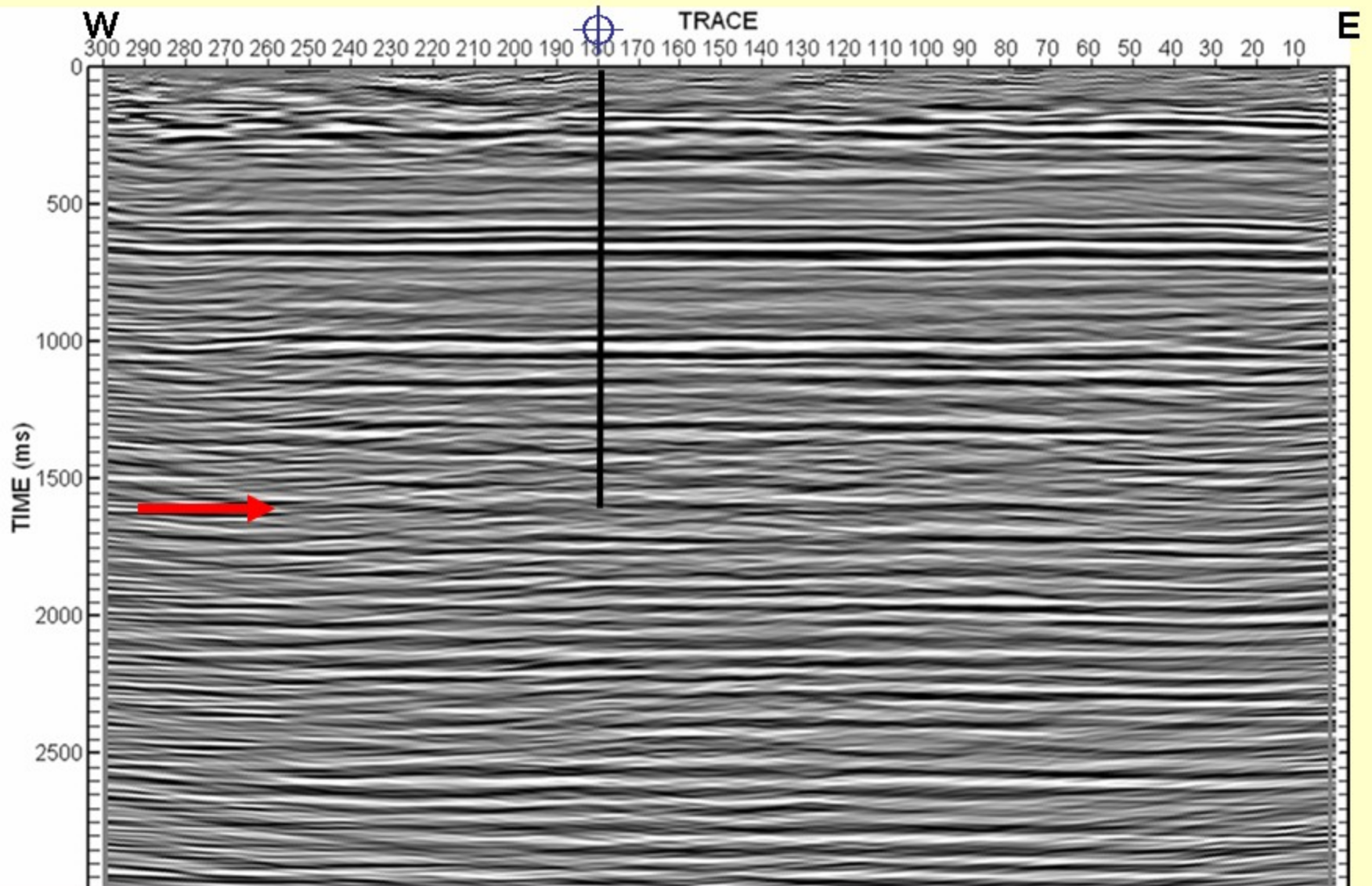
Penn West CO₂ EOR Pilot



