Numerical modeling of shear-wave splitting and azimuthal velocity analysis in fractured media

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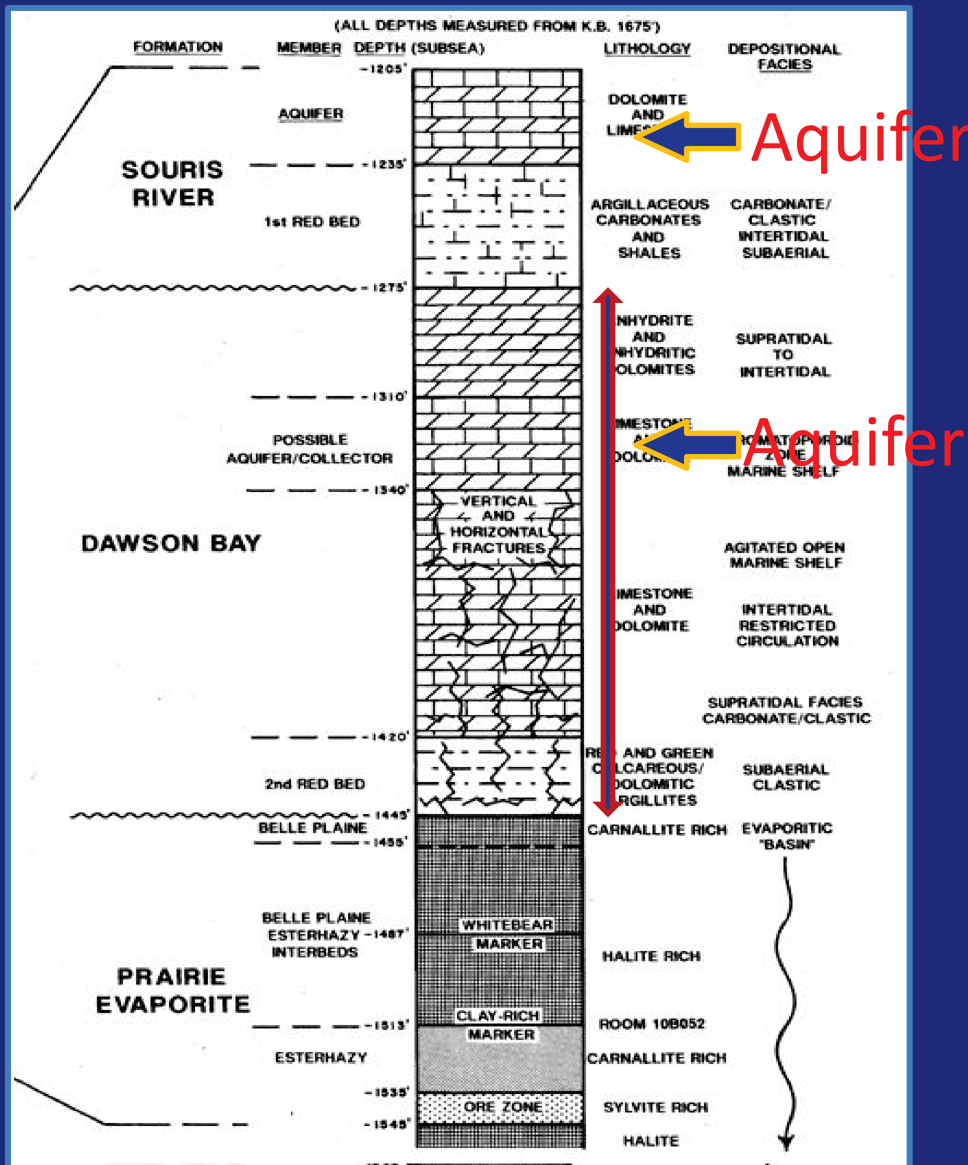
Outline

- ❑ Introduction
- ❑ Numerical seismic modeling
- ❑ 3C-3D seismic data processing
- ❑ Results
- ❑ Conclusions
- ❑ Acknowledgements



Fracture effects from previous study:

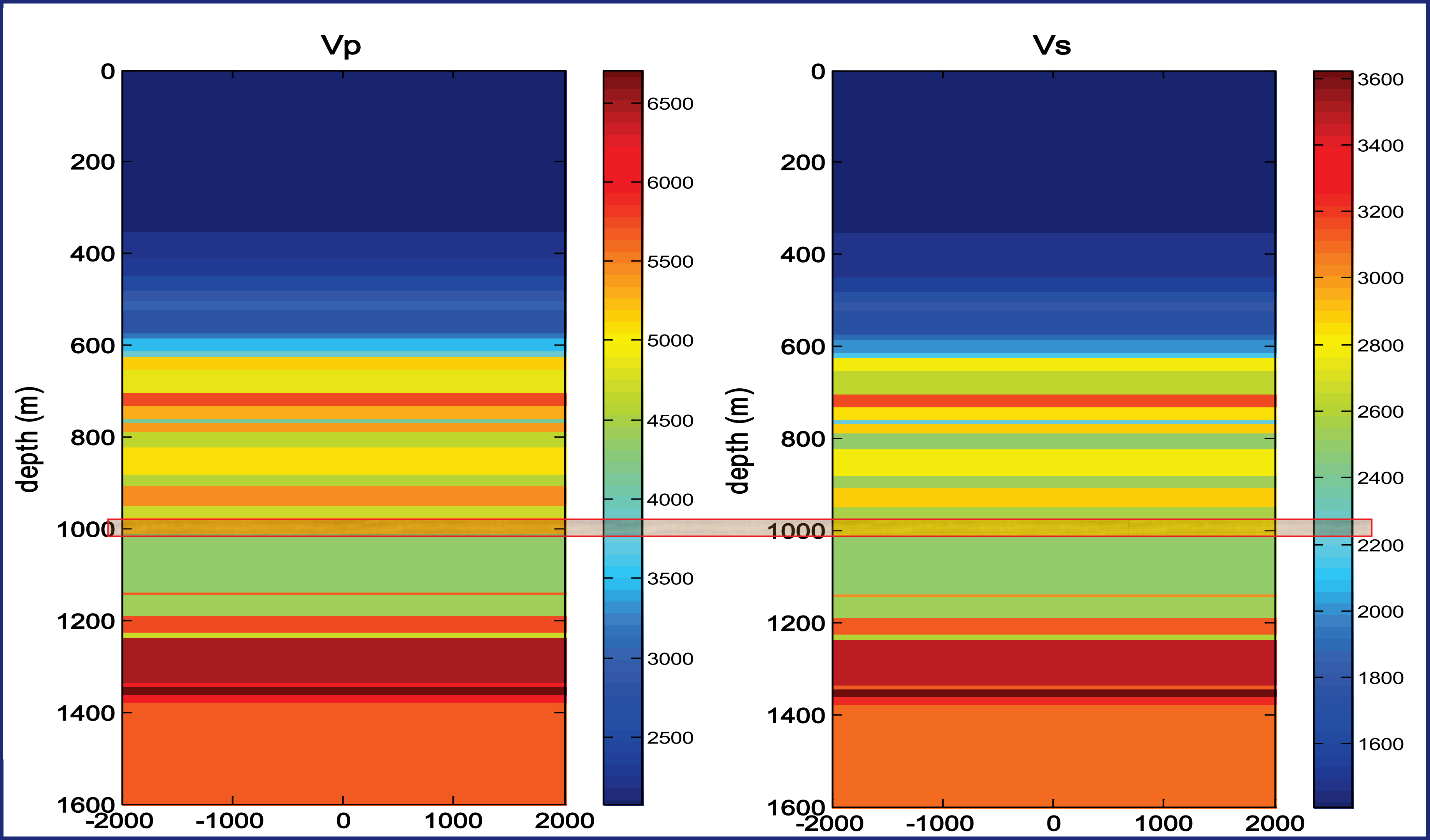
1) Velocity decreases, S velocity drops over 20%
2) P- and S-velocity anisotropy with aligned fractures

Local stratigraphy of Prairie Evaporite and overlying formations in the mining area (from R. Edgecombe, 2008).

