A Multicomponent, time-lapse investigation of fracturing in a potash mining region

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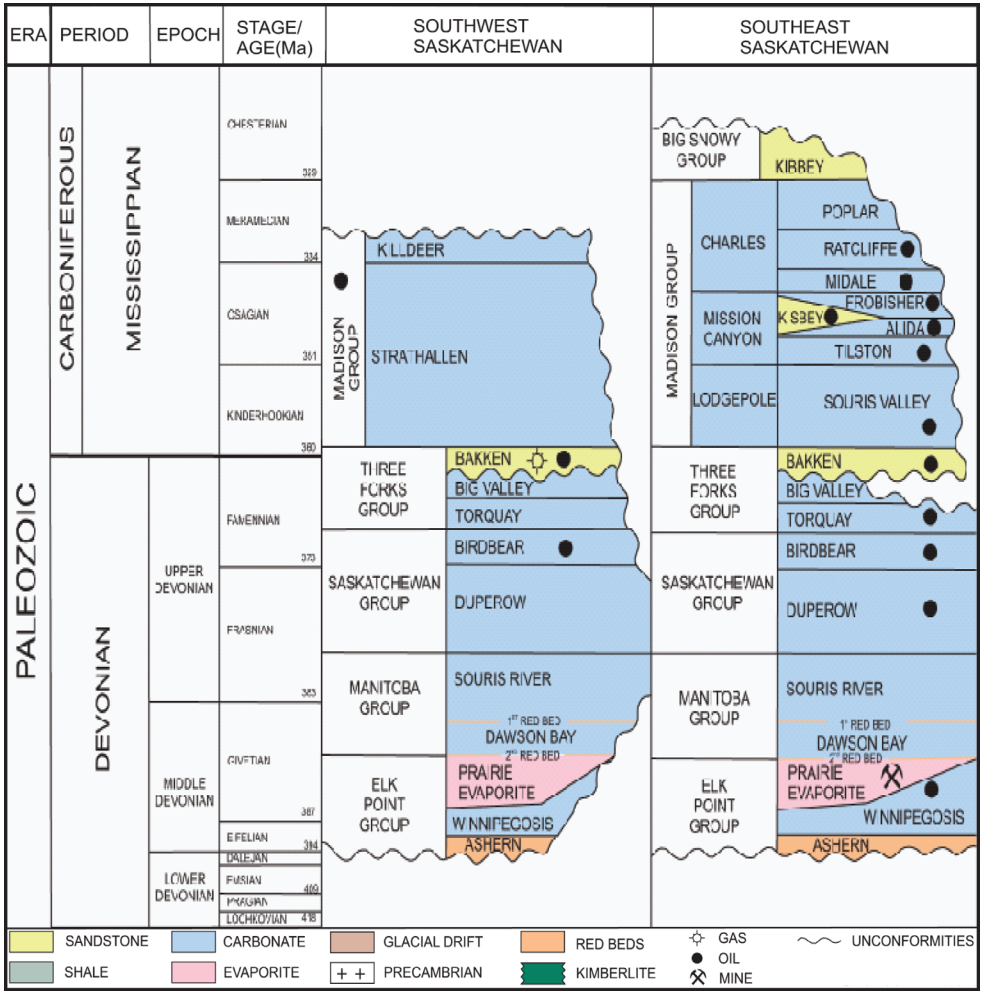
Overview

- Geology
- Multicomponent Seismology
- Synthetic ties
- PP-PS Registration
- Interpretation
- Horizontal Transverse Isotropy
- Azimuthal Differencing
- Vp/Vs Analysis
- Conclusions

Geology

Potash Region

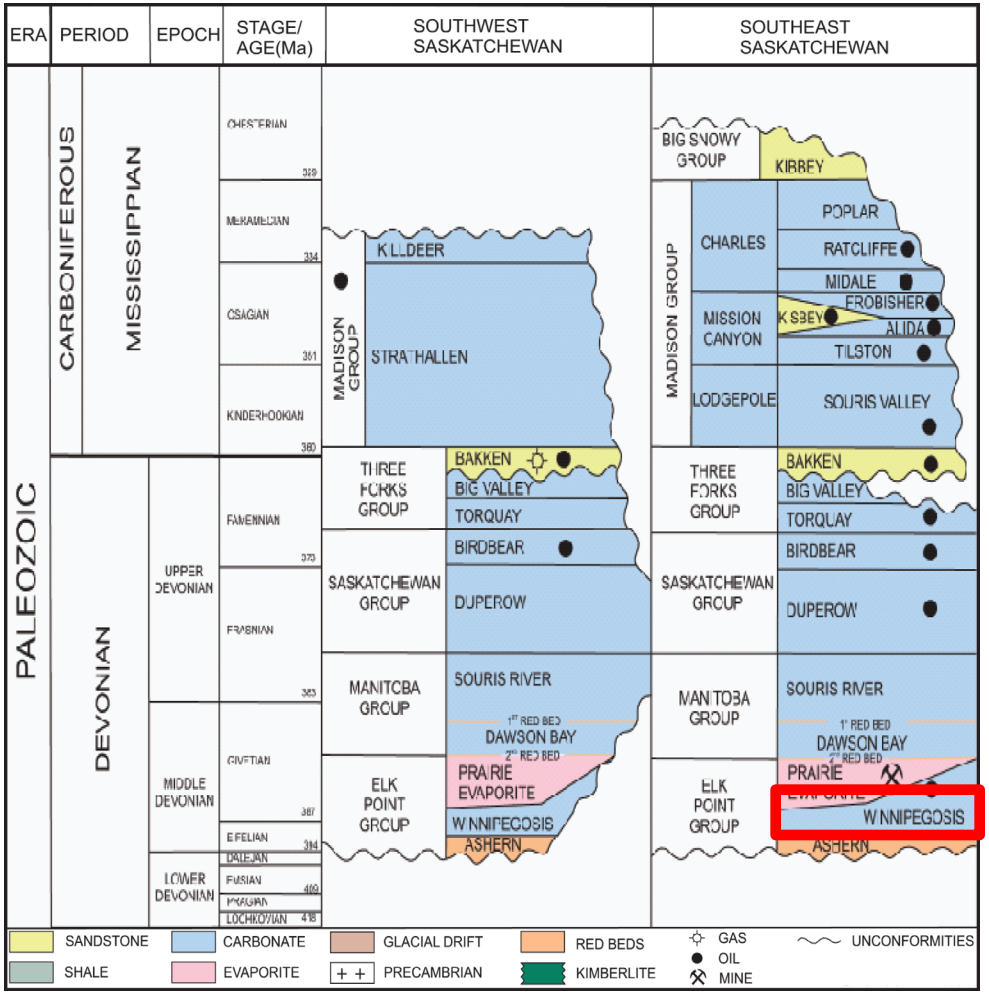
From Fuzesy 1982



Modified from www.er.gov.sk.ca/stratchart

Geology

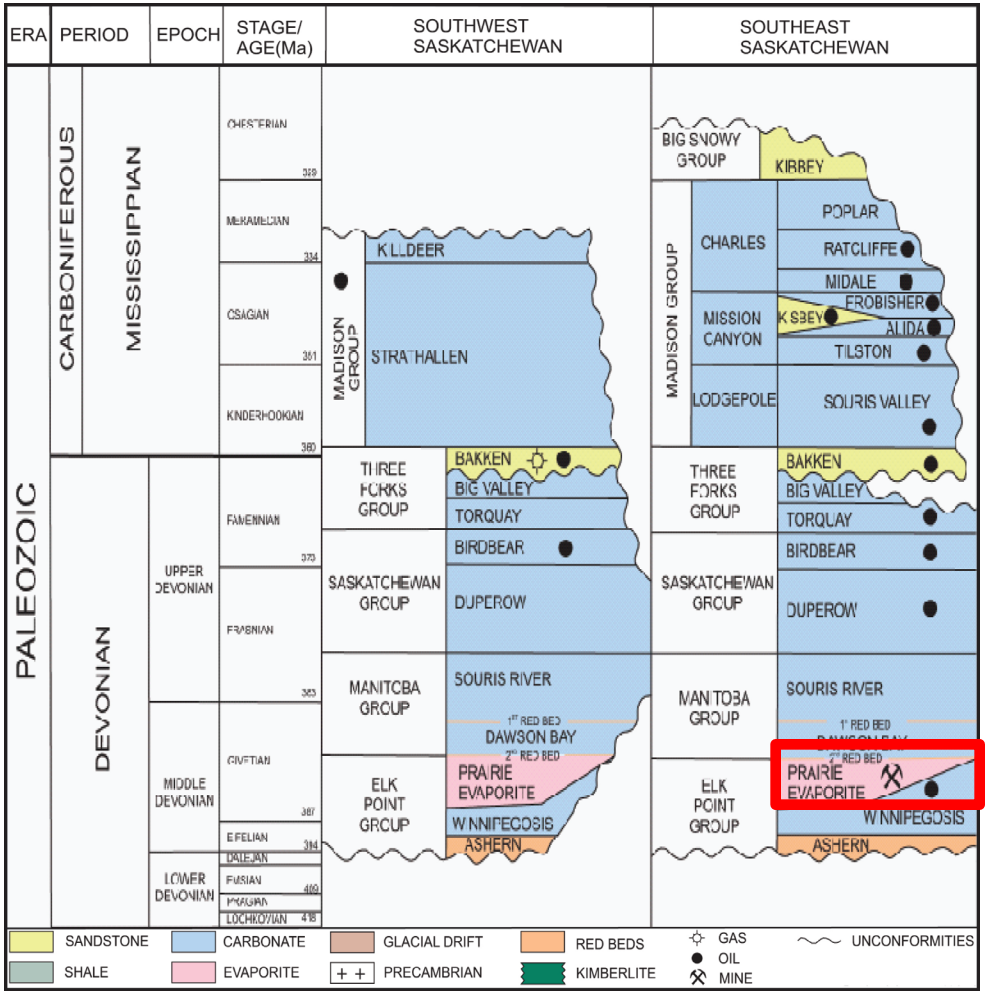
- Top of Winnipegosis carbonates marks base of possible extent of potash



Modified from www.er.gov.sk.ca/stratchart

Geology

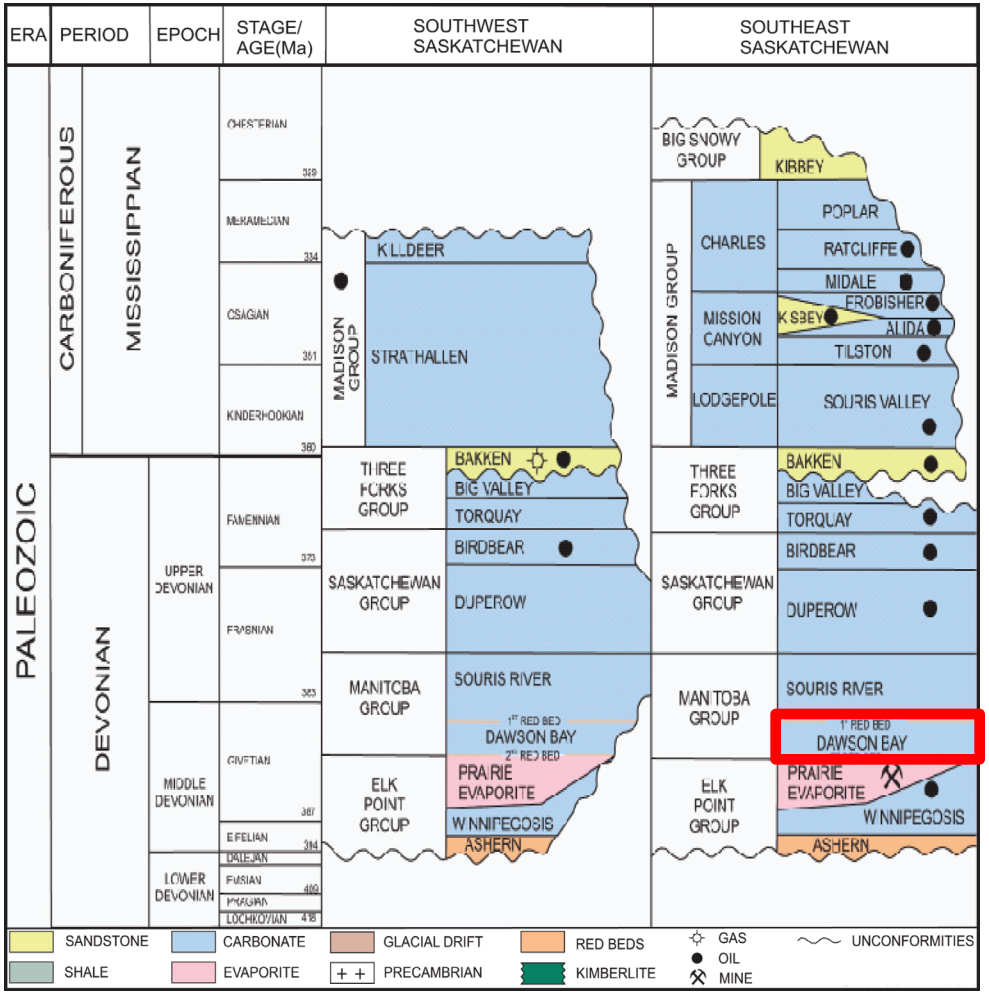
- Top of Winnipegosis carbonates marks base of possible extent of potash
- Prairie Evaporite Fm. contains potash ore



Modified from www.er.gov.sk.ca/stratchart

Geology

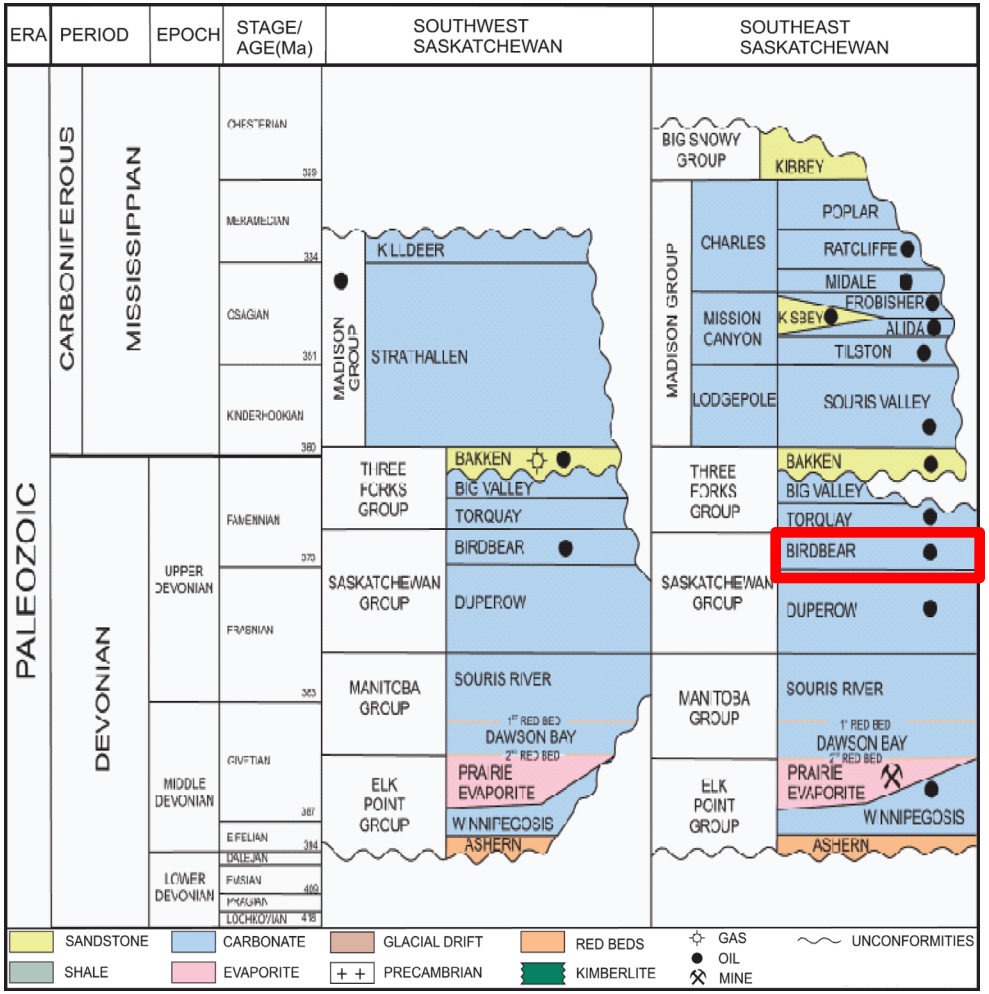
- Top of Winnipegosis carbonates marks base of possible extent of potash
- Prairie Evaporite Fm. contains potash ore
- Upper portion of fractured Dawson Bay carbonates contain aquifer