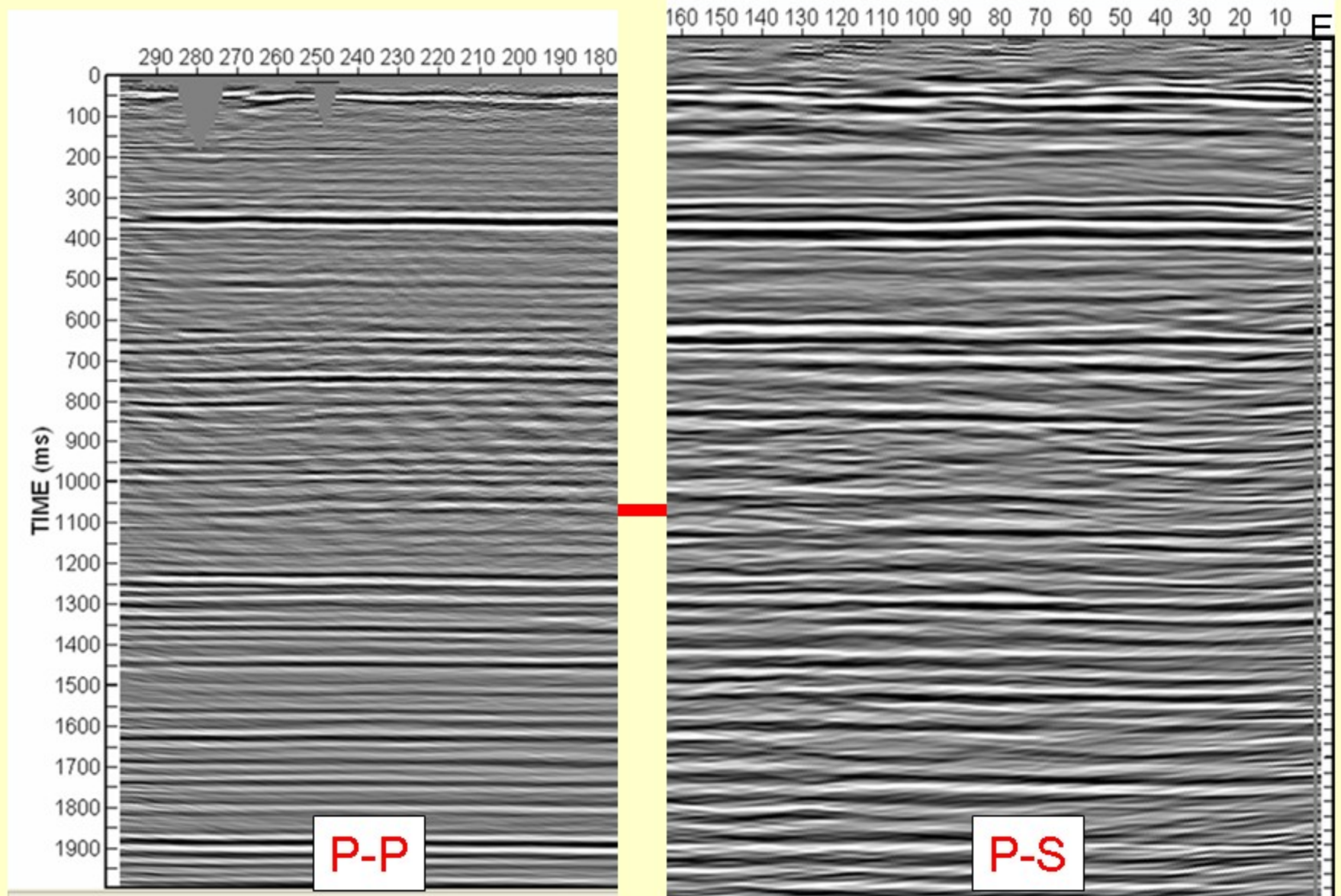
Line 3 migrated P-P section