Objectives

1) Is fracture induced anisotropy detectable?
2) Can we see and use shear-wave splitting for fracture characterization?
3) Compare the sensitivity of P-waves and S-waves to fractures.

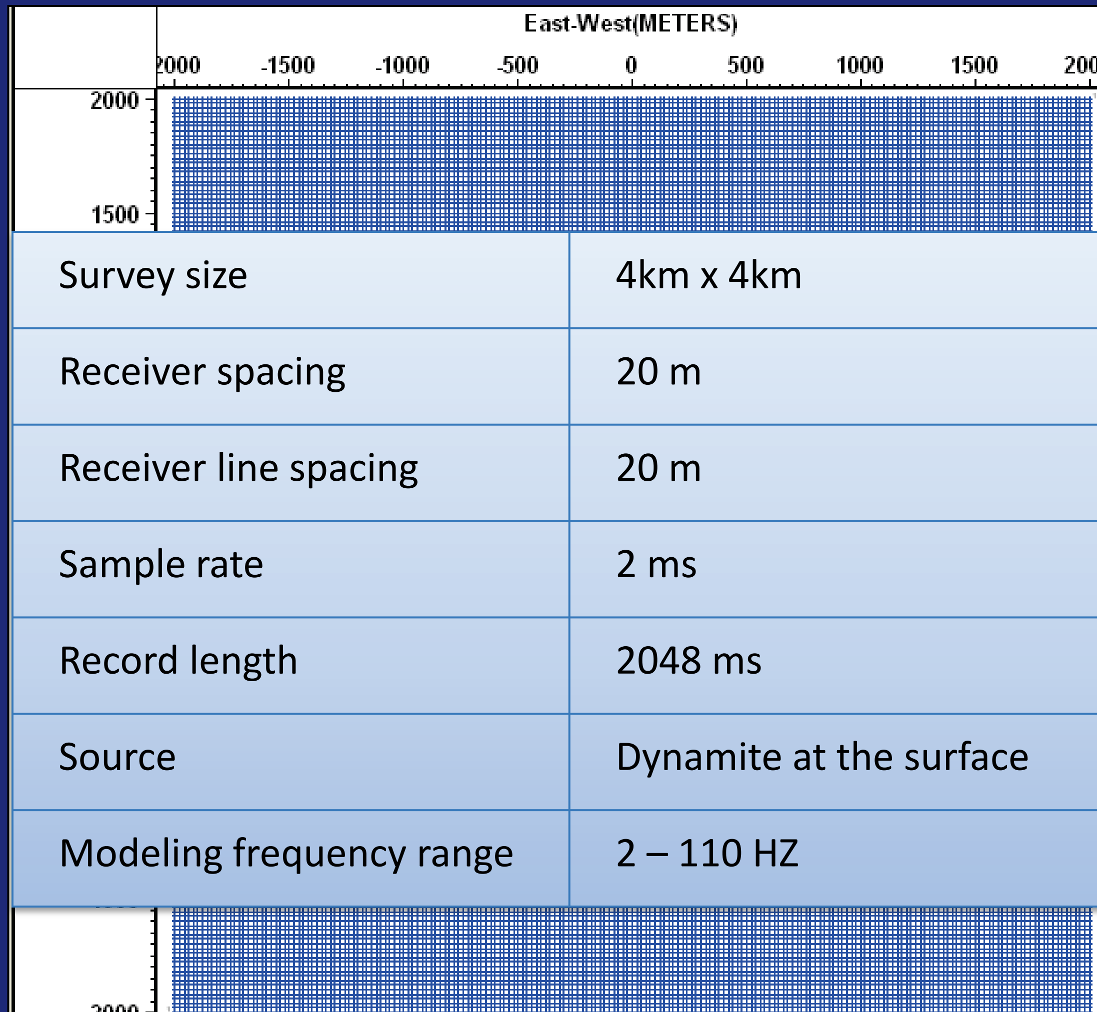
Blocked well logs and stratigraphic chart (after Fuzesy, 1982)



Rock properties of fractured layer

Top	970.8 m	
Thickness	40.4 m	
Crack parameters	1% penny-shape vertically aligned (along y axis of the survey) fractures, filled by brine with Vp 1430m/s, density 1100 kg/m^3.	
	fractured	unfractured
Density	2603.9 kg/m^3	2630.2 kg/ m^3
Stiffness matrix ($x10^{10}$ $kg/m^2 \cdot s$)	5.610 2.354 2.354 0 0 0 2.354 6.813 2.710 0 0 0 2.354 2.710 6.813 0 0 0 0 0 0 2.052 0 0 0 0 0 0 1.243 0 0 0 0 0 0 1.243	Vp: 5184.7 m/s Vs: 2792.9 m/s

Survey design



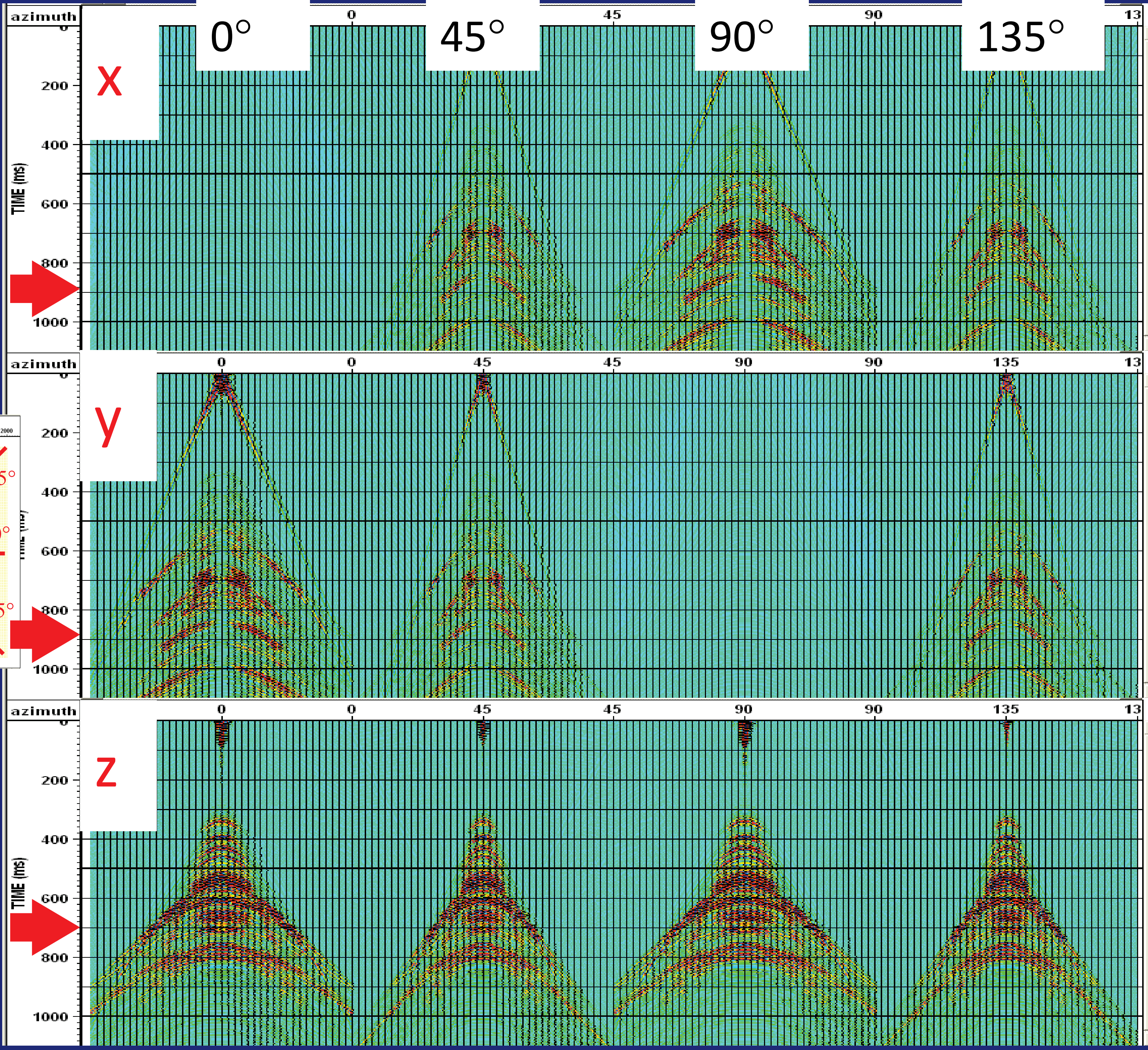
Survey size	4km x 4km
Receiver spacing	20 m
Receiver line spacing	20 m
Sample rate	2 ms
Record length	2048 ms
Source	Dynamite at the surface
Modeling frequency range	2 – 110 HZ