Modified from www.er.gov.sk.ca/stratchart

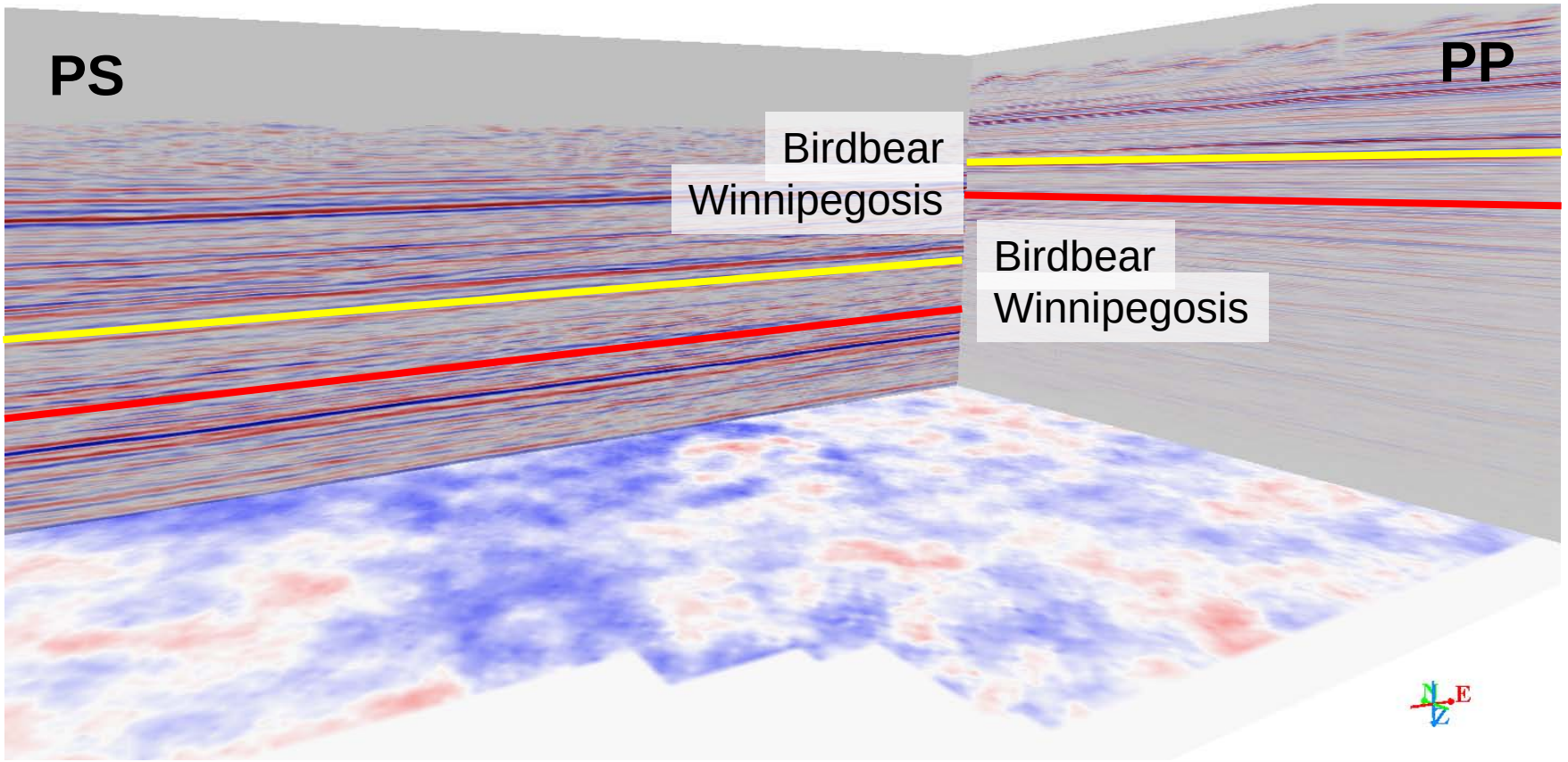
Geology

- Top of Winnipegosis carbonates marks base of possible extent of potash
- Prairie Evaporite Fm. contains potash ore
- Upper portion of fractured Dawson Bay carbonates contain aquifer
- Birdbear Formation - upper bound to strata of interest



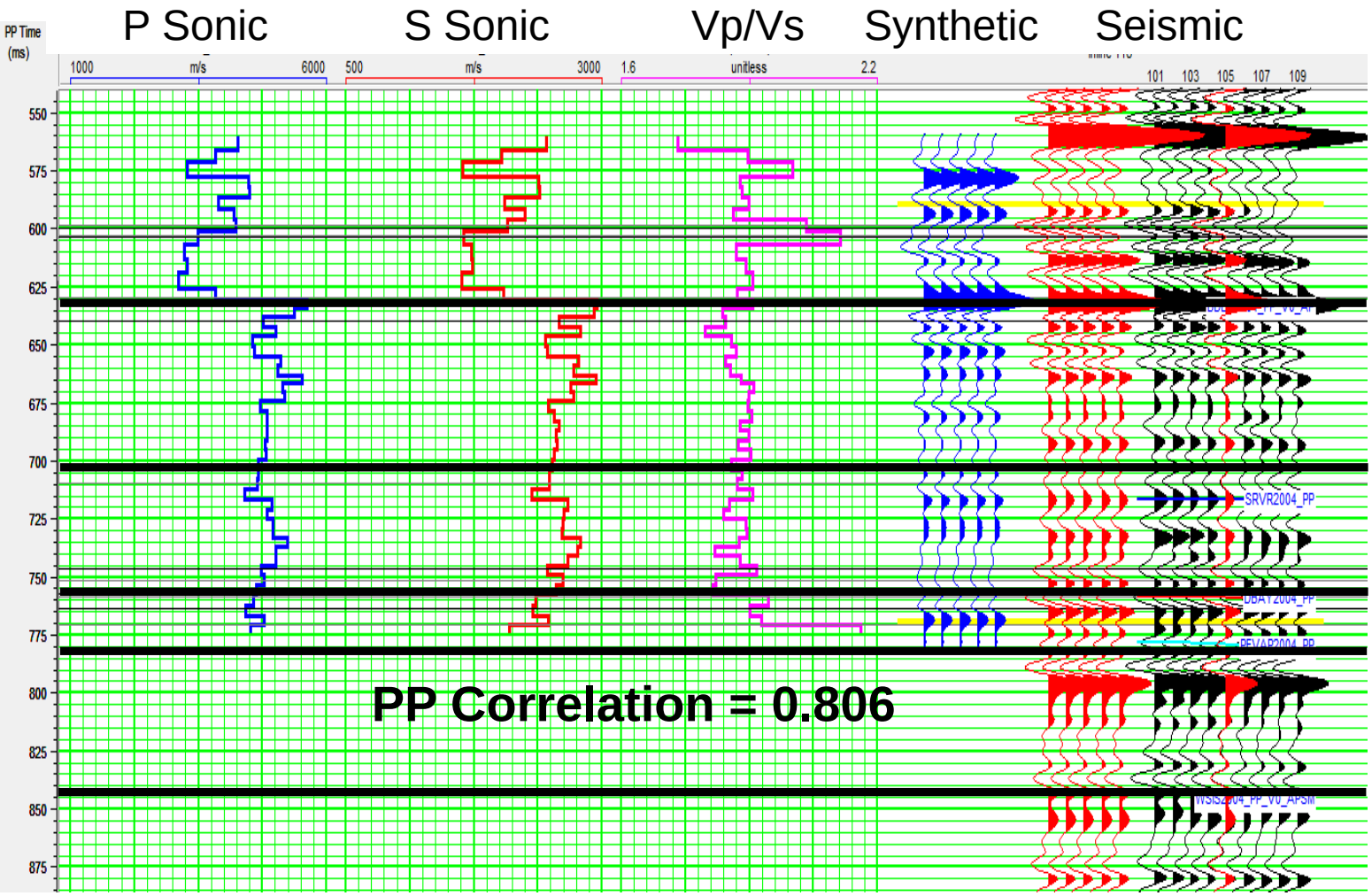
Modified from www.er.gov.sk.ca/stratchart

Multicomponent Seismology



Birdbear (yellow) and Winnipegosis (red) horizons on PP (right) and PS (left) datasets.