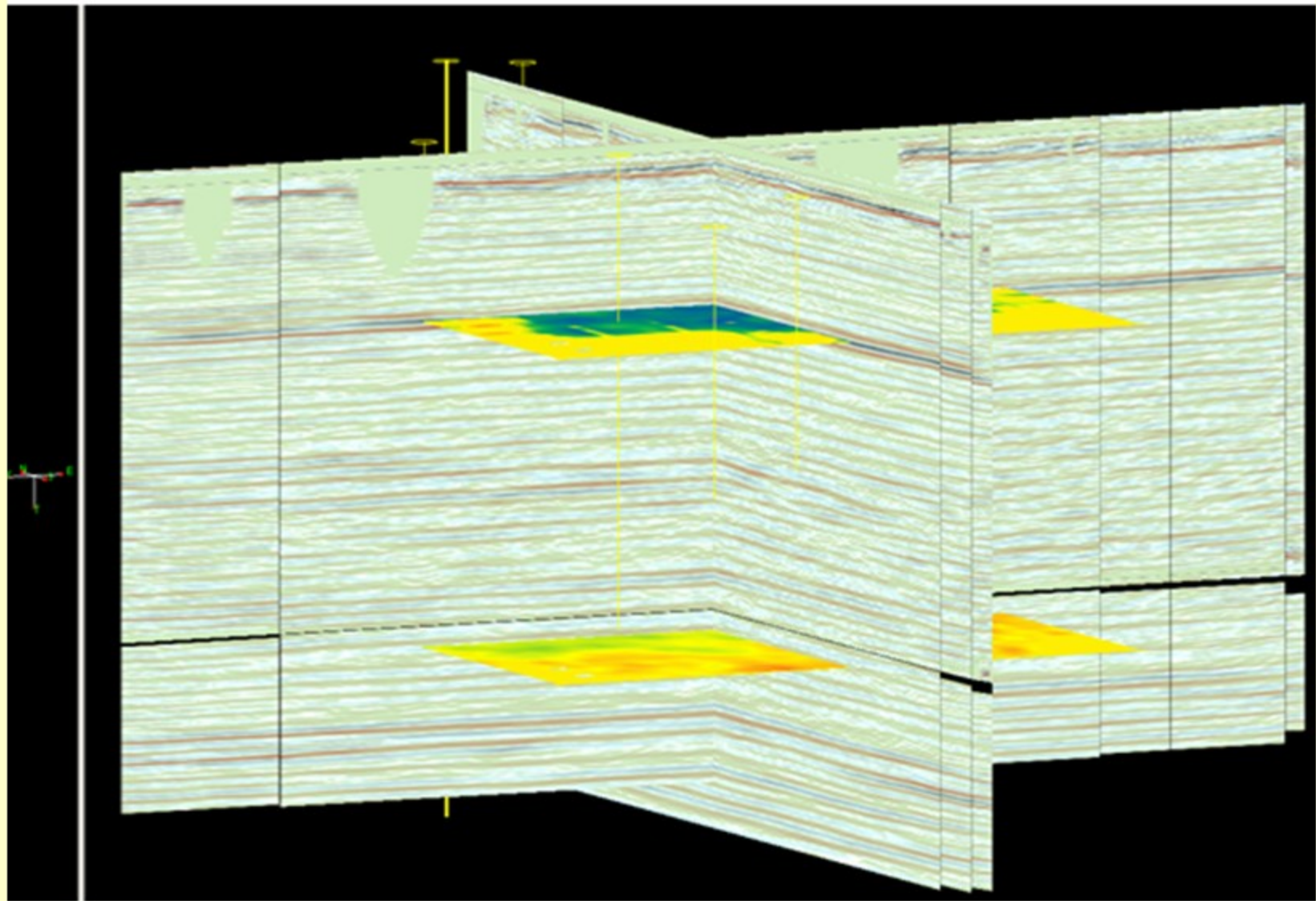
Line 3 migrated P-S section