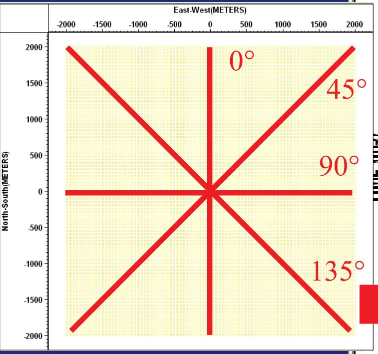
Fracture direction

y

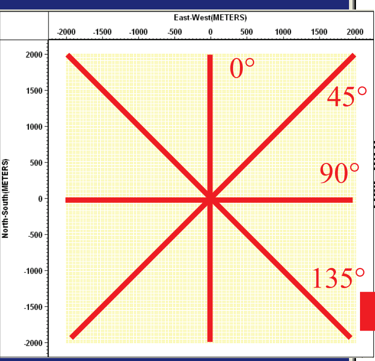
x

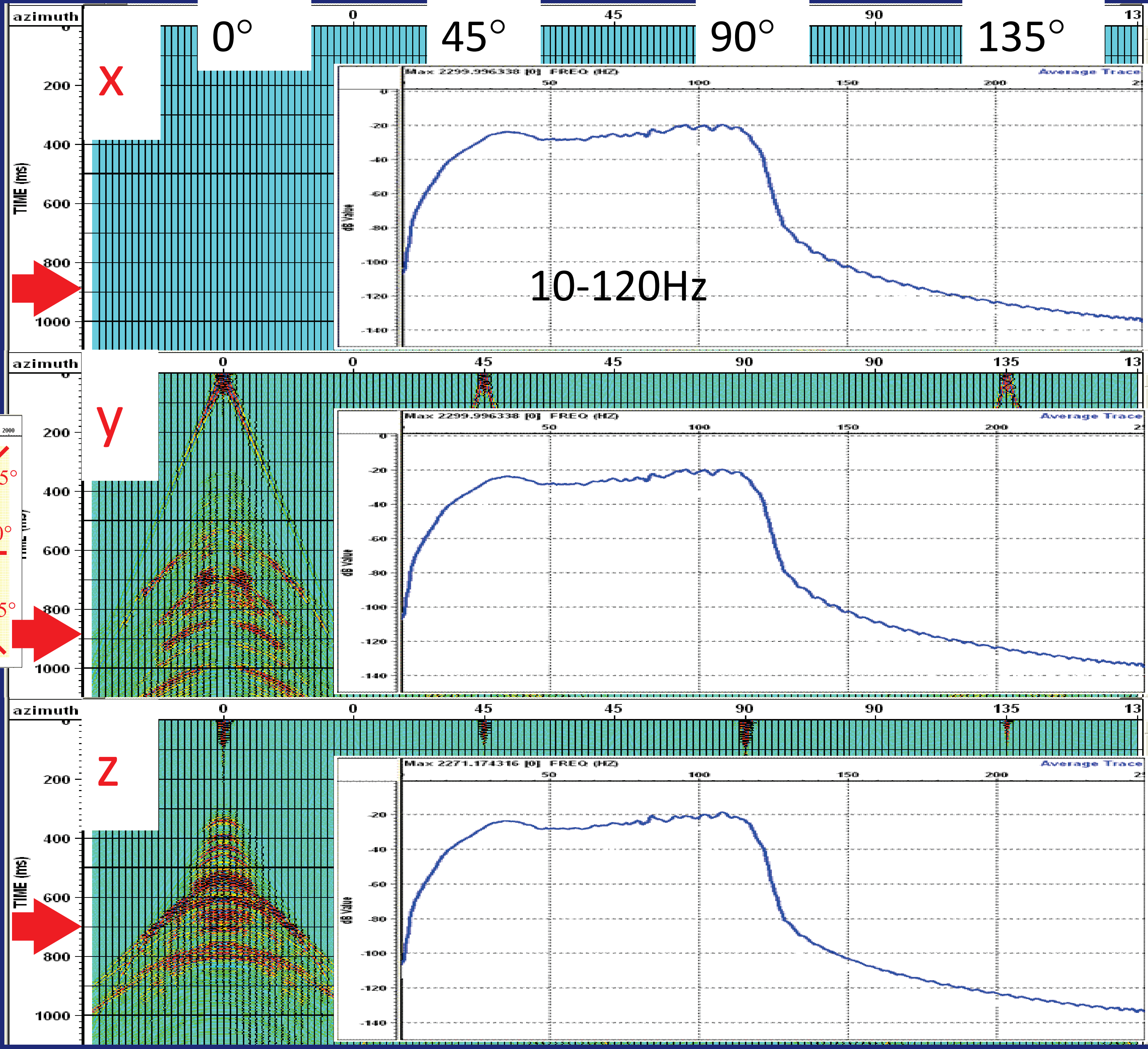
Raw data (isotropic)