Interpretation – PP Synthetic Tie

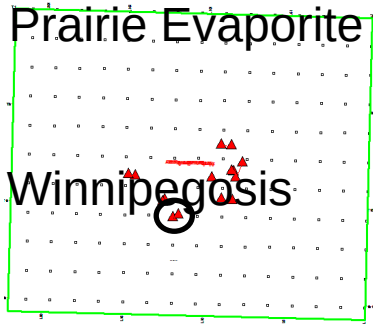


Birdbear

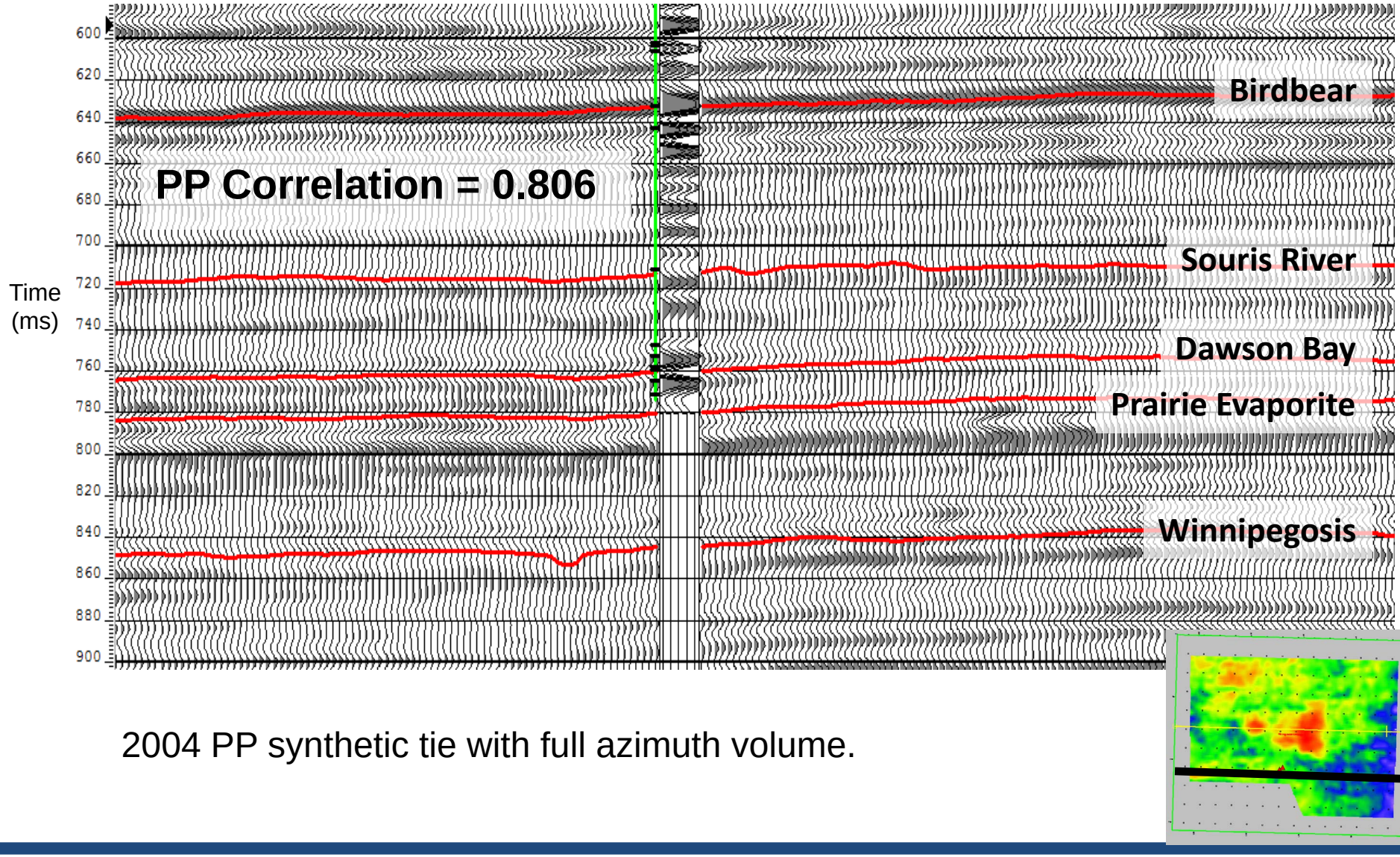
Souris River

Dawson Bay

Prairie Evaporite

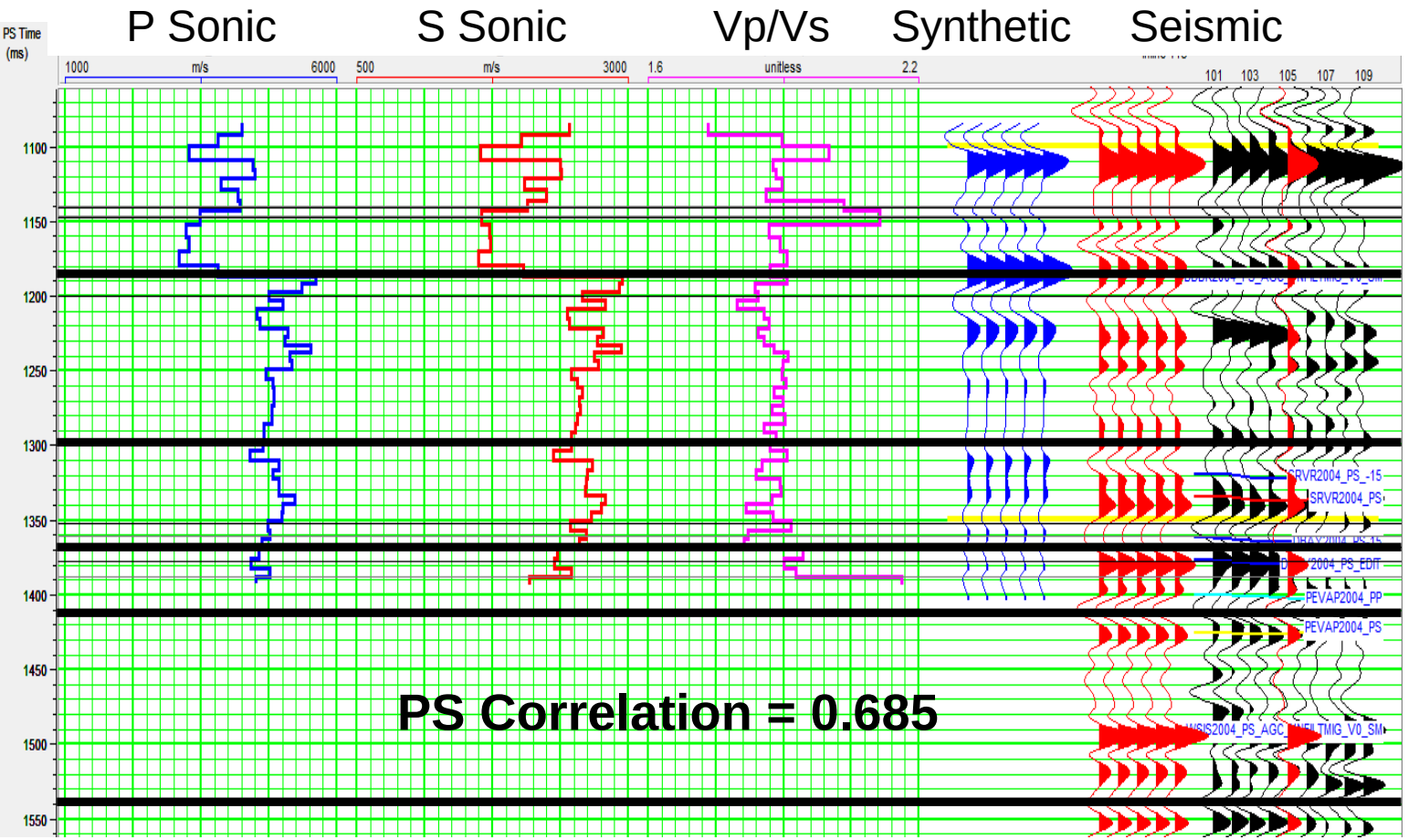


Interpretation – PP Synthetic Tie



2004 PP synthetic tie with full azimuth volume.

PP–PS Registration



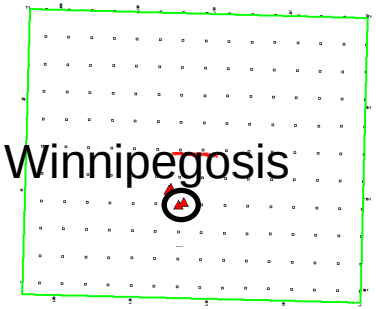
Birdbear

Souris River

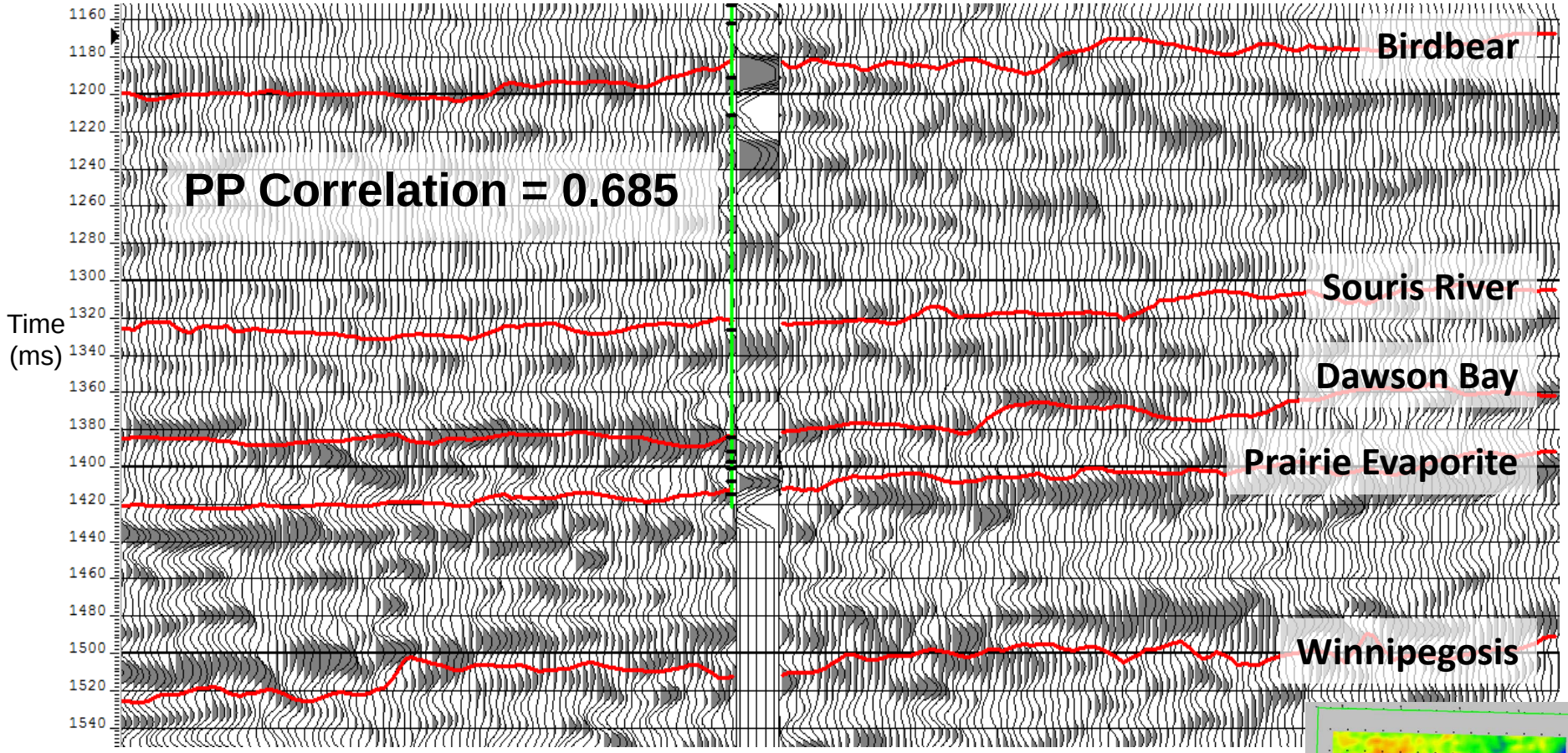
Dawson Bay

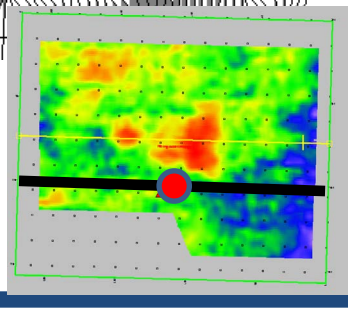
Prairie Evaporite

Winnipegosis



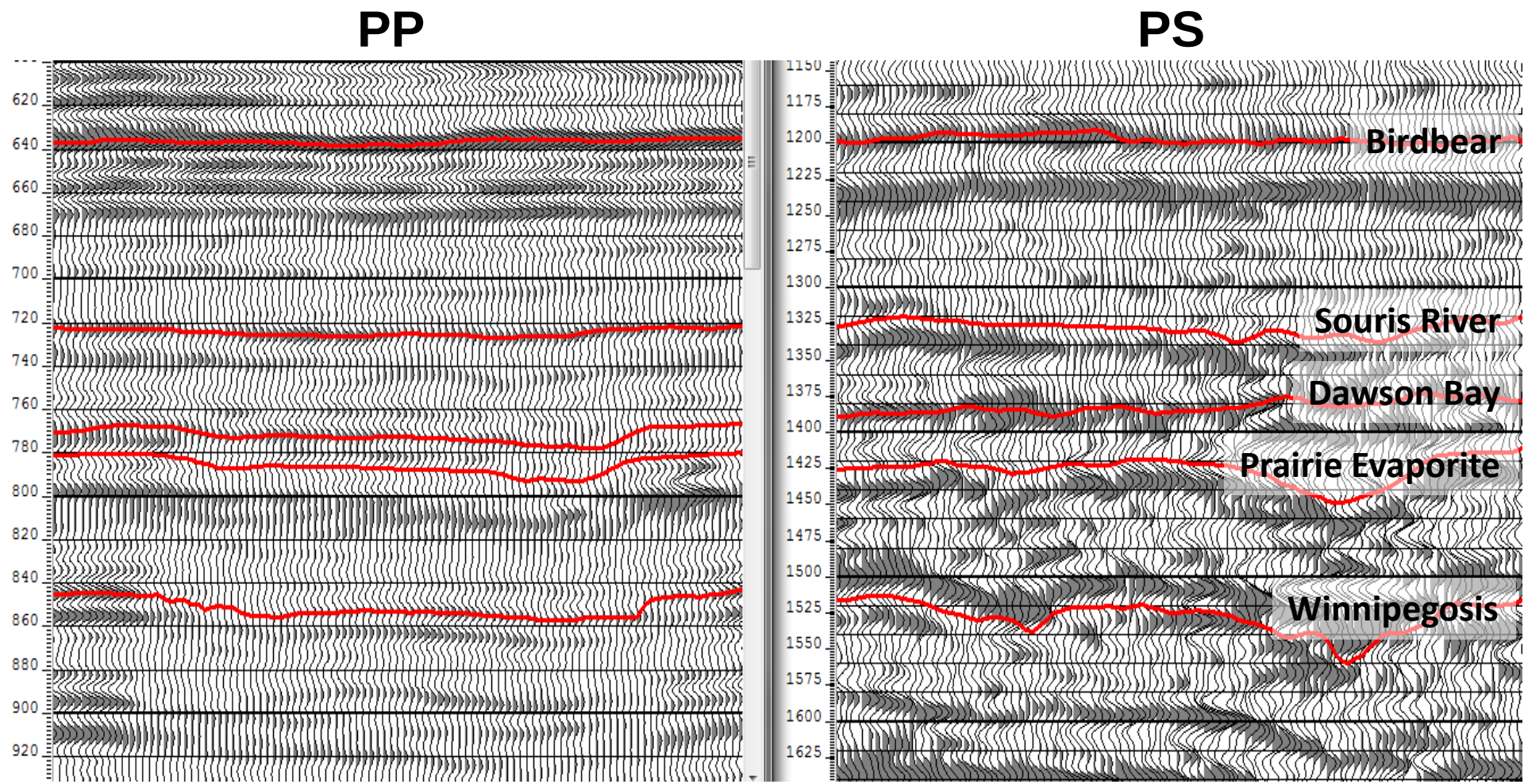
PP–PS Registration





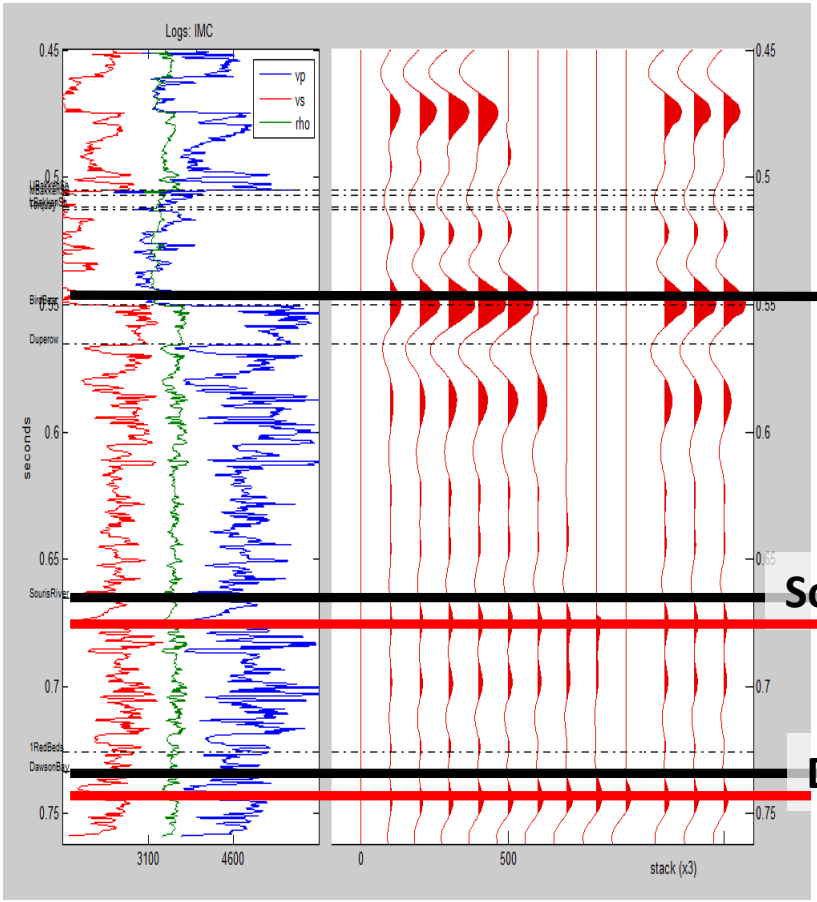
2004 PS synthetic tie with full azimuth volume.

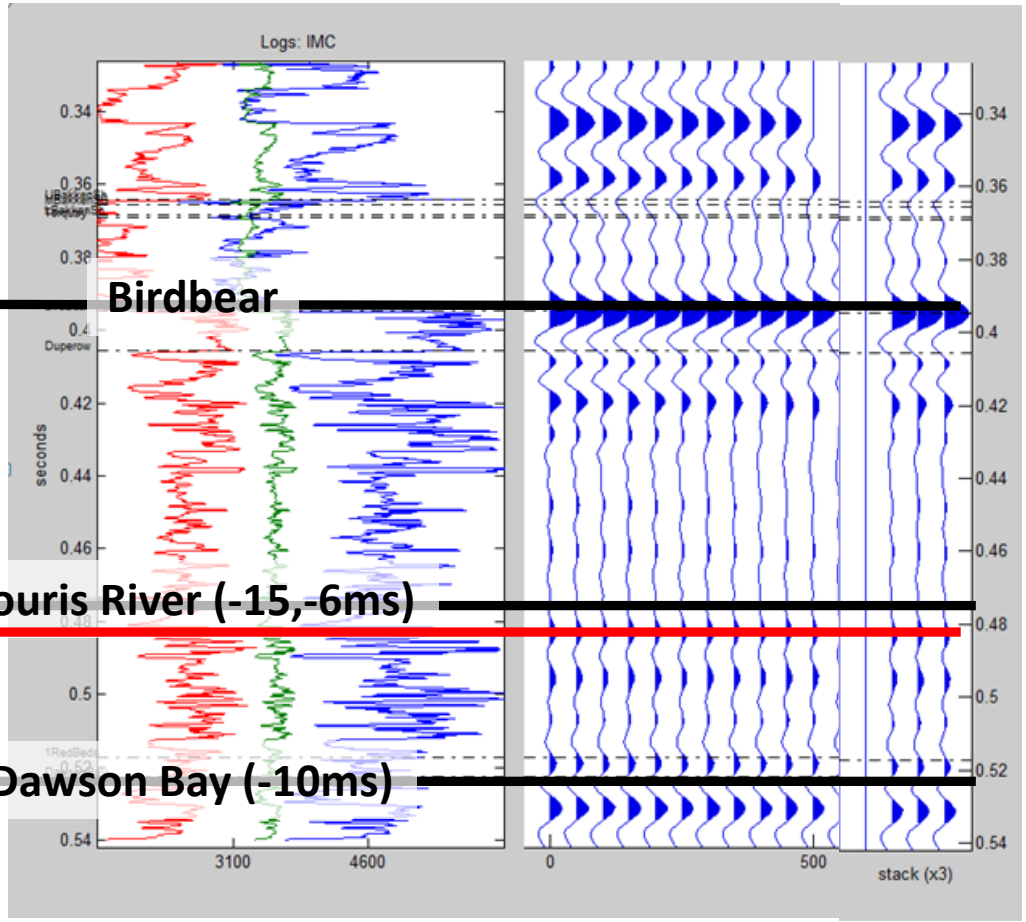
PP–PS Registration



PS section squeezed in time using Vp/Vs = 2.0

PP–PS Registration



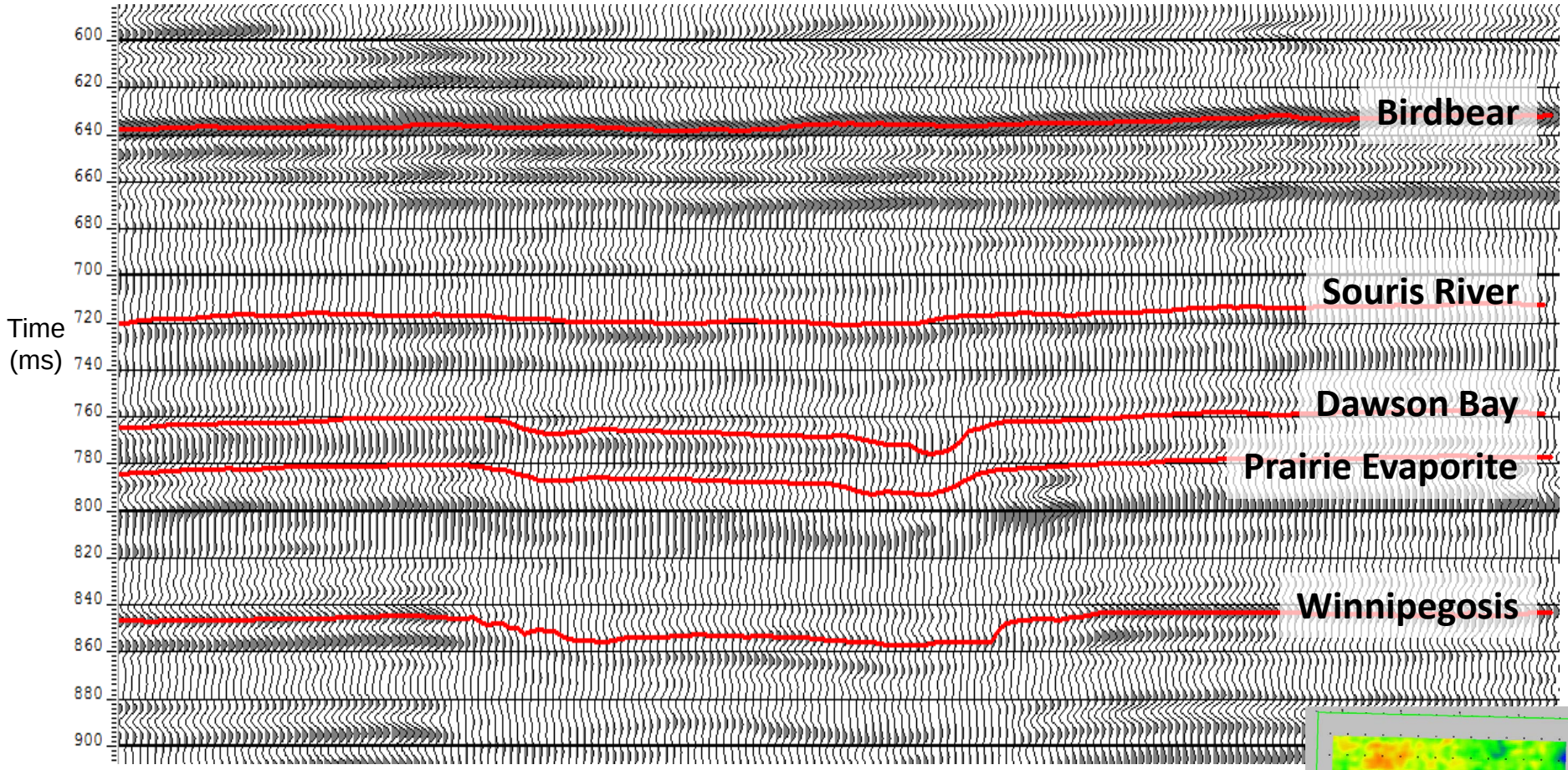


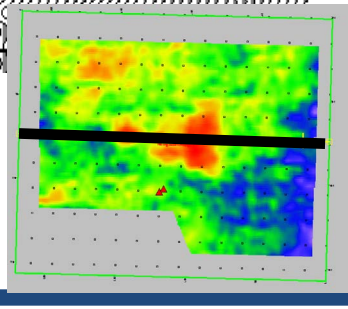
Lower frequency PS data makes picking the event corresponding to a well top difficult. Time shifting closest picked events refines registration.