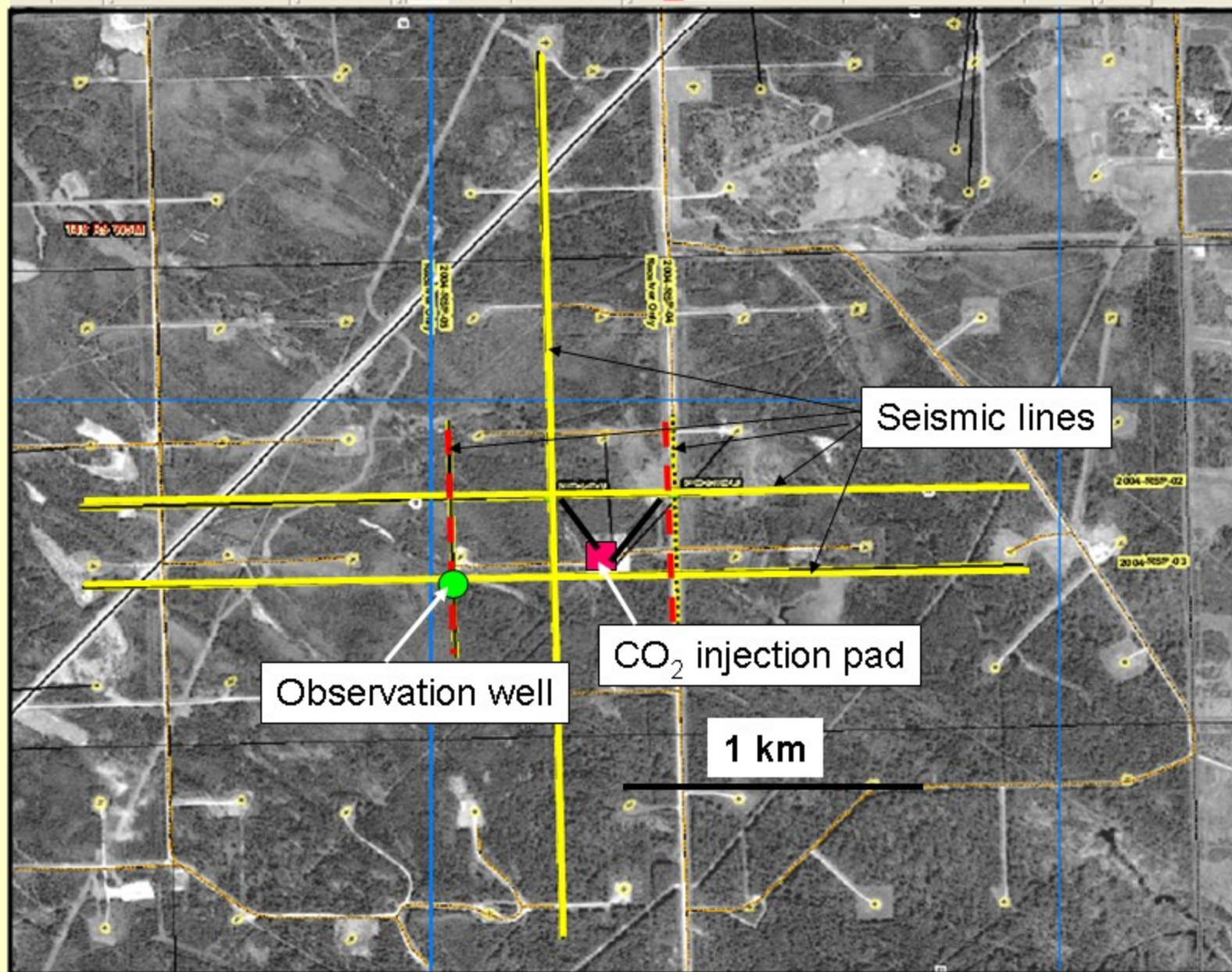
Line 3 P-P & P-S correlation



3D volume display [P-P]