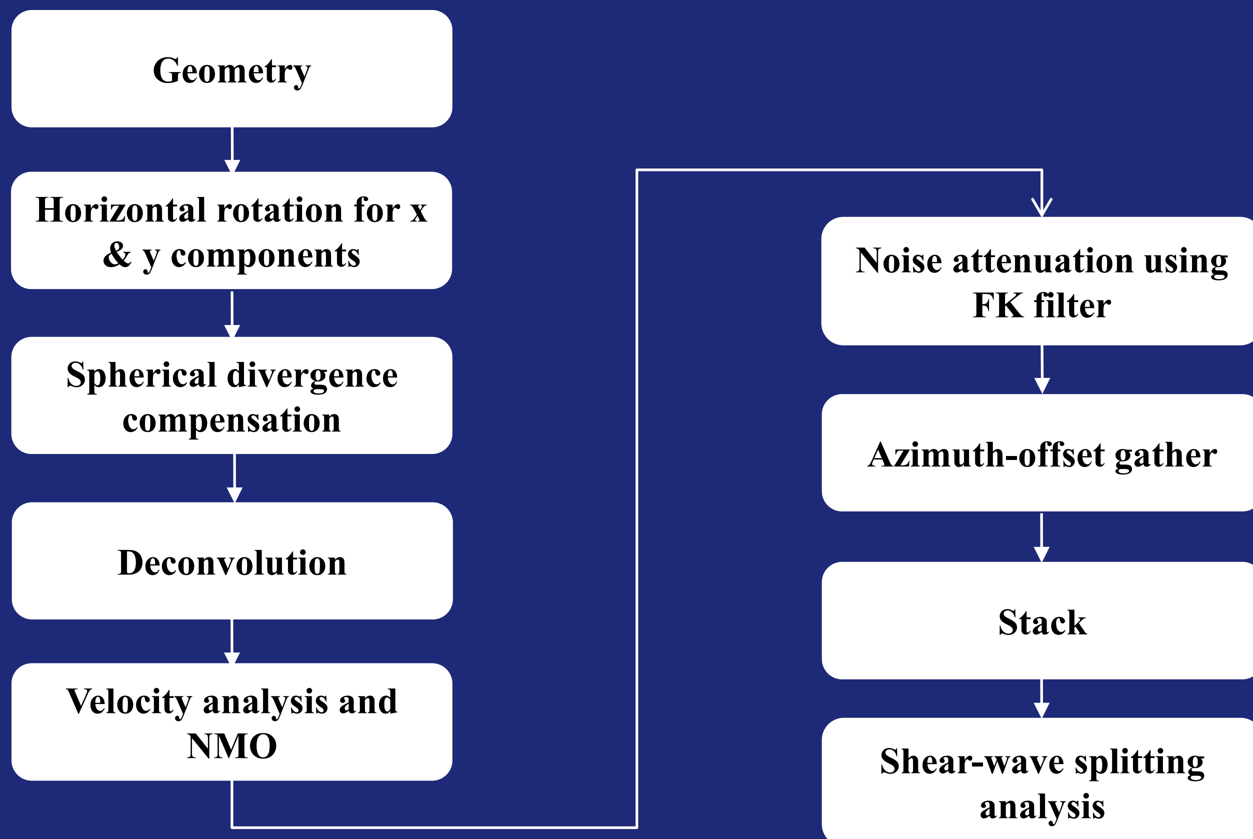


Raw data (HTI)


East-West(METERS)
North-South(METERS)
0°
45°
90°
135°


azimuth
0°
45°
90°
135°
x
y
z
TIME (ms)
dB Value
Max 2299.996338 [0] FREQ (HZ)
Max 2271.174316 [0] FREQ (HZ)
Average Trace
10-120Hz

3C seismic data processing workflow

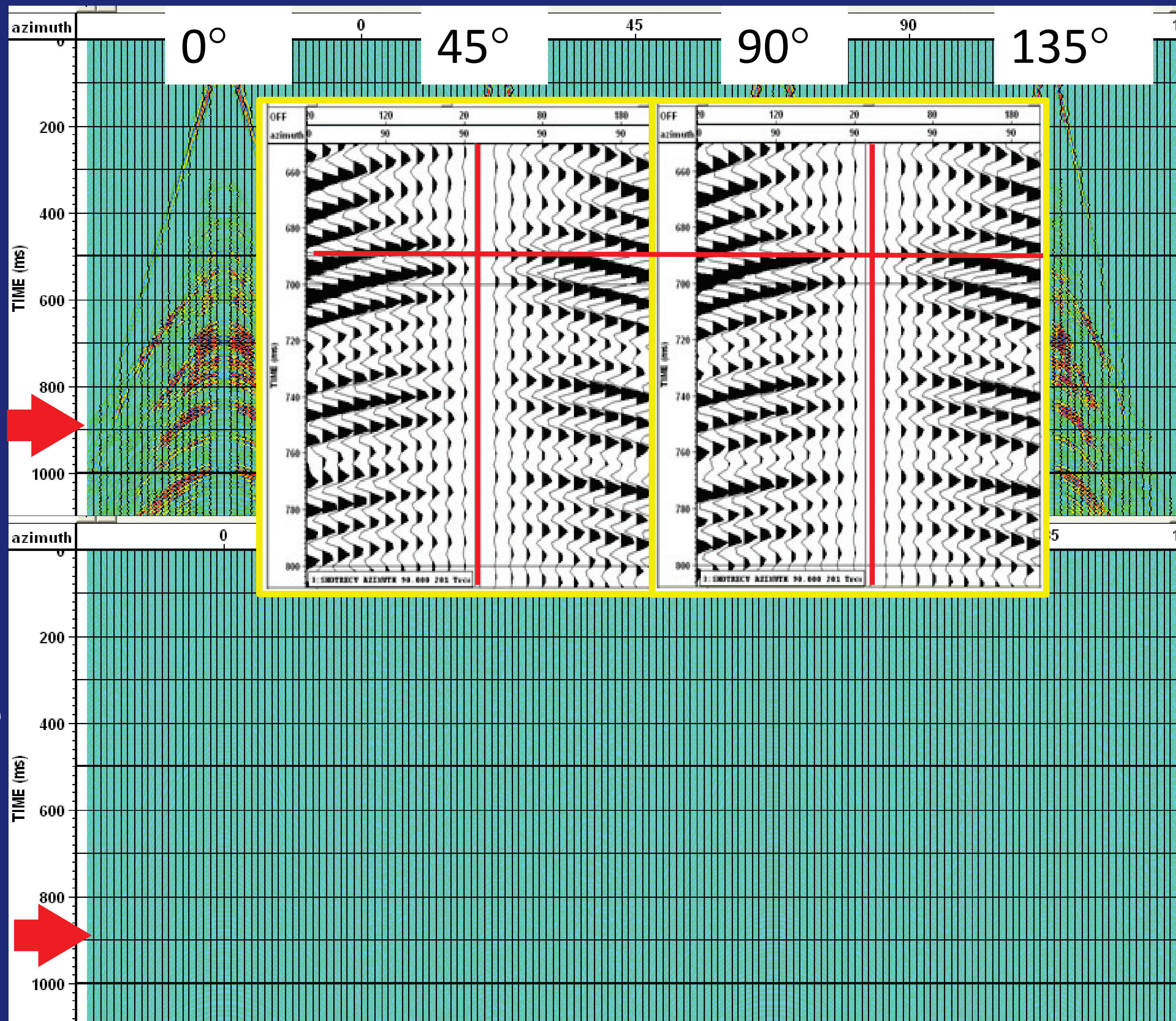


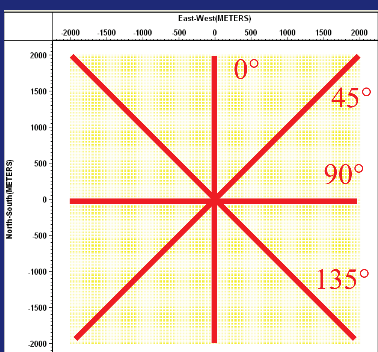
Radial and transverse components of isotropic model

(from horizontal rotation)