Log top

Picked Event

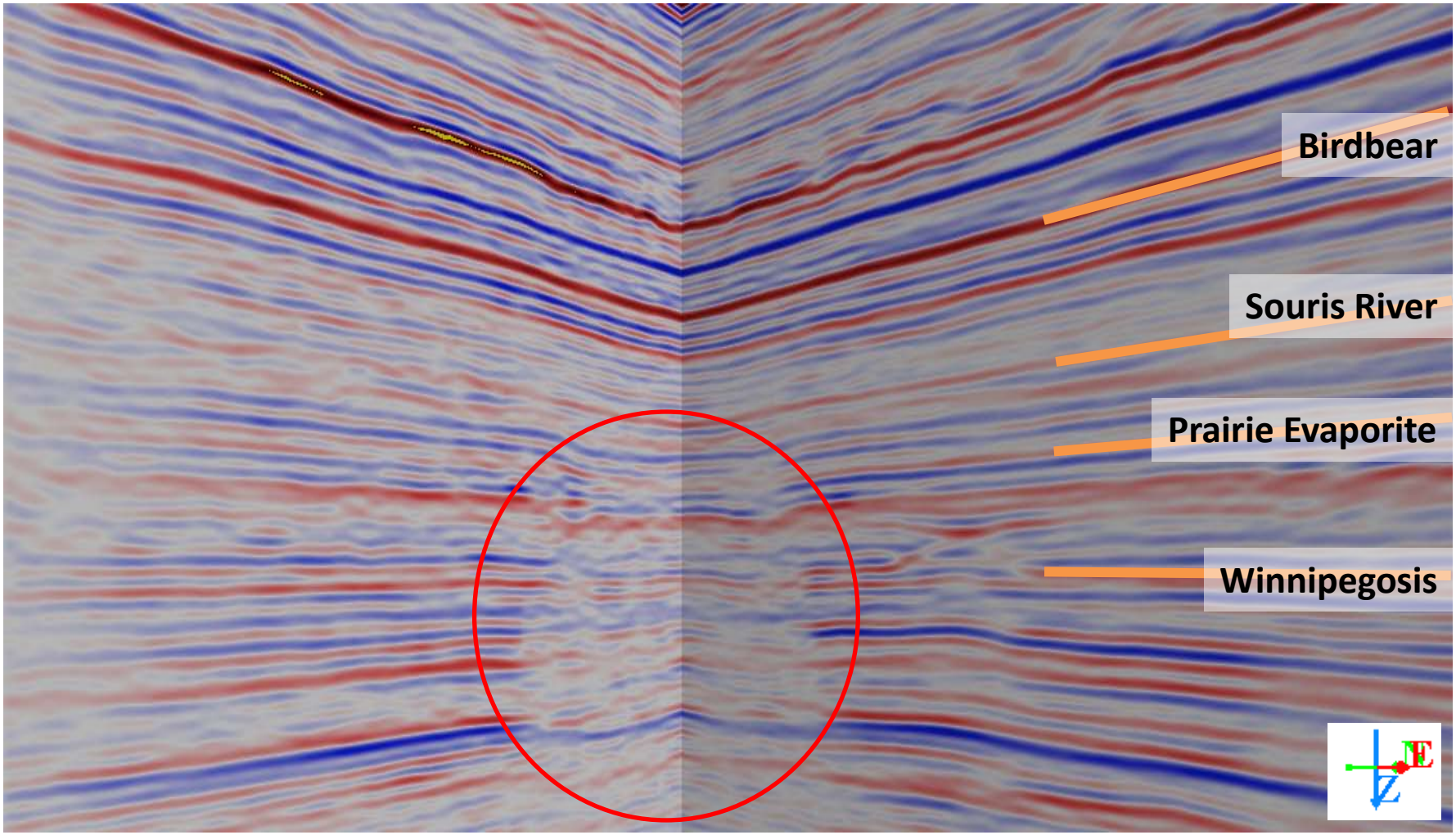
Interpretation – PP Low Velocity Anomaly



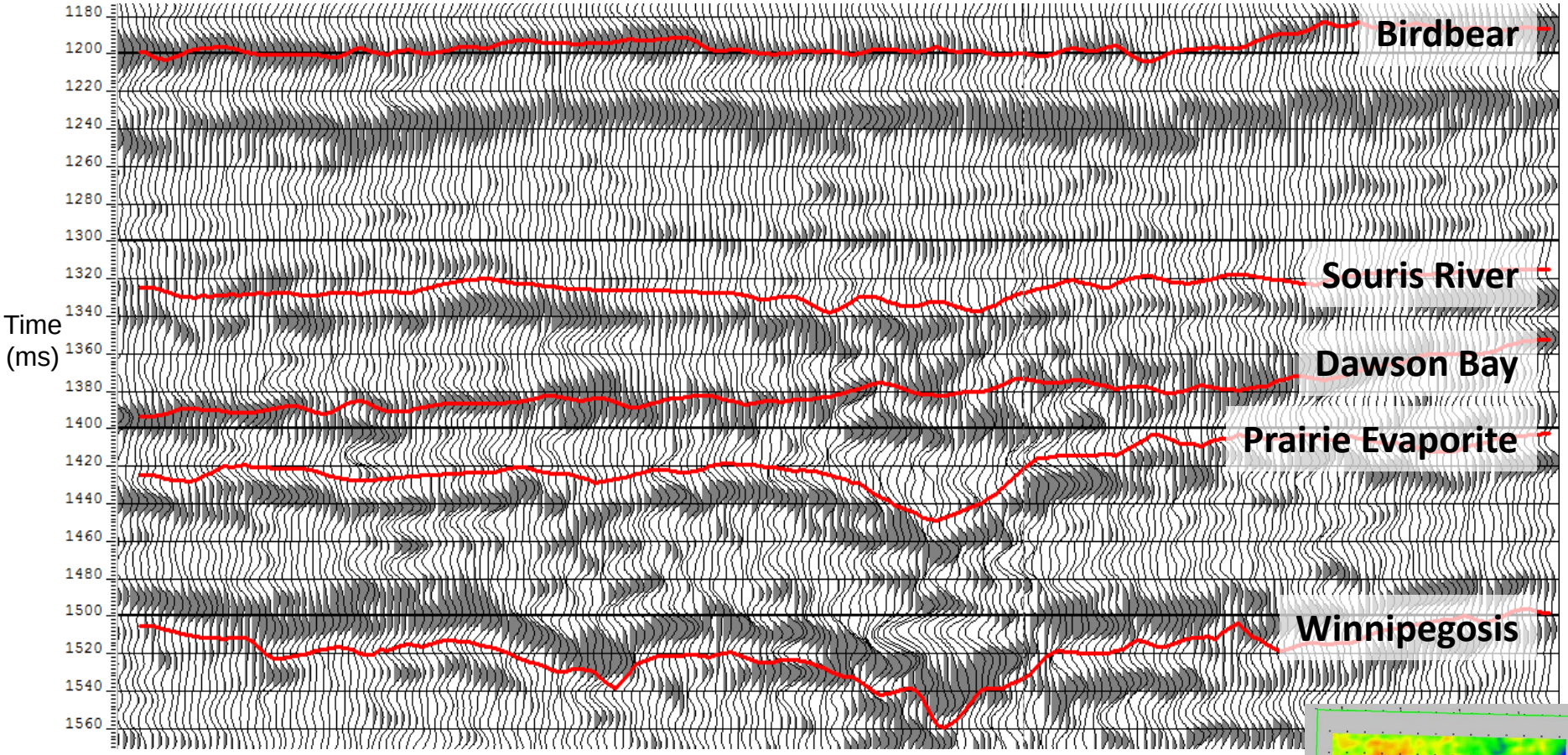


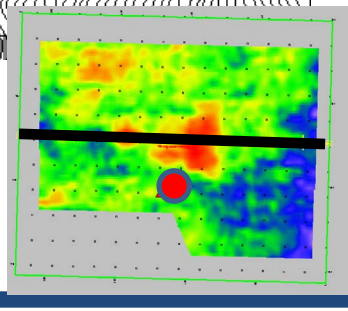
2004 PP full azimuth volume. Note the increase in traveltime and reduction in seismic amplitude in the middle of the line where a low velocity anomaly is interpreted.

Interpretation – PP Velocity Anomaly



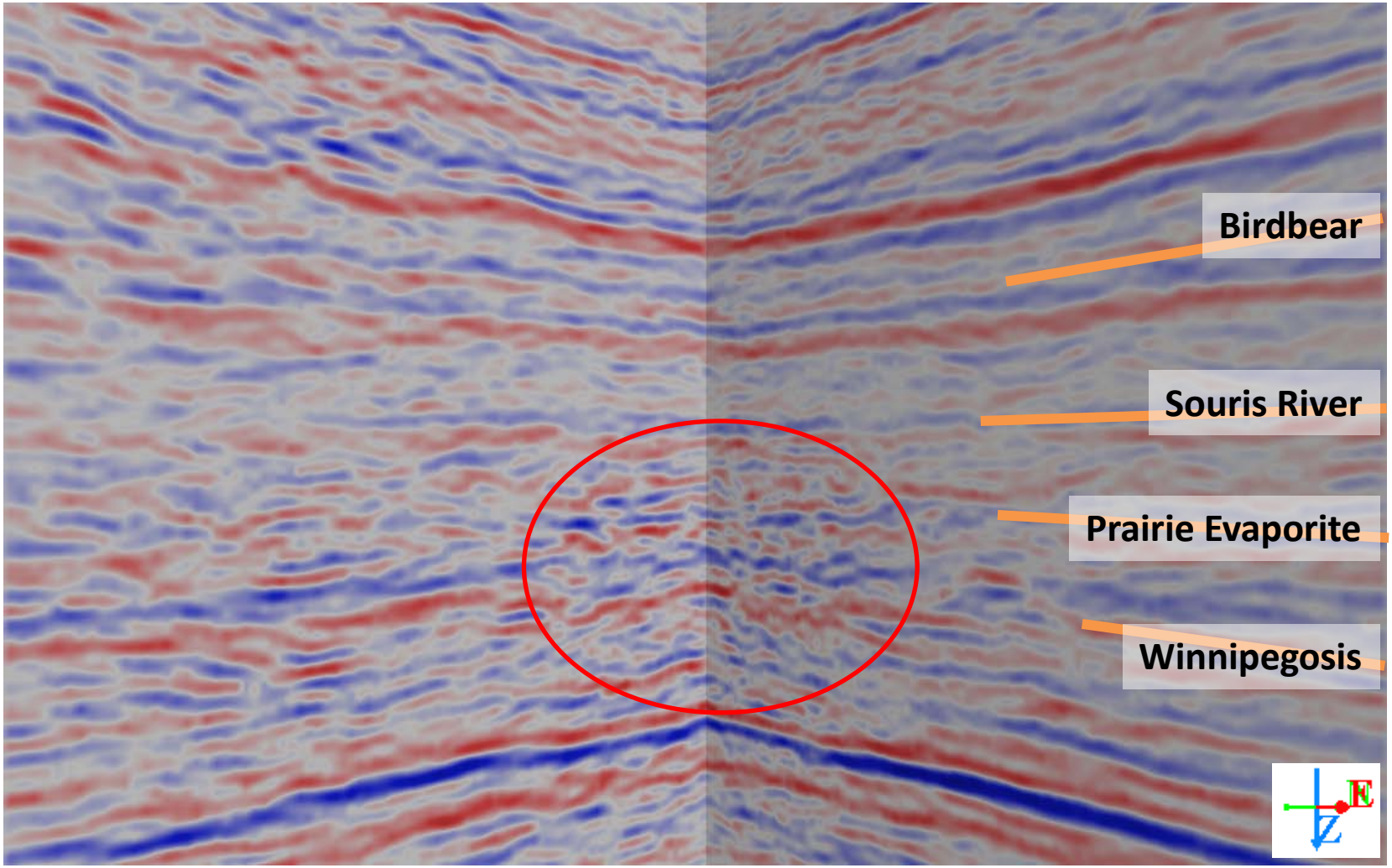
Interpretation – PS





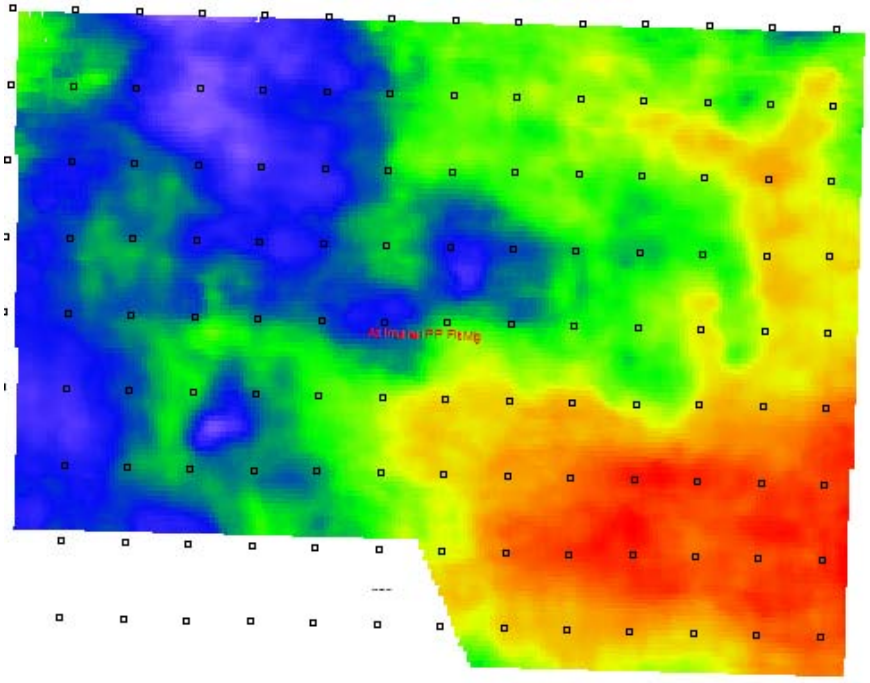
2004 PS full azimuth volume. Low velocity anomaly shown in the middle of the line, with little to no reduction in seismic amplitude.