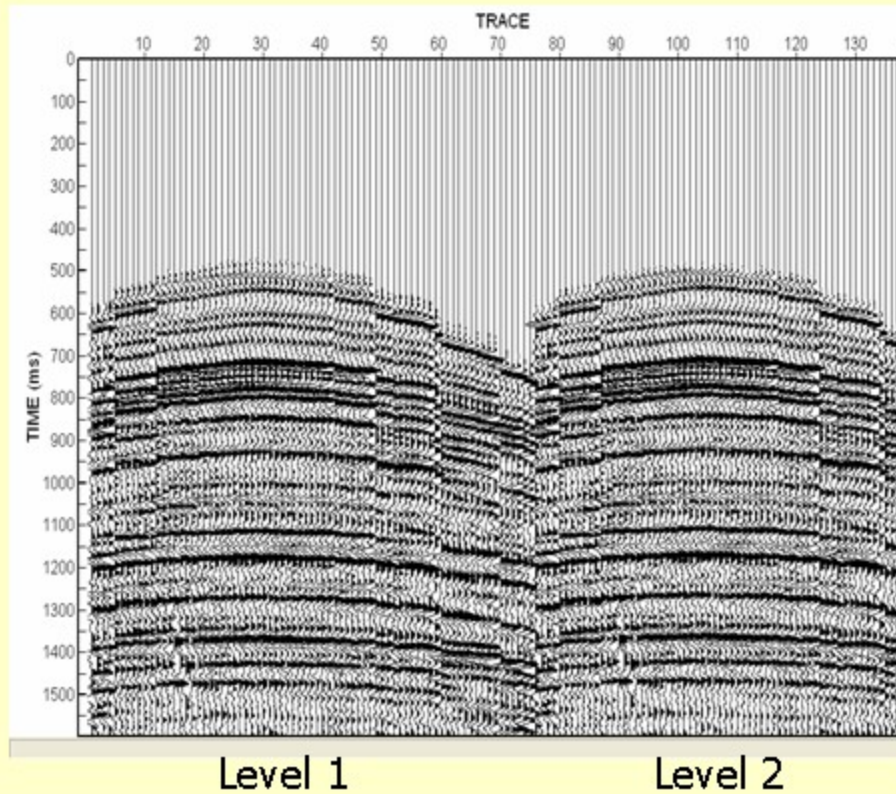


Penn West CO₂ EOR Pilot

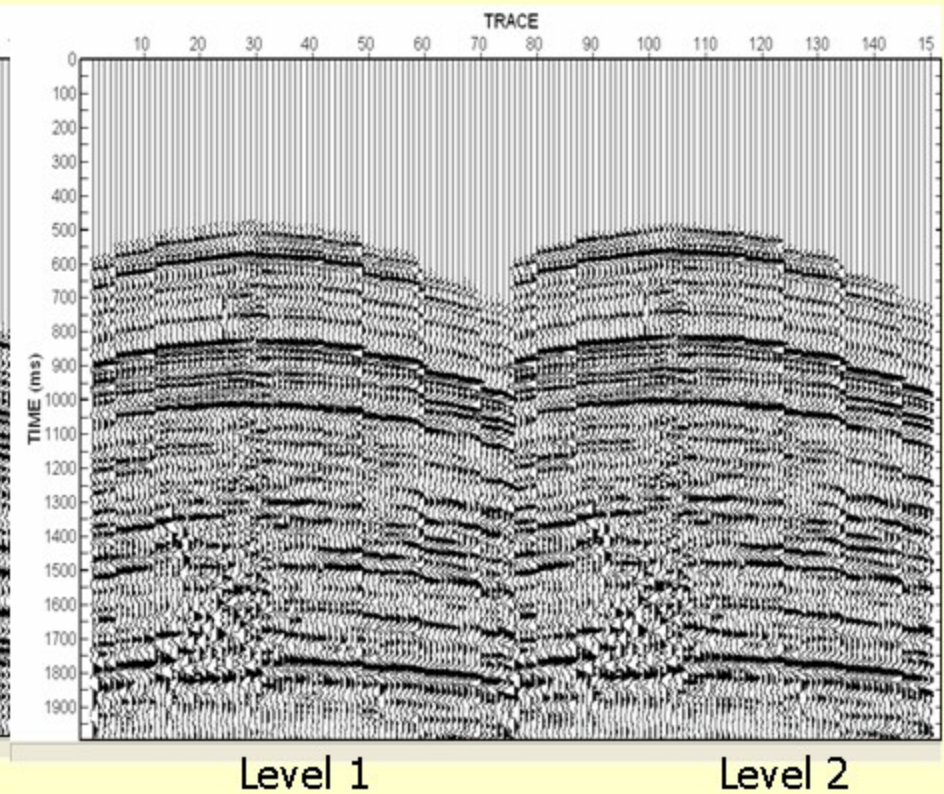


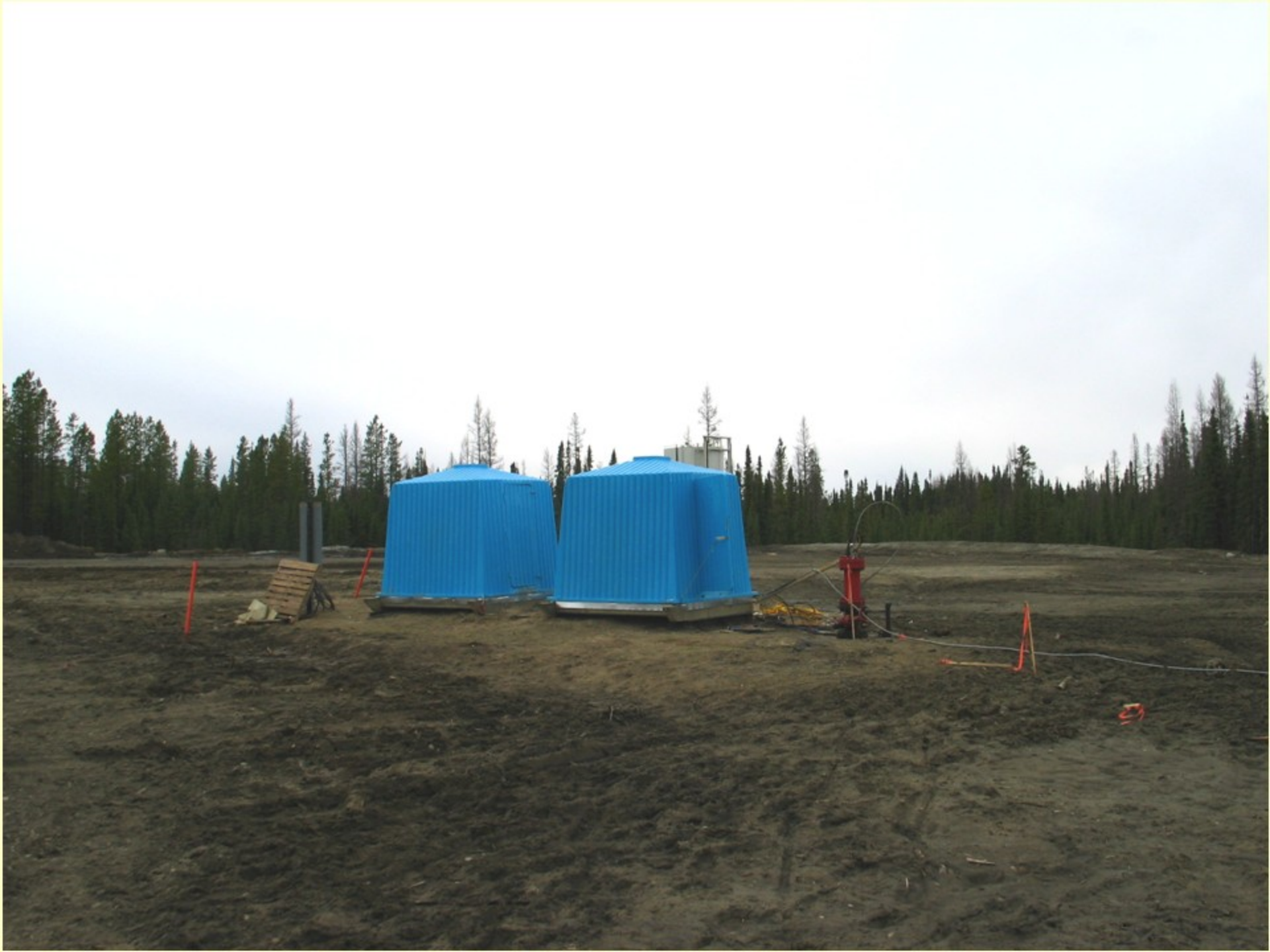
Line 3 VSP separated wavefields

Upgoing P-wave



Upgoing S-wave

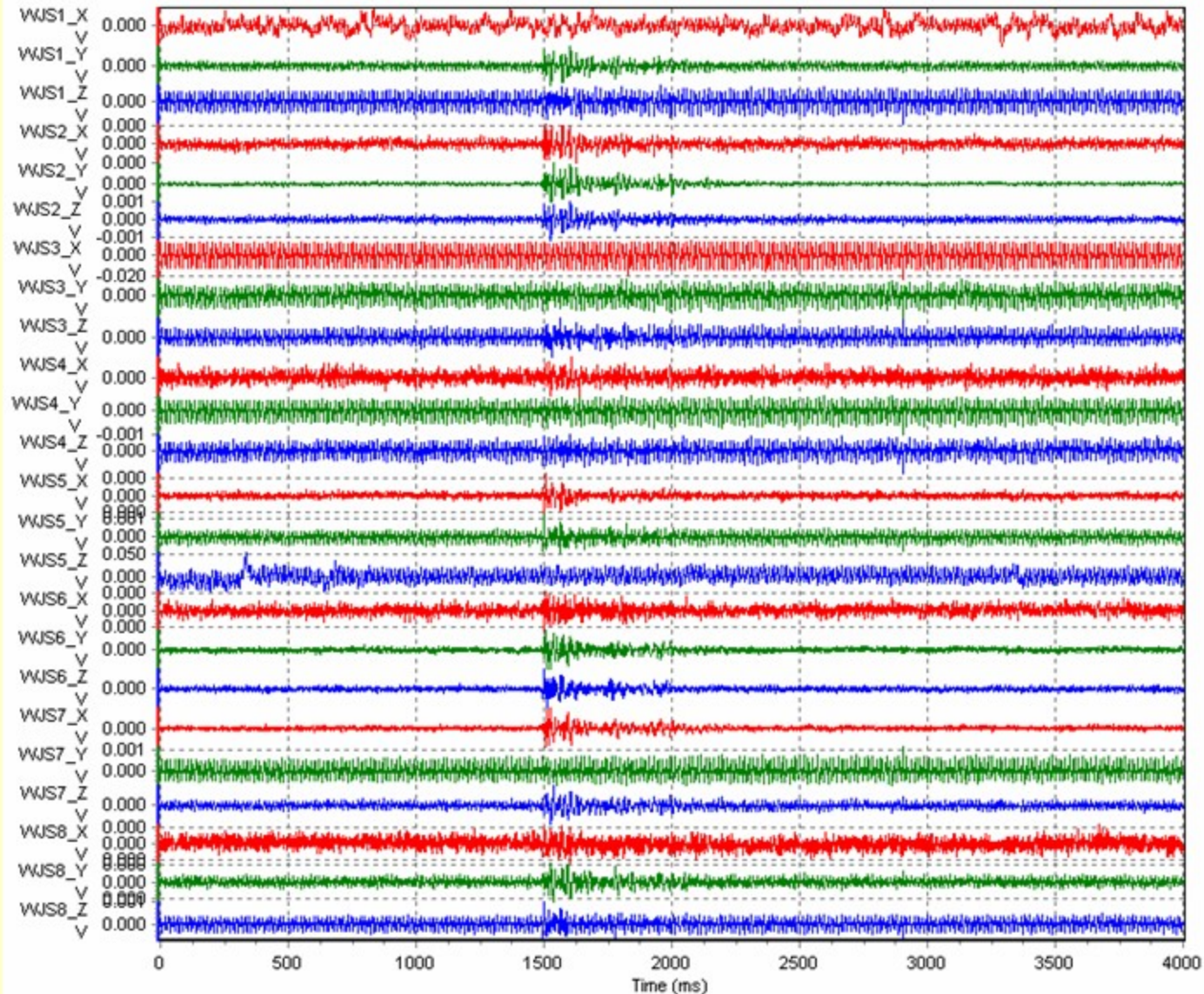






Passive seismic record

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Discussion

- Sparse 3D baseline surface seismic survey completed successfully; good images
- Observation well instrumented with geophones
 - some noisy elements
- High fidelity VSP images obtained around observation well
- Passive seismic system recording, no significant events over first 6 months
- First monitor survey scheduled for December 18

Acknowledgements

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