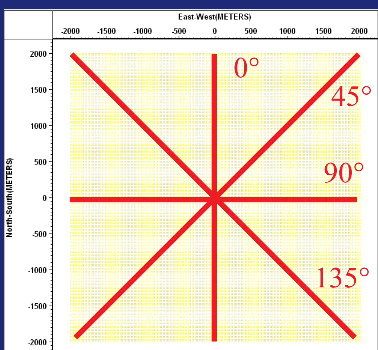
radial

transverse



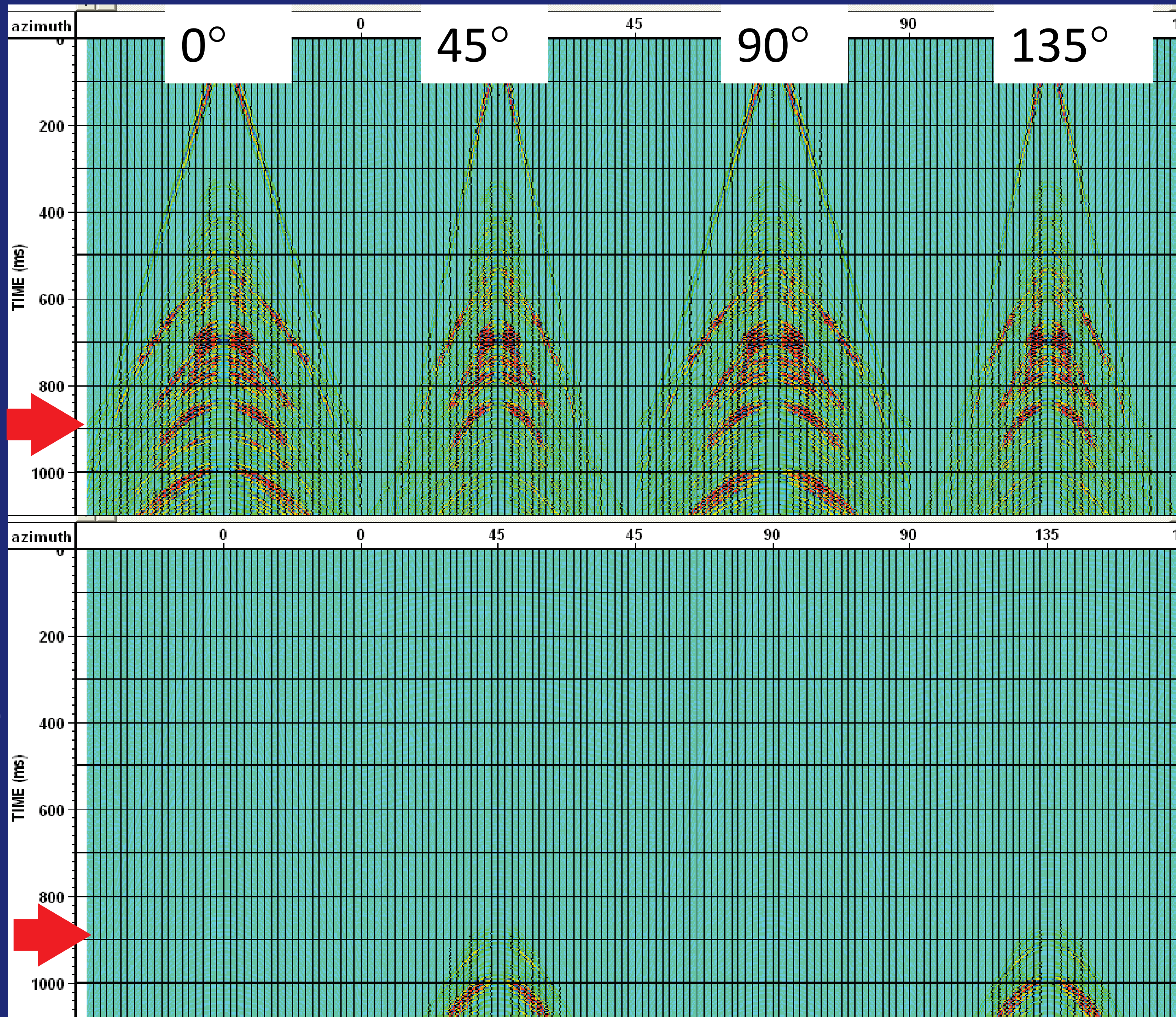


Radial and transverse components of HTI model
(from horizontal rotation)