Interpretation – PS Velocity Anomaly



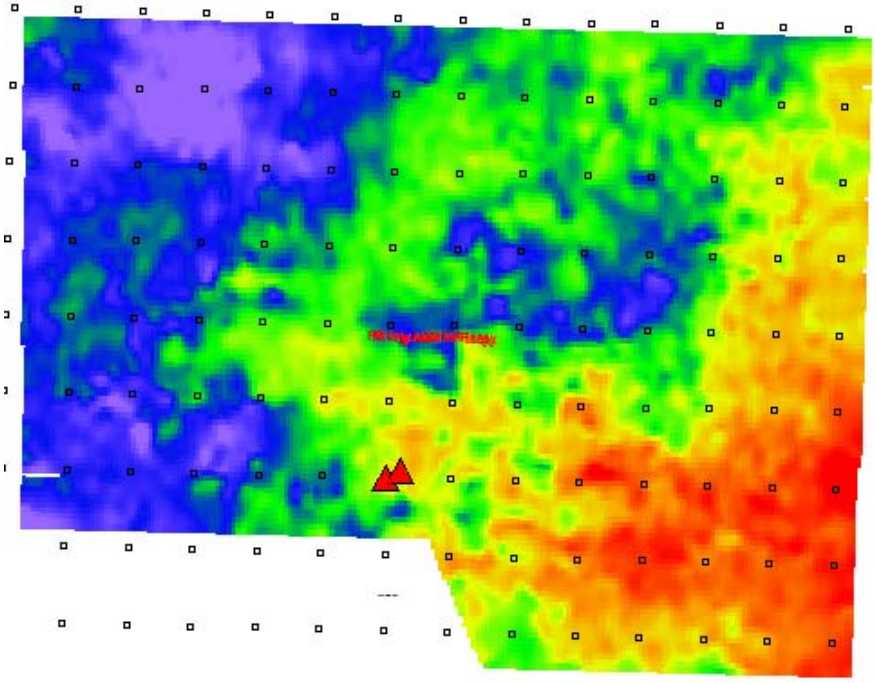
Interpretation

PP



625 (ms) 640

PS

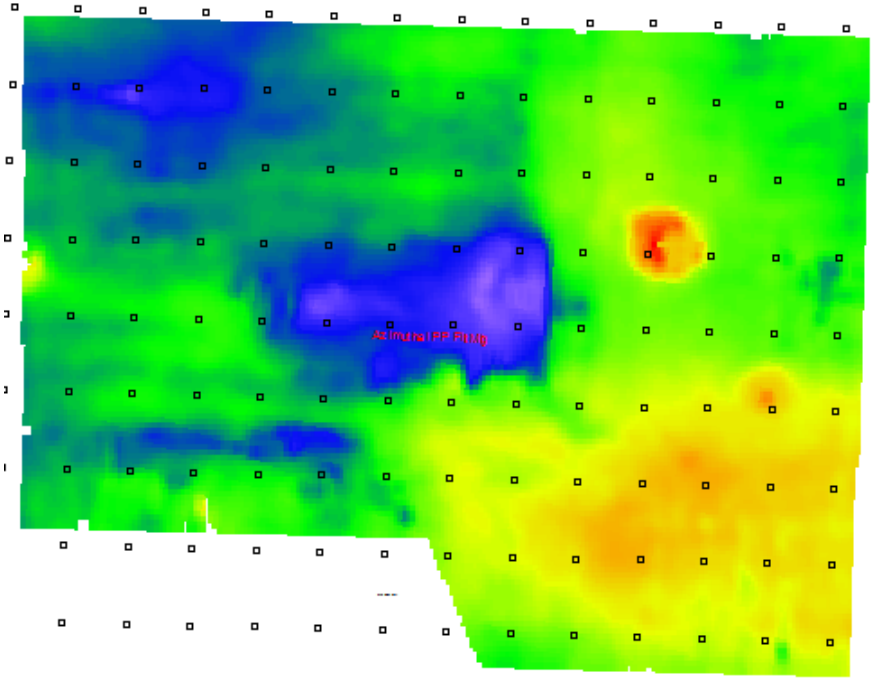


1170 (ms) 1205

Time structure of Birdbear horizon from baseline survey.

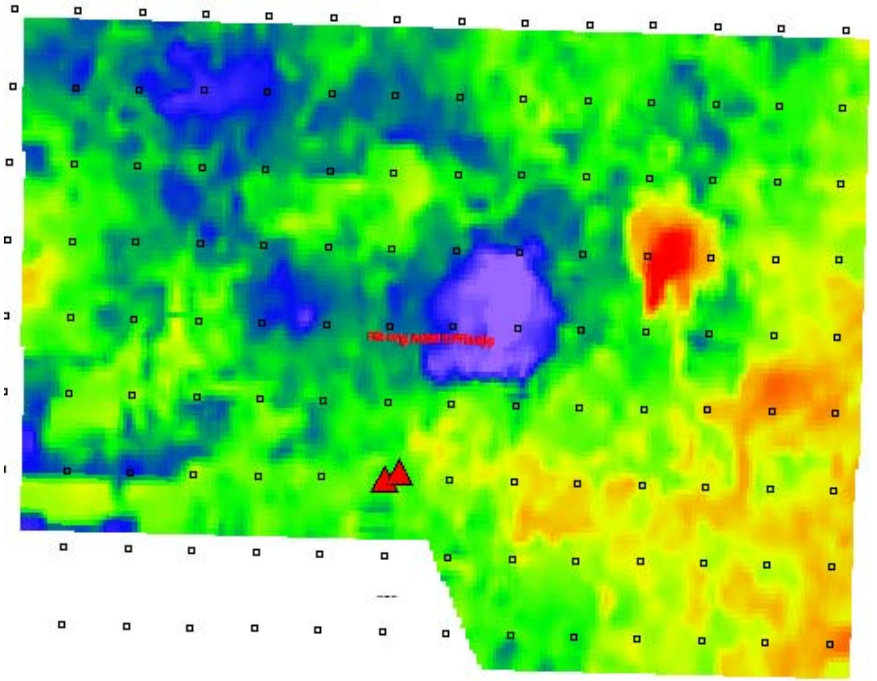
Interpretation

PP



830 (ms) 860

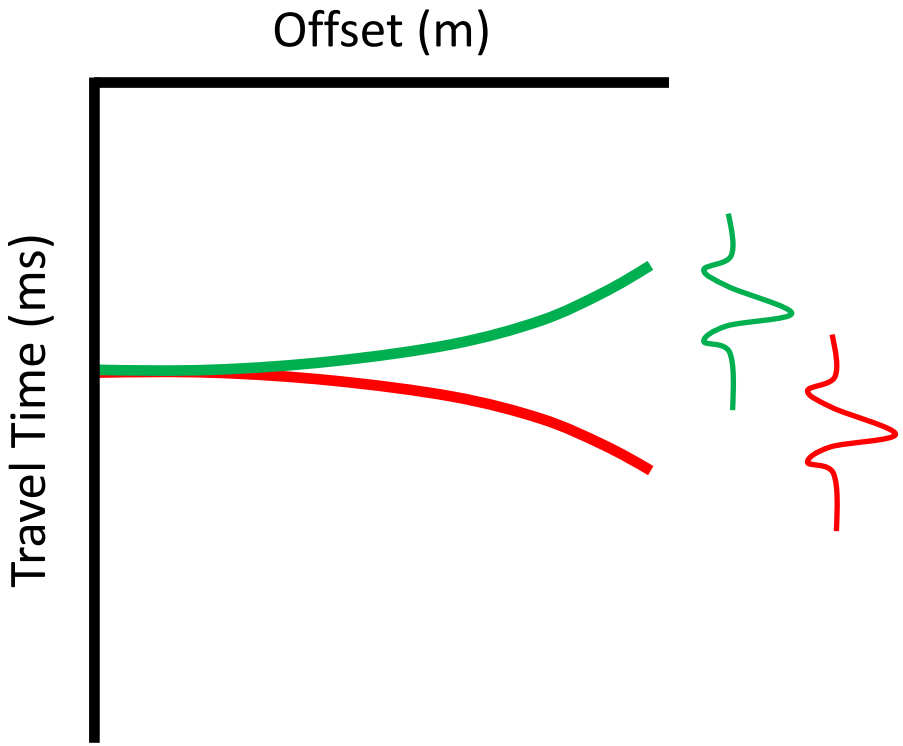
PS



1470 (ms) 1540

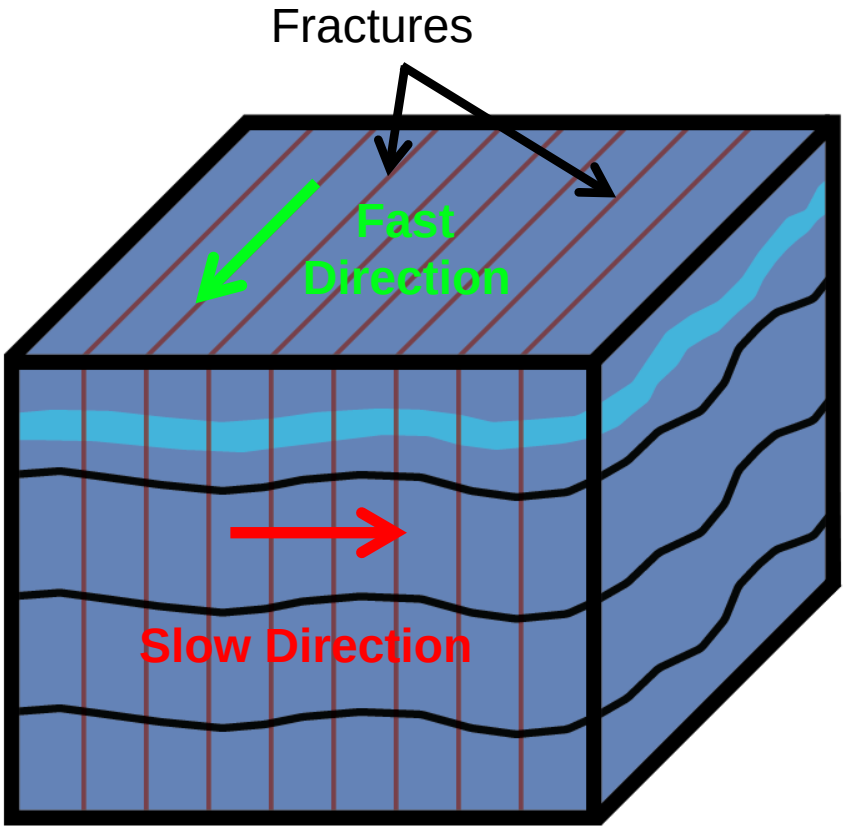
Time structure of Winnipegosis horizon from baseline survey.

Horizontal Transverse Isotropy (HTI)



sectored gather & stack in fast direction

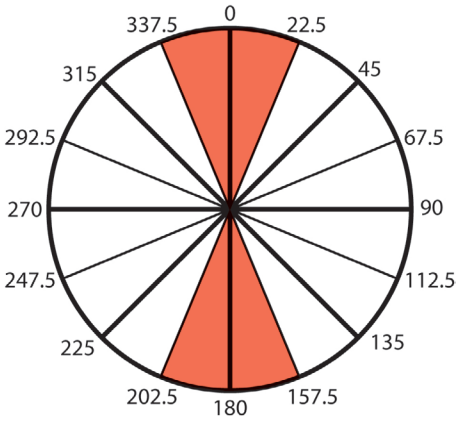
sectored gather & stack in slow direction



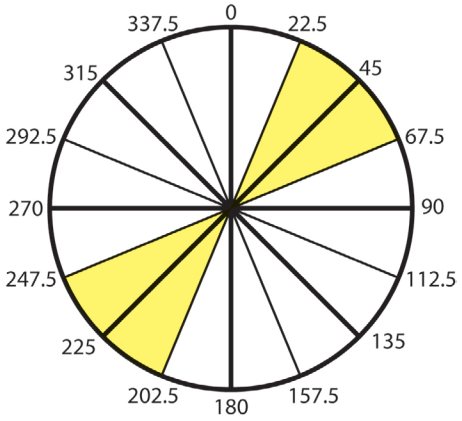
Azimuthal Differencing

- Multicomponent seismic data
  - Only vertical component used here
- 2004 survey repeated in 2008
- Seismic volumes used:
  - Full azimuth
  - 4x45º sectored volumes centred on
    - 0 &180 degrees
    - 45 & 225 degrees
    - 90 & 270 degrees
    - 135 & 315 degrees
- All data are post-stack, time migrated, NMO corrected with full volume velocities

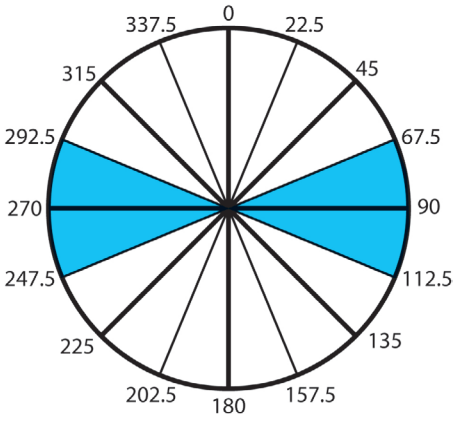
4 Sectored Azimuthal Volumes



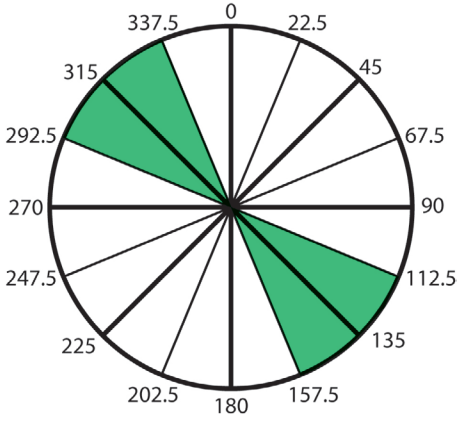
0&180



45&225

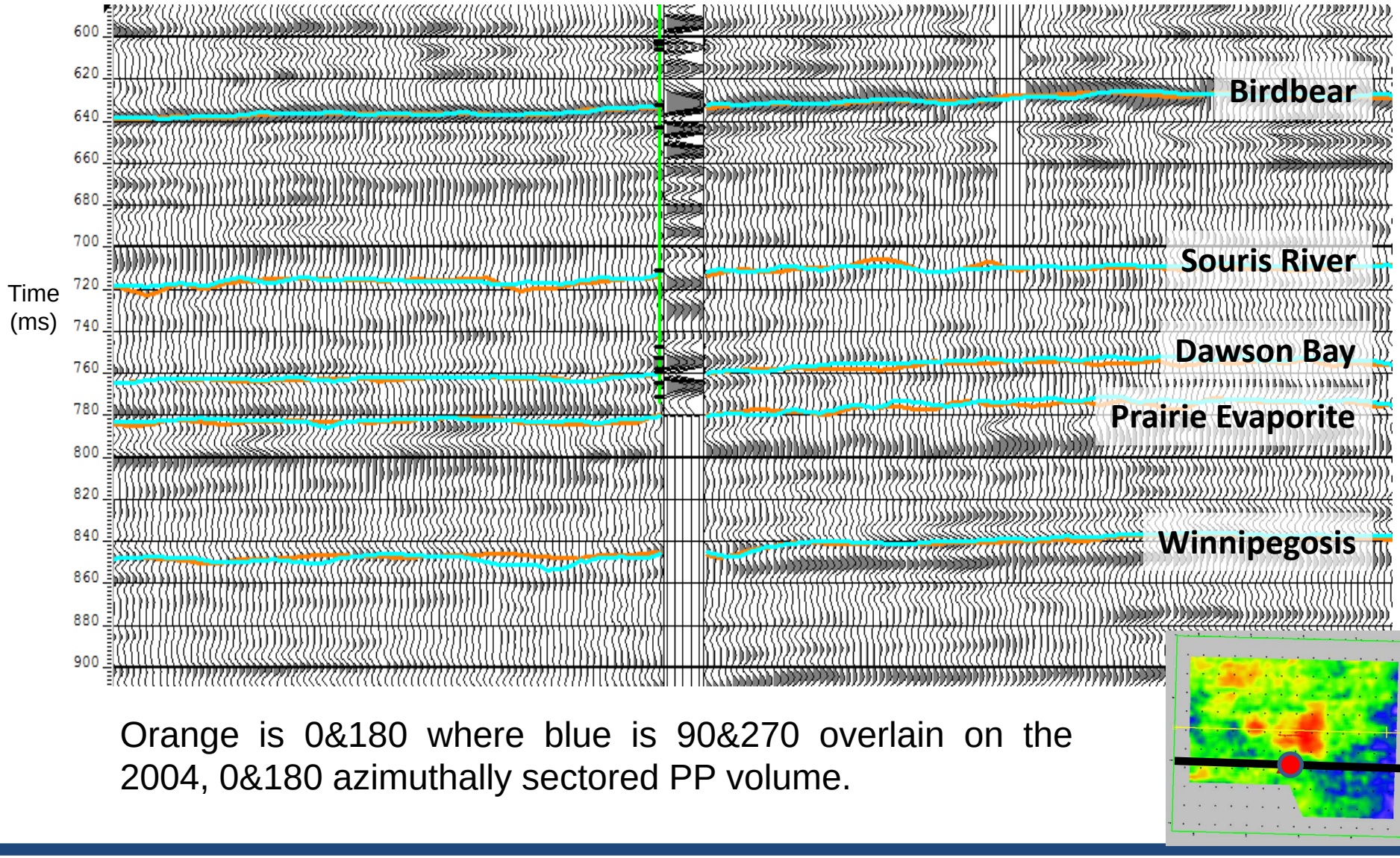


90&270



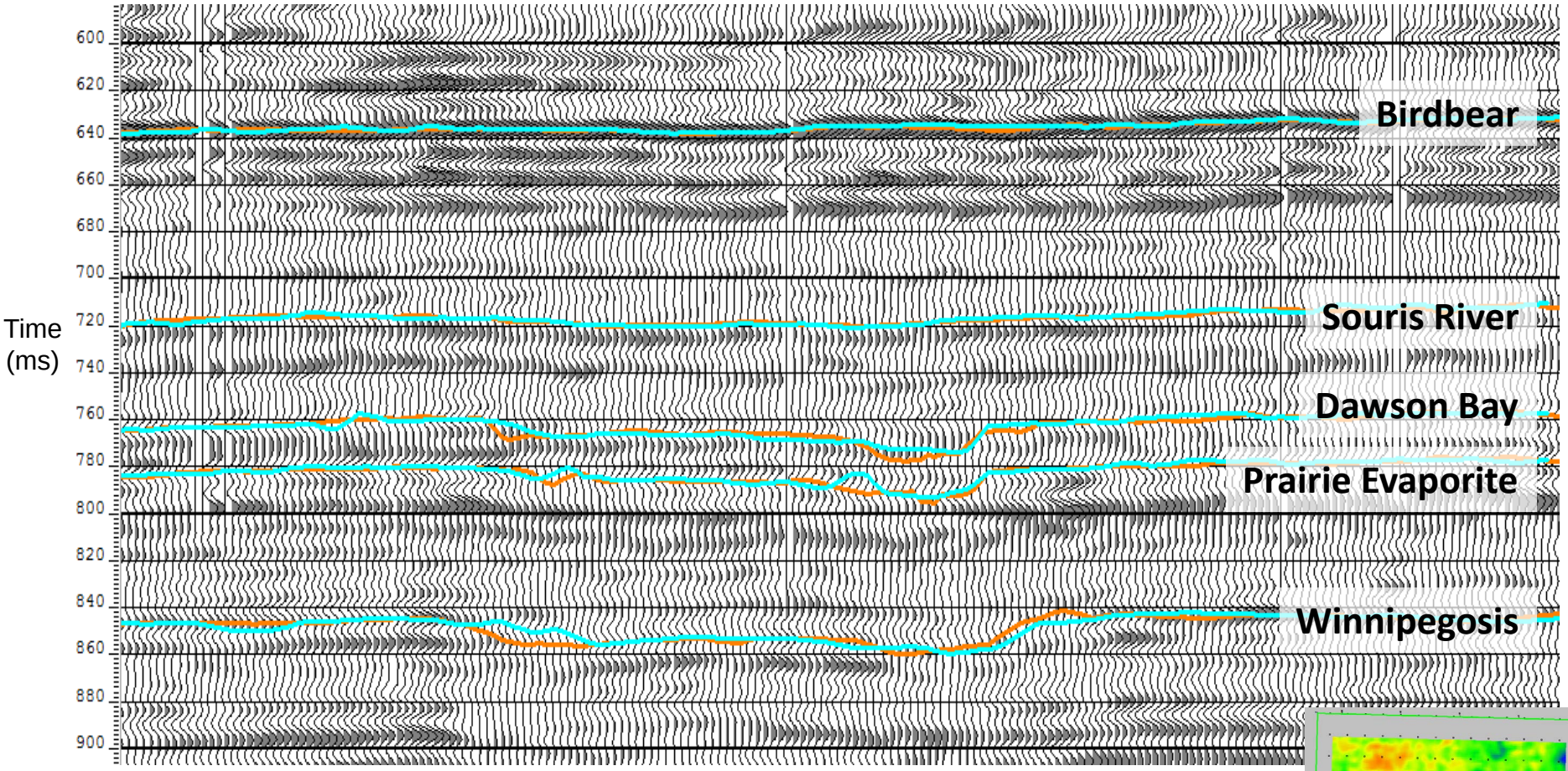
135&315

Azimuthal Differencing

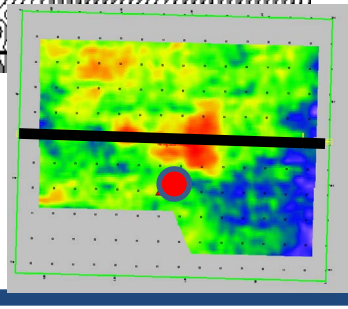


Orange is 0&180 where blue is 90&270 overlain on the 2004, 0&180 azimuthally sectored PP volume.

Azimuthal Differencing

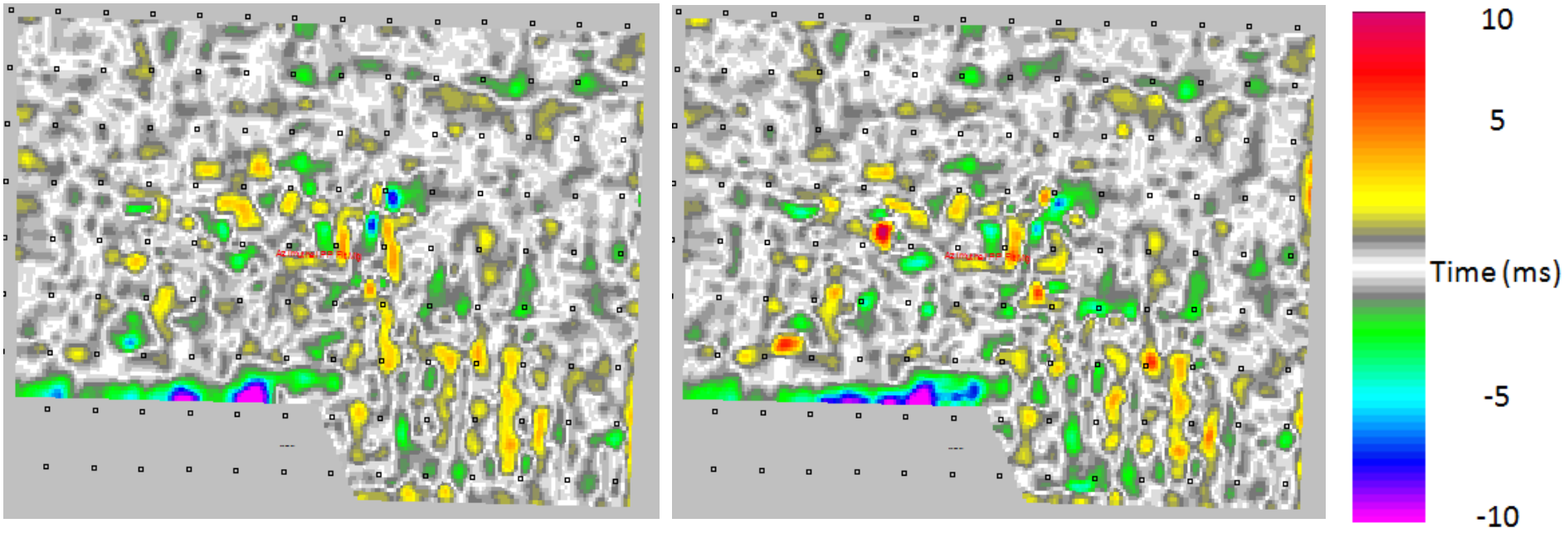


Orange is 0&180 where blue is 90&270 overlain on the 2004, 0&180 azimuthally sectored PP volume through the low velocity anomaly.



Azimuthal Differencing

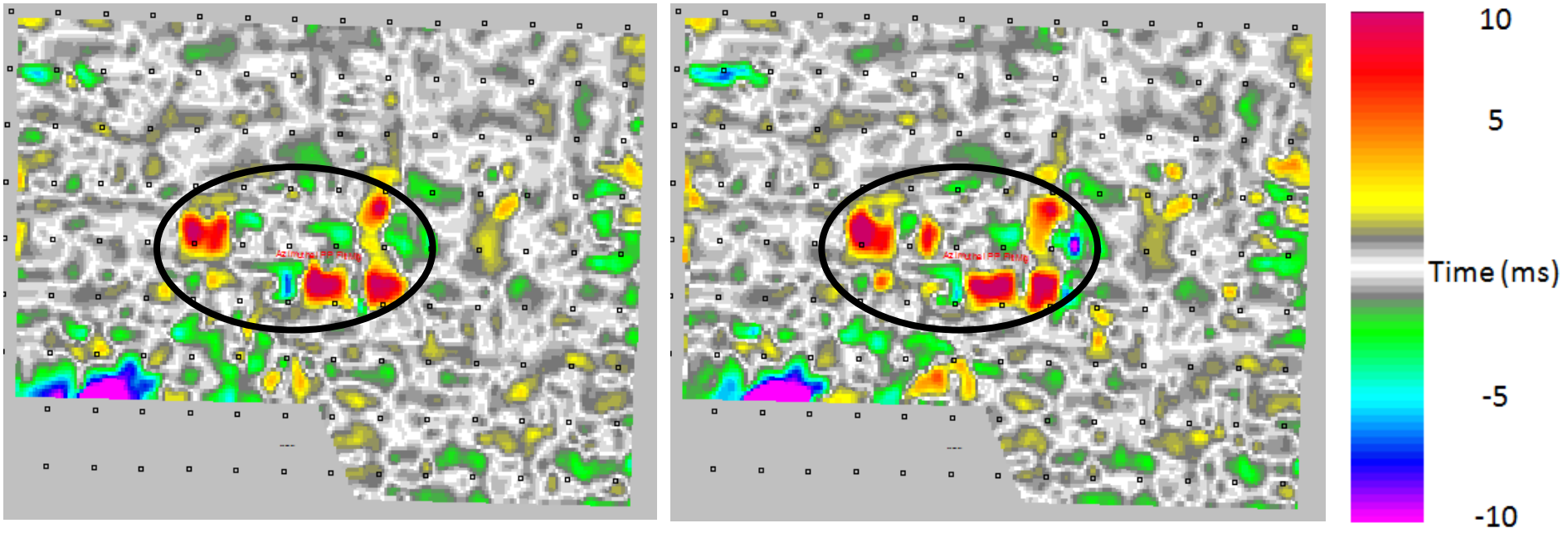
0&180 - 90&270



2004 (left) and 2008 (right) map of PP azimuthal travel-time difference at the Prairie Evaporite Formation.

Azimuthal Differencing

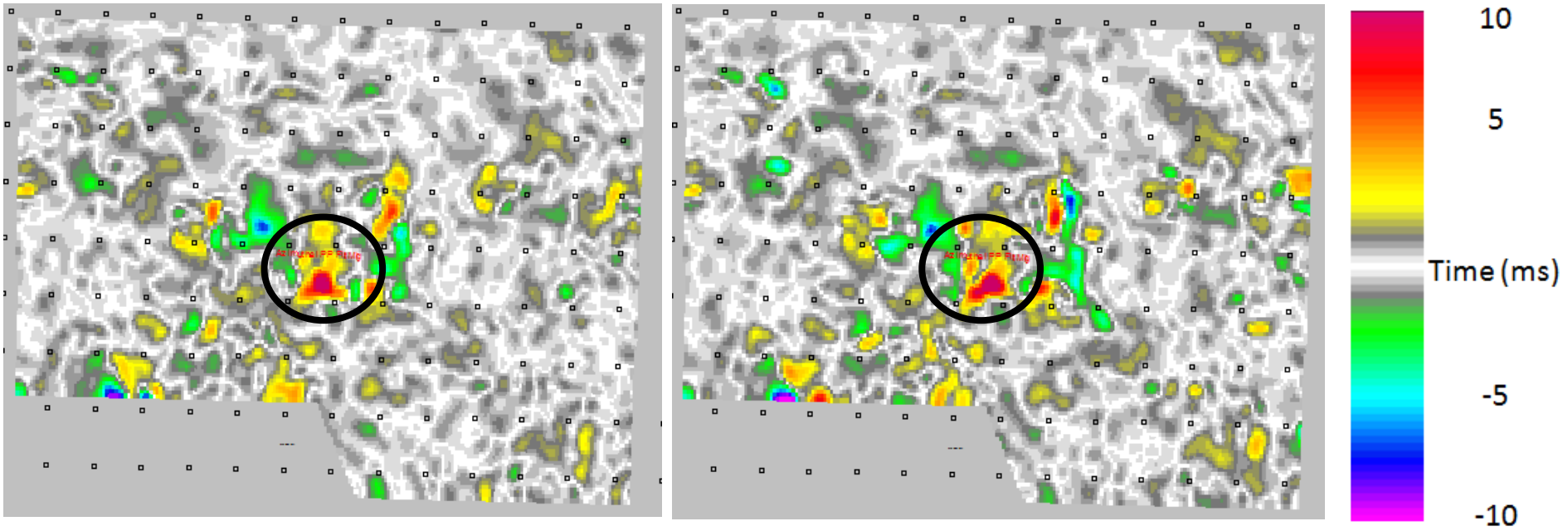
0&180 - 90&270



2004 (left) and 2008 (right) map of PP azimuthal travel-time difference at the Winnipegosis Formation.

Azimuthal Differencing

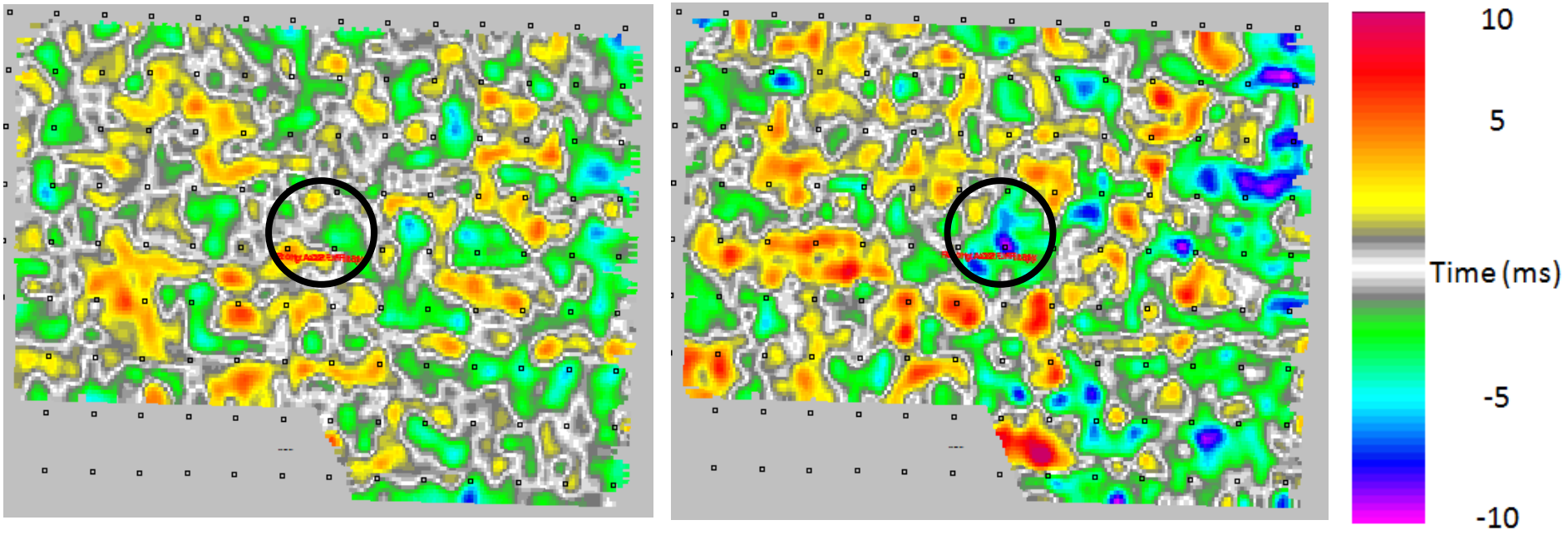
45&225 – 135&315



2004 (left) and 2008 (right) map of PP azimuthal travel-time difference at the Winnipegosis Formation.