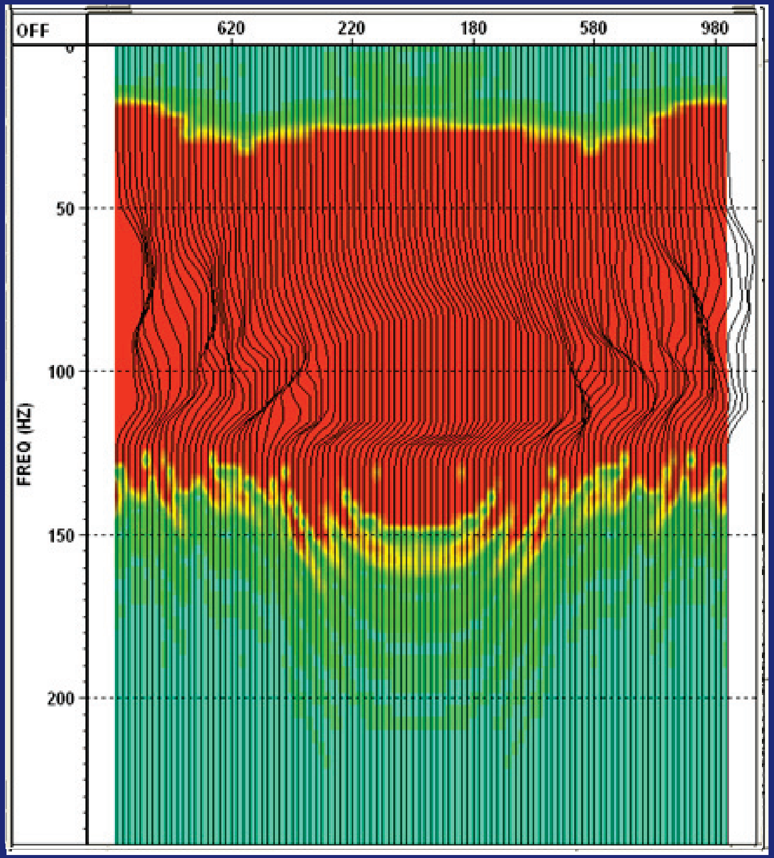
radial

transverse

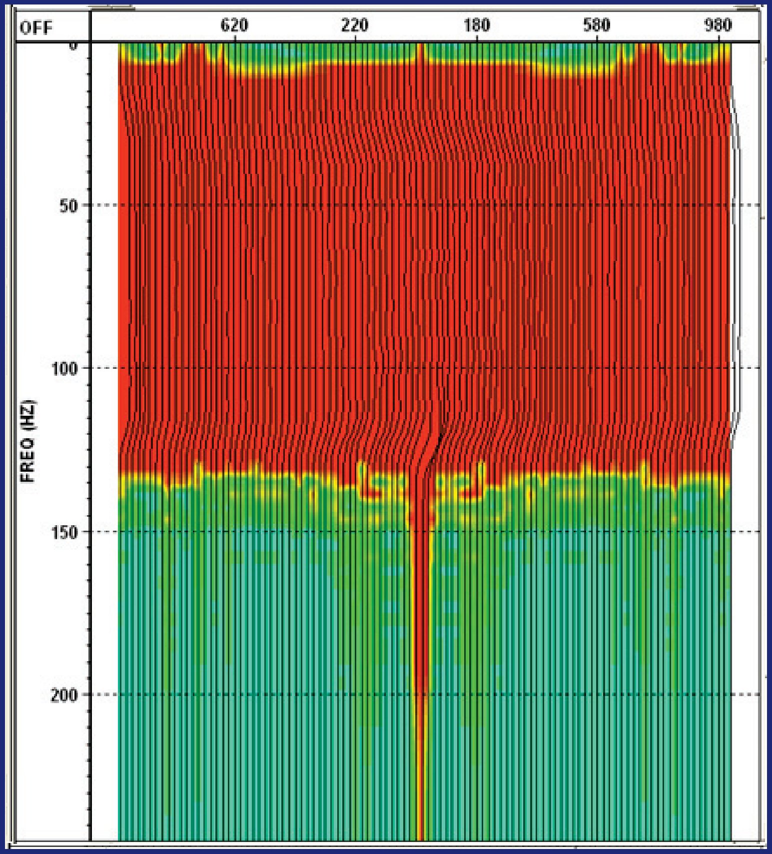


Deconvolution

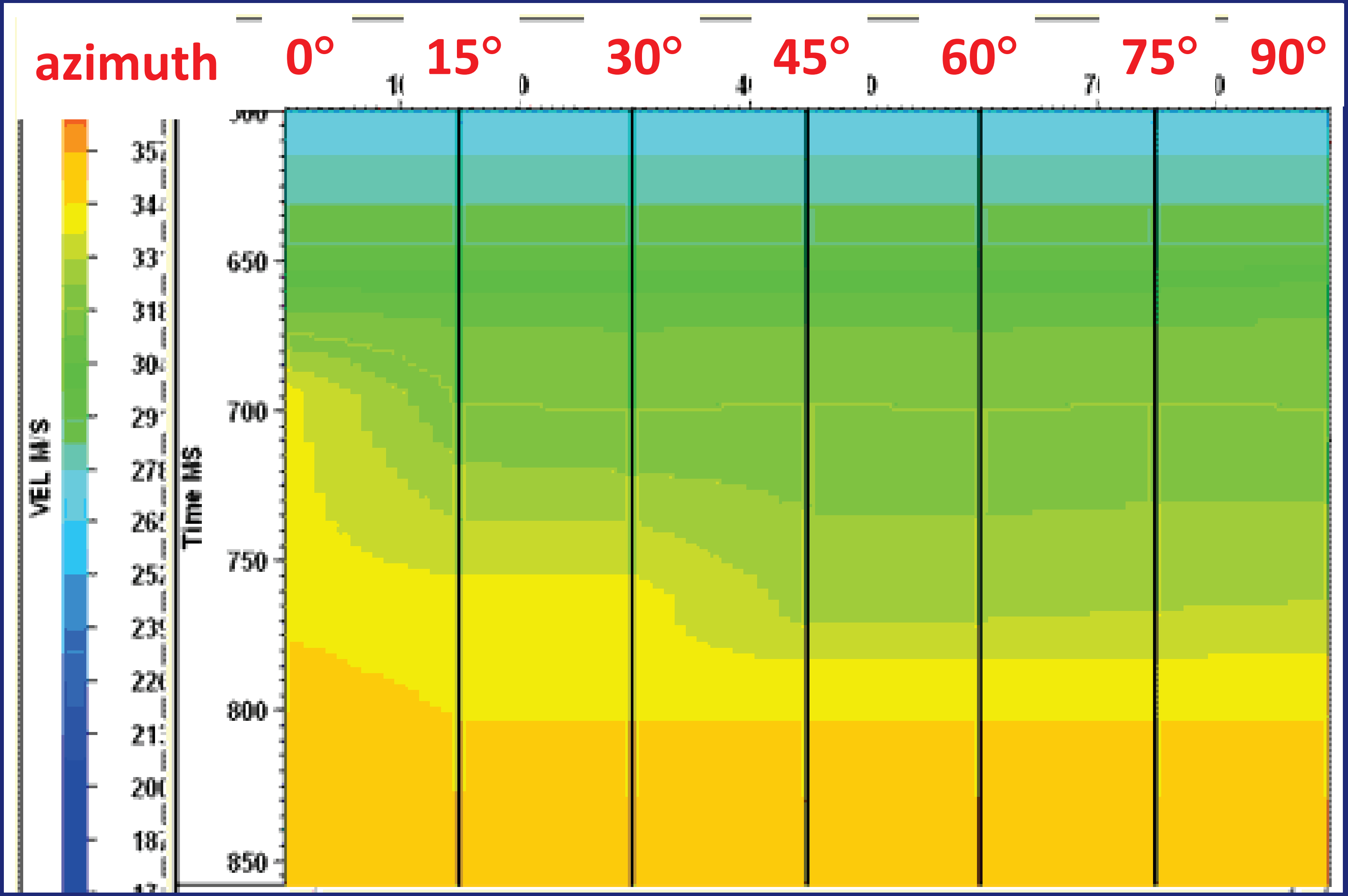
Before deconvolution



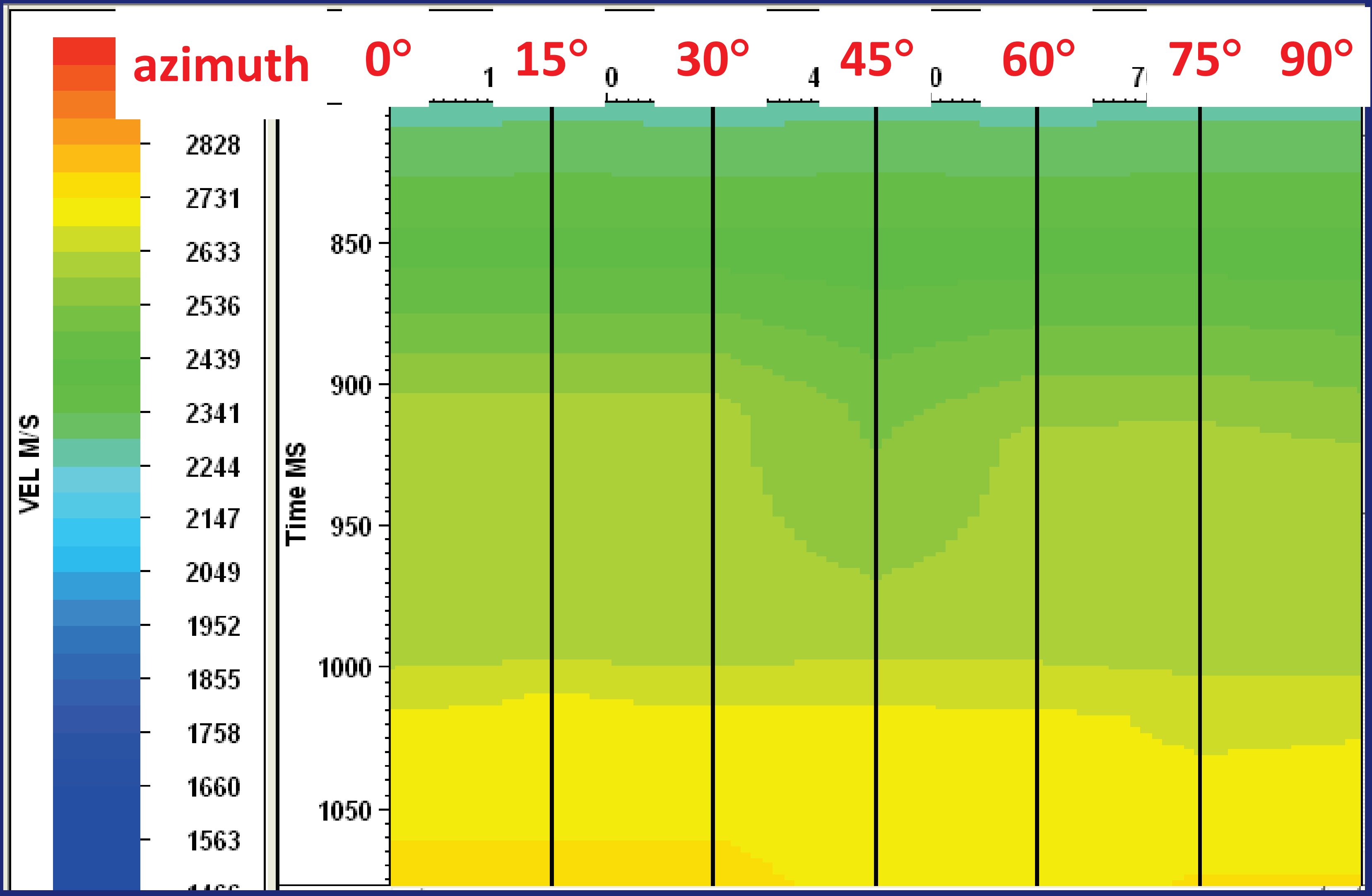