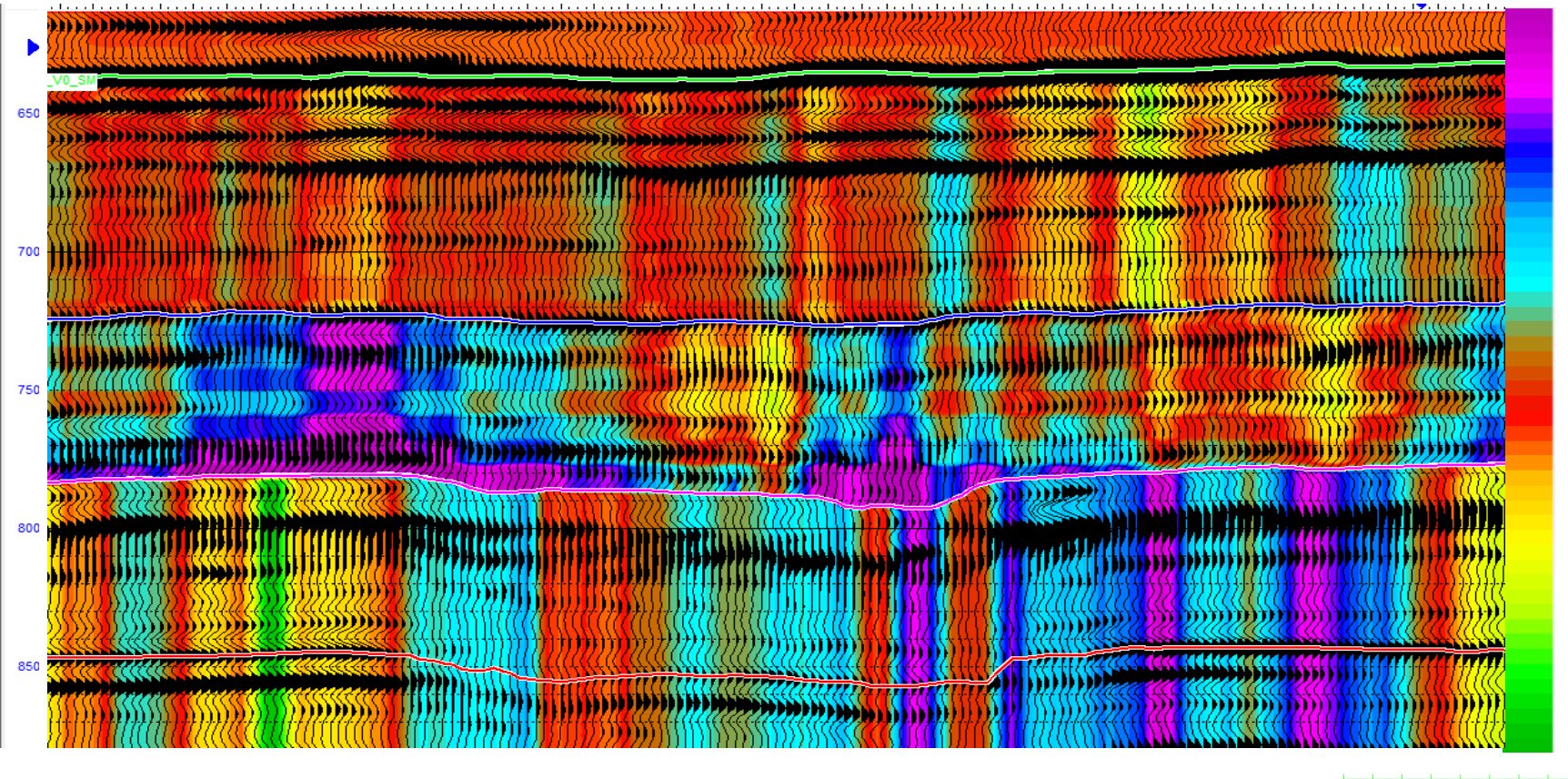
Azimuthal Differencing

0&180 - 90&270

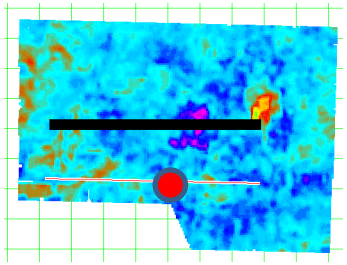


2004 (left) and 2008 (right) map of PS azimuthal travel-time difference at the Prairie Evaporite Formation.

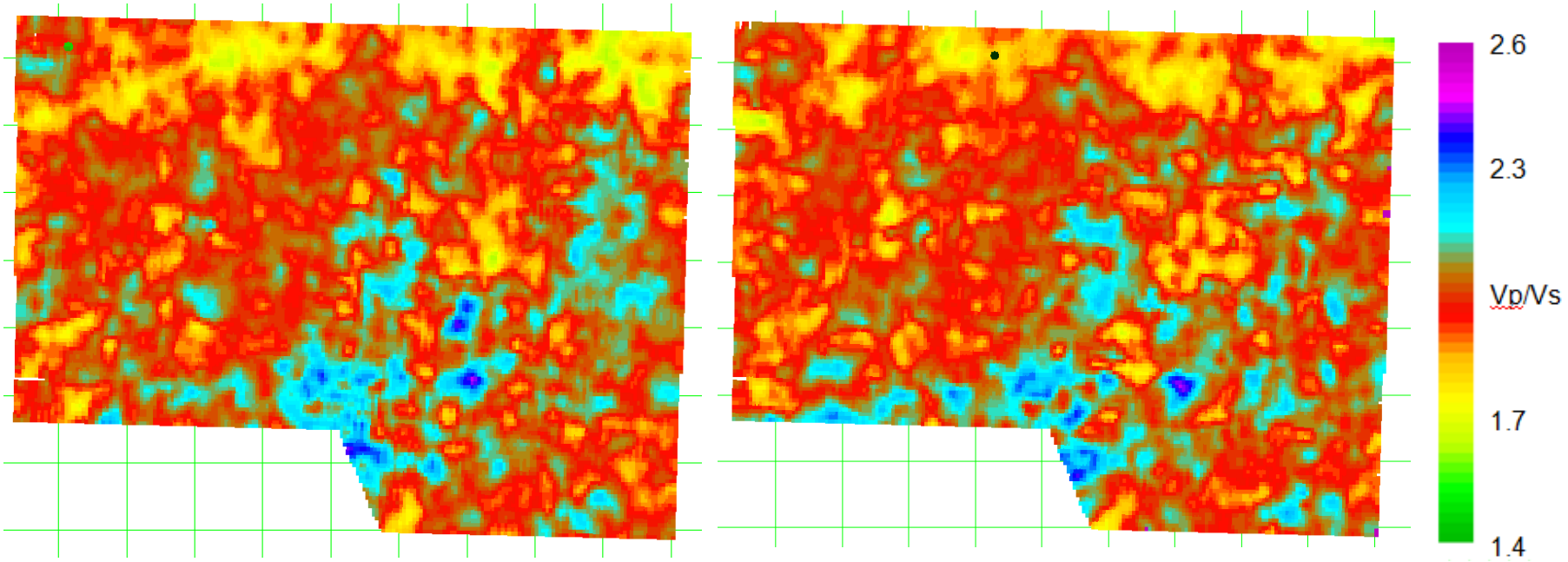
Vp/Vs Analysis



2004 full azimuth PP seismic volume (wiggle trace) with Vp/Vs ratio (color).



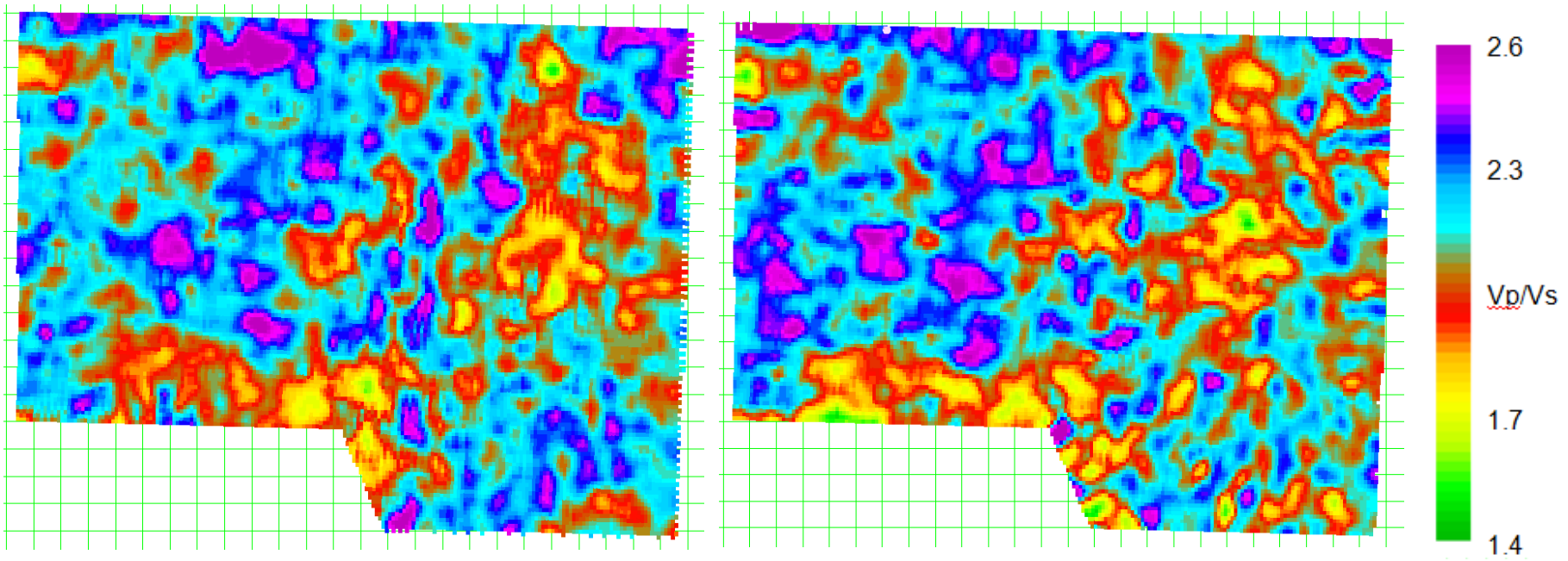
Interval Vp/Vs



2004 (left) and 2008 (right) map of interval Vp/Vs for the Birdbear – Souris River interval.

Vp/Vs Analysis

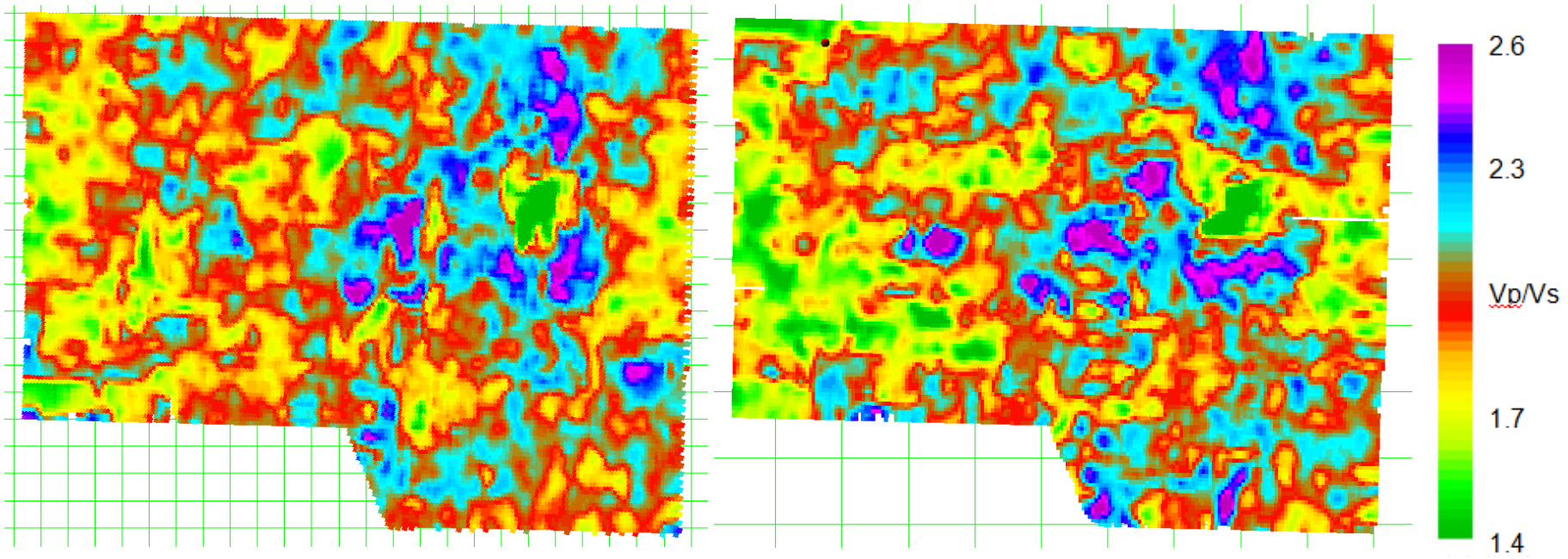
Interval Vp/Vs



2004 (left) and 2008 (right) map of interval Vp/Vs for the Souris River – Prairie Evaporite interval.

Vp/Vs Analysis

Interval Vp/Vs



2004 (left) and 2008 (right) map of interval Vp/Vs for the Prairie Evaporite – Winnipegosis interval.

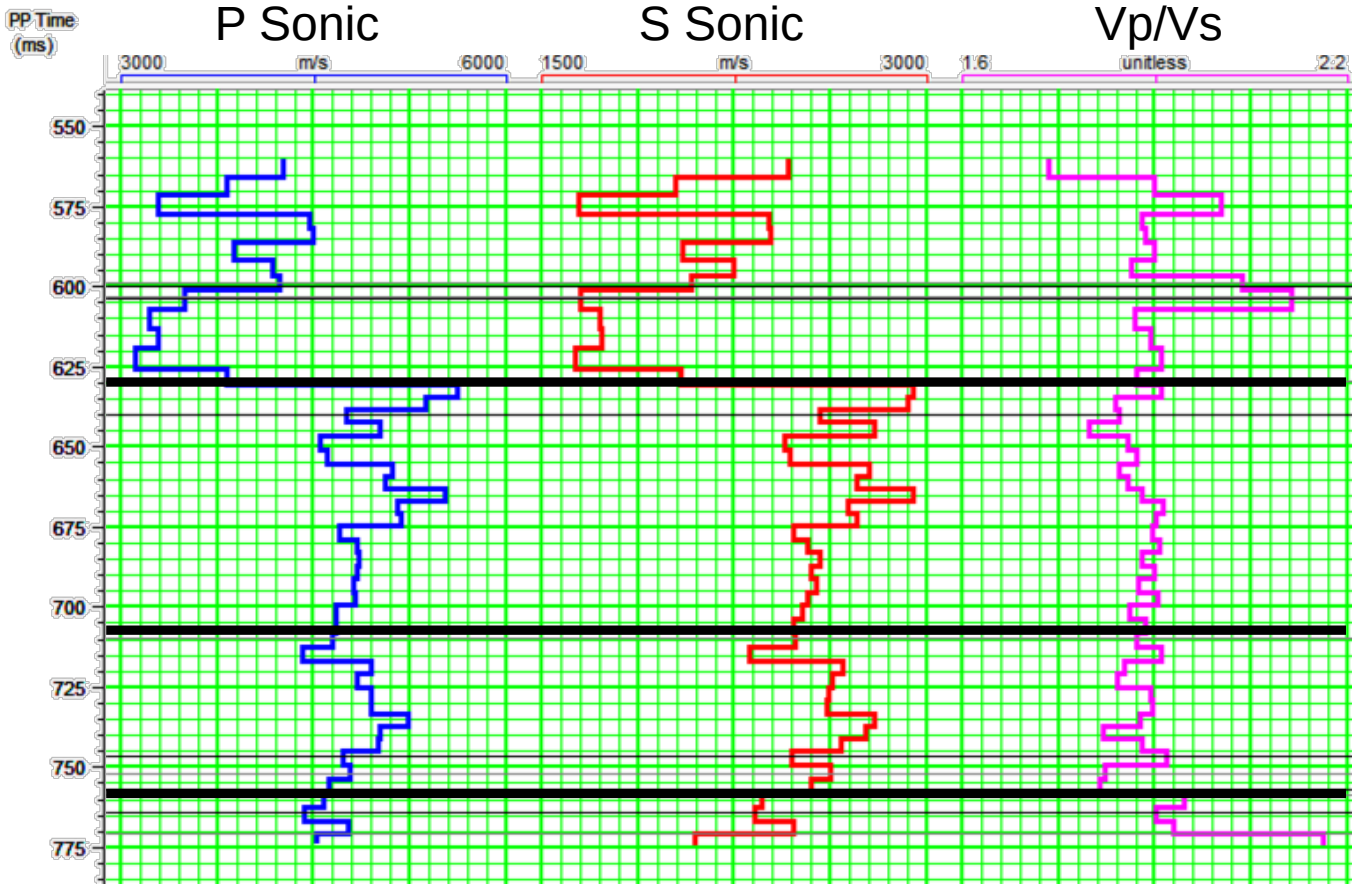
Conclusions

- Fractures propagate through Dawson Bay Formation, possibly as far up as Souris River Formation.
- Travel time differences between orthogonal azimuths suggest preferential orientation of fractures.
- Decrease in Vs is responsible for high Vp/Vs in centre of survey area due to subvertical fracturing.
- Horizon registration combined with well data produces Vp/Vs indicative of fractured Dawson Bay Formation strata.

Acknowledgements

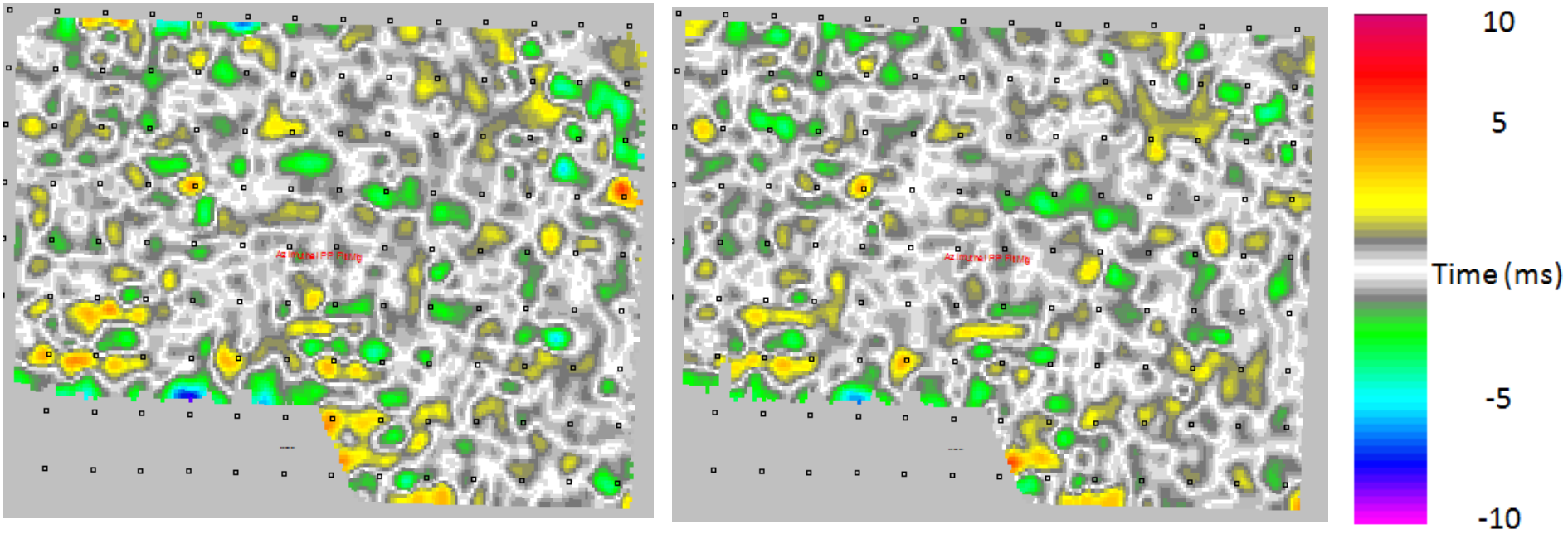
- CREWES Sponsors
- RPS Boyd Petrosearch for the use of the dataset
- The University of Calgary – Department of Geoscience
- Hampson-Russell Software Services
- SeisWare

Well Logs


PP Time (ms)
P Sonic
3000
m/s
6000
S Sonic
1500
m/s
3000
Vp/Vs
1.6
unitless
2.2
550
575
600
625
650
675
700
725
750
775
Birdbear
Souris River
Dawson Bay

Azimuthal Differencing

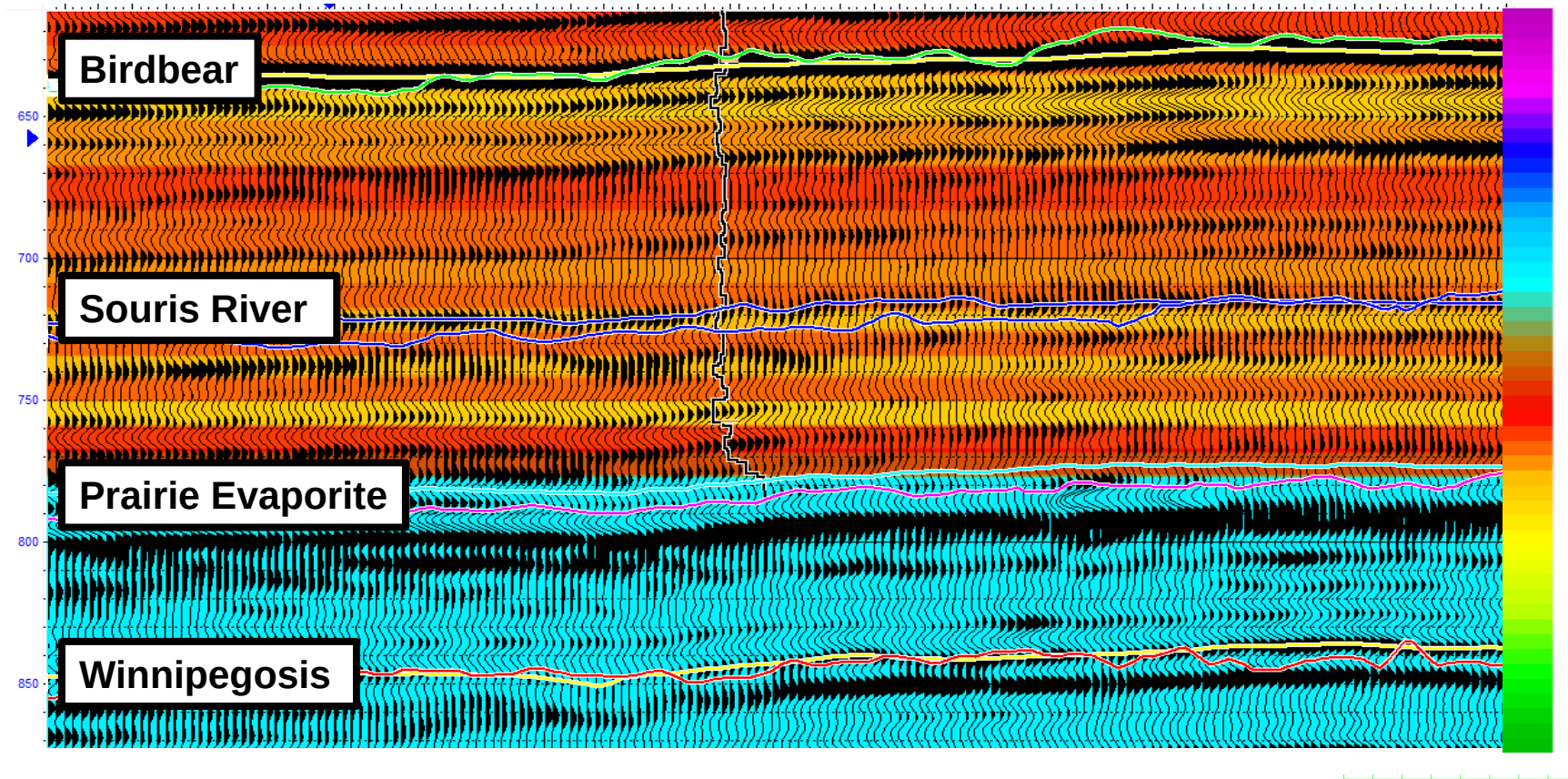
0&180 - 90&270



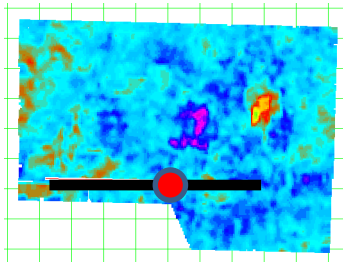
2004 (left) and 2008 (right) map of PP azimuthal travel-time difference at the Souris River Formation.

Vp/Vs Analysis

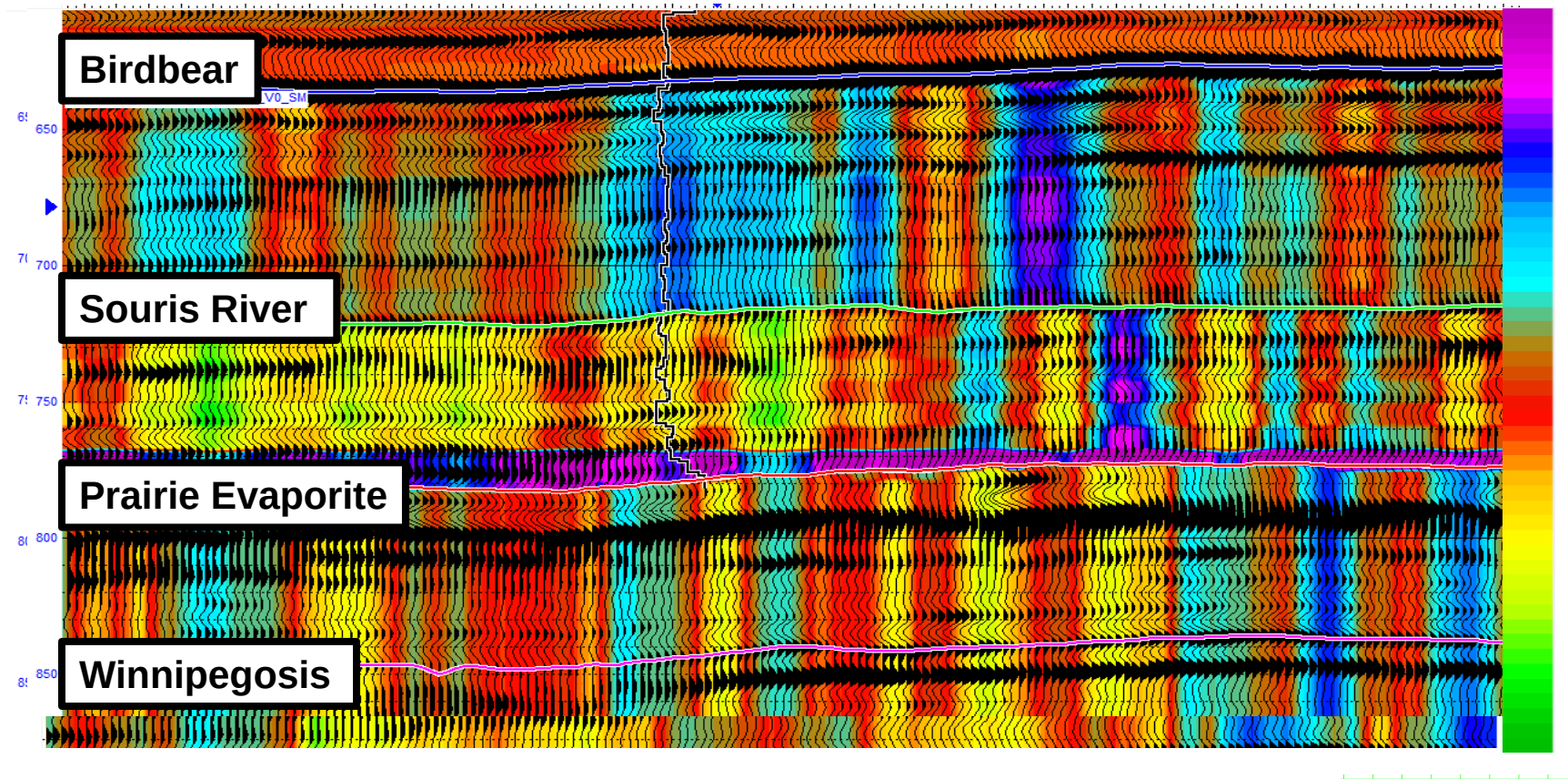
Well Control Only



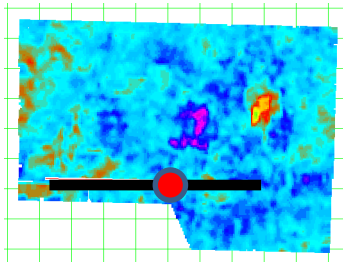
2004 full azimuth PP seismic volume (wiggle trace) with Vp/Vs ratio (color).



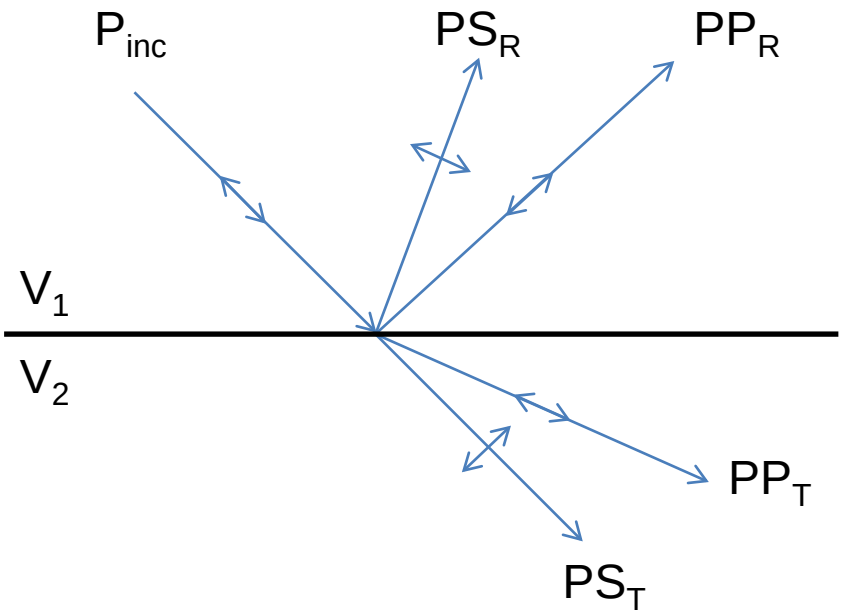
Vp/Vs Analysis



2004 full azimuth PP seismic volume (wiggle trace) with Vp/Vs ratio (color).



Multicomponent Seismology



Snell's Law governs the partitioning of seismic energy at a lithology boundary.

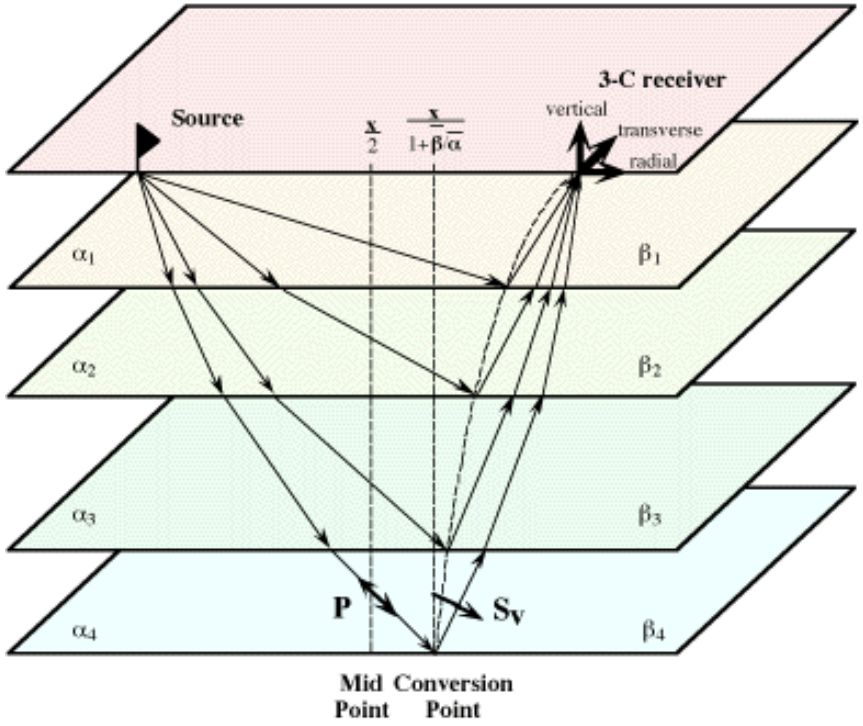


Image showing the asymptotic conversion point where P energy is converted into shear energy. (www.CREWES.org)