After deconvolution



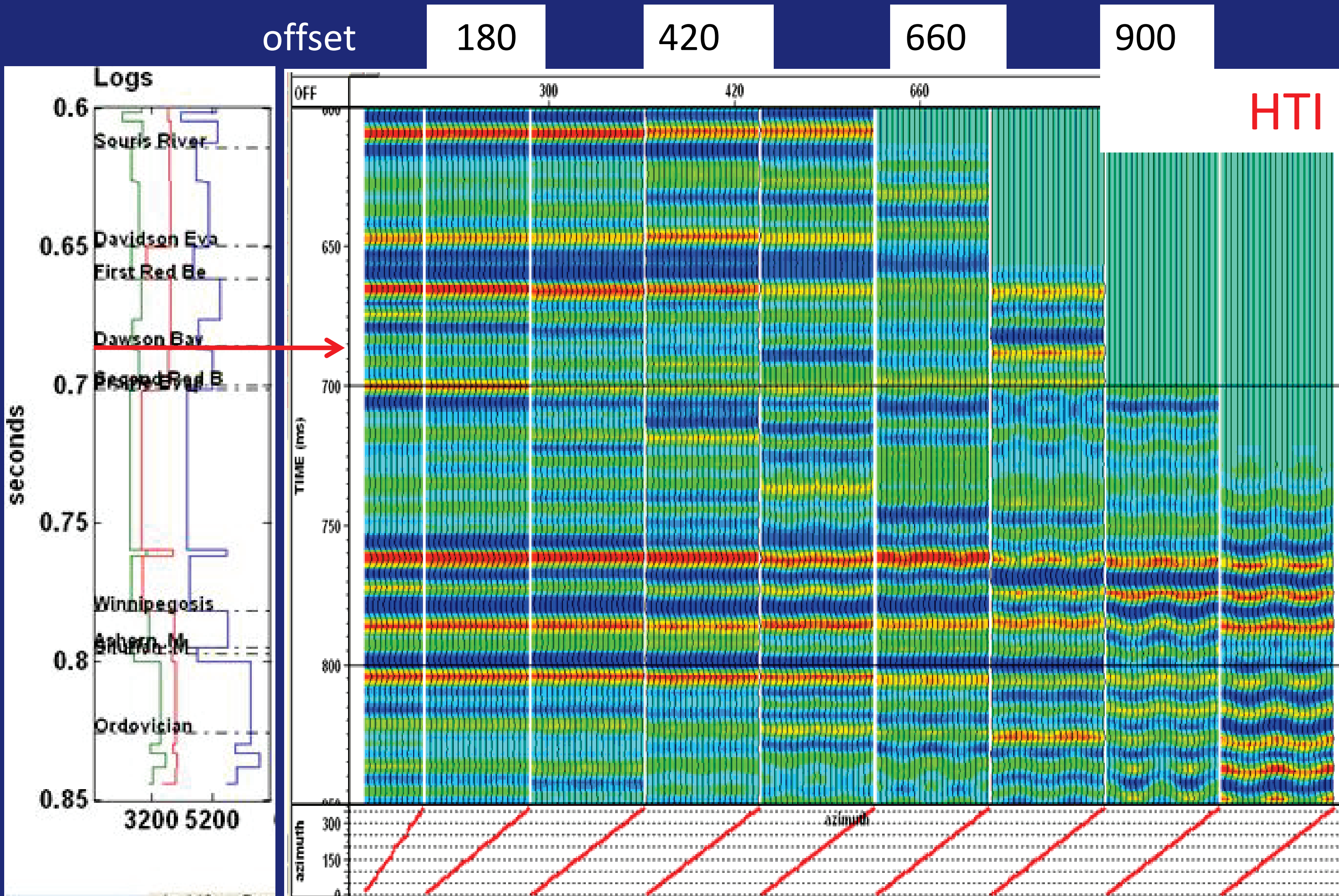
Azimuthal velocity analysis
(vertical component, HTI)



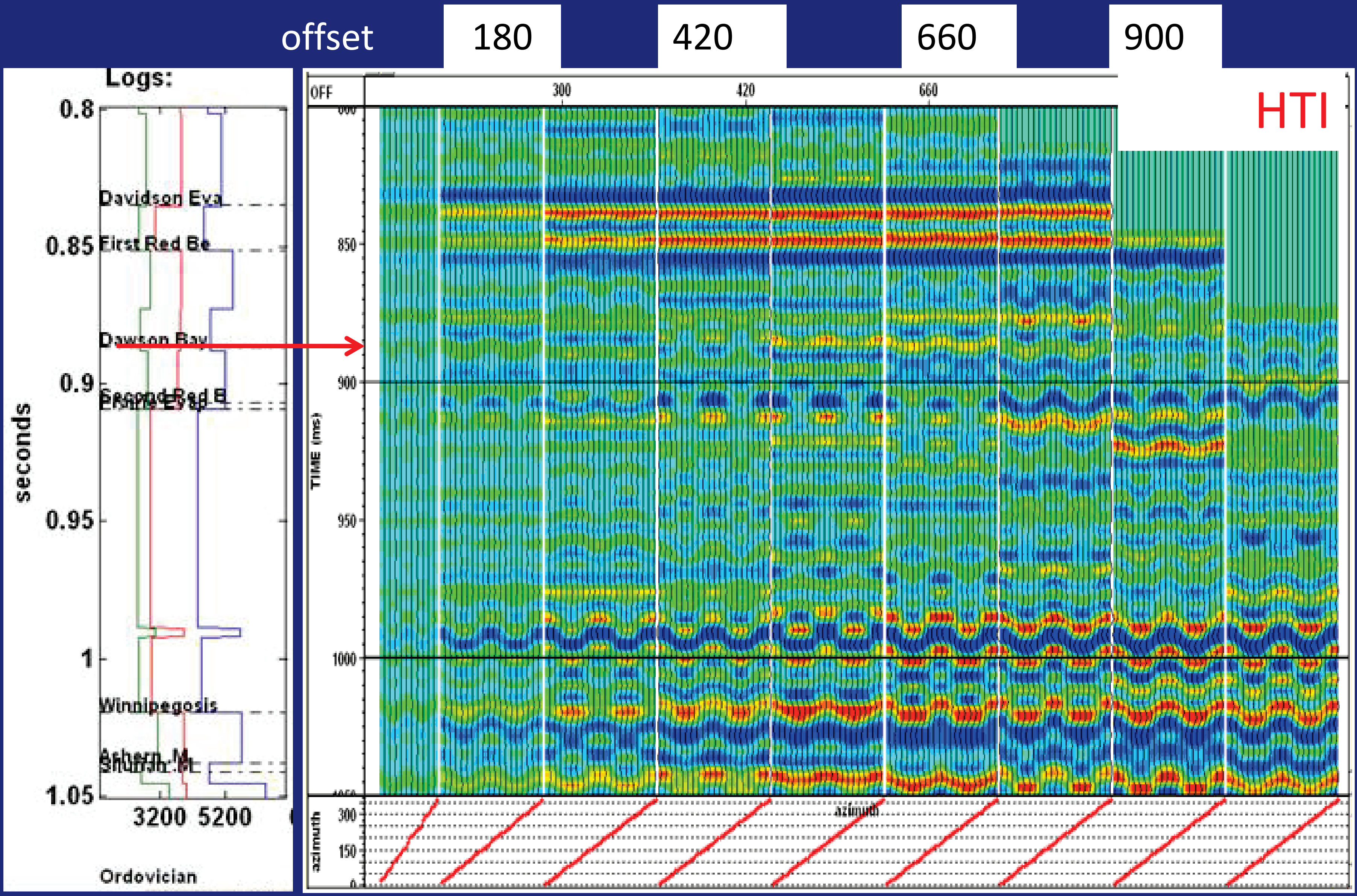
Azimuthal velocity analysis
(radial component, HTI)



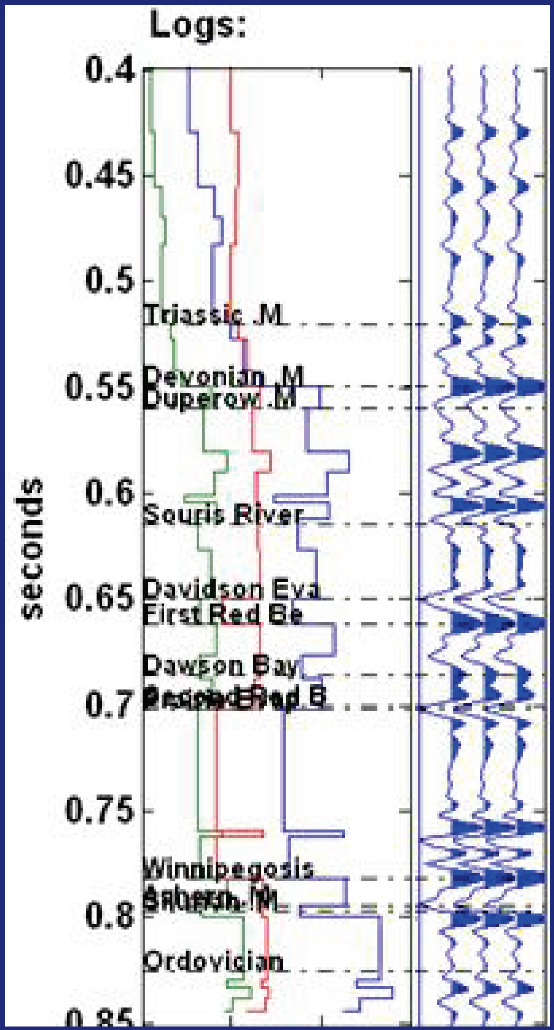
offset-azimuth gathers of vertical component

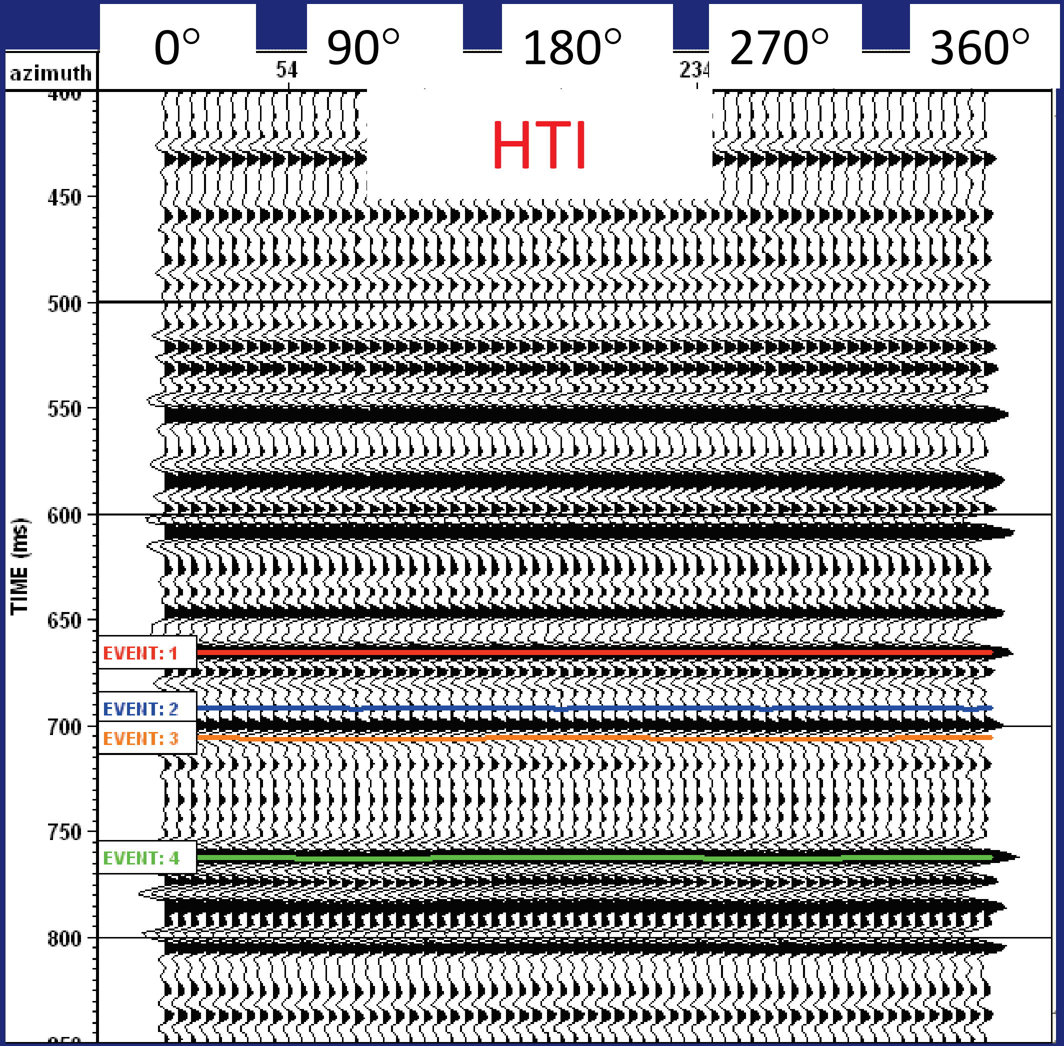


offset-azimuth gathers of radial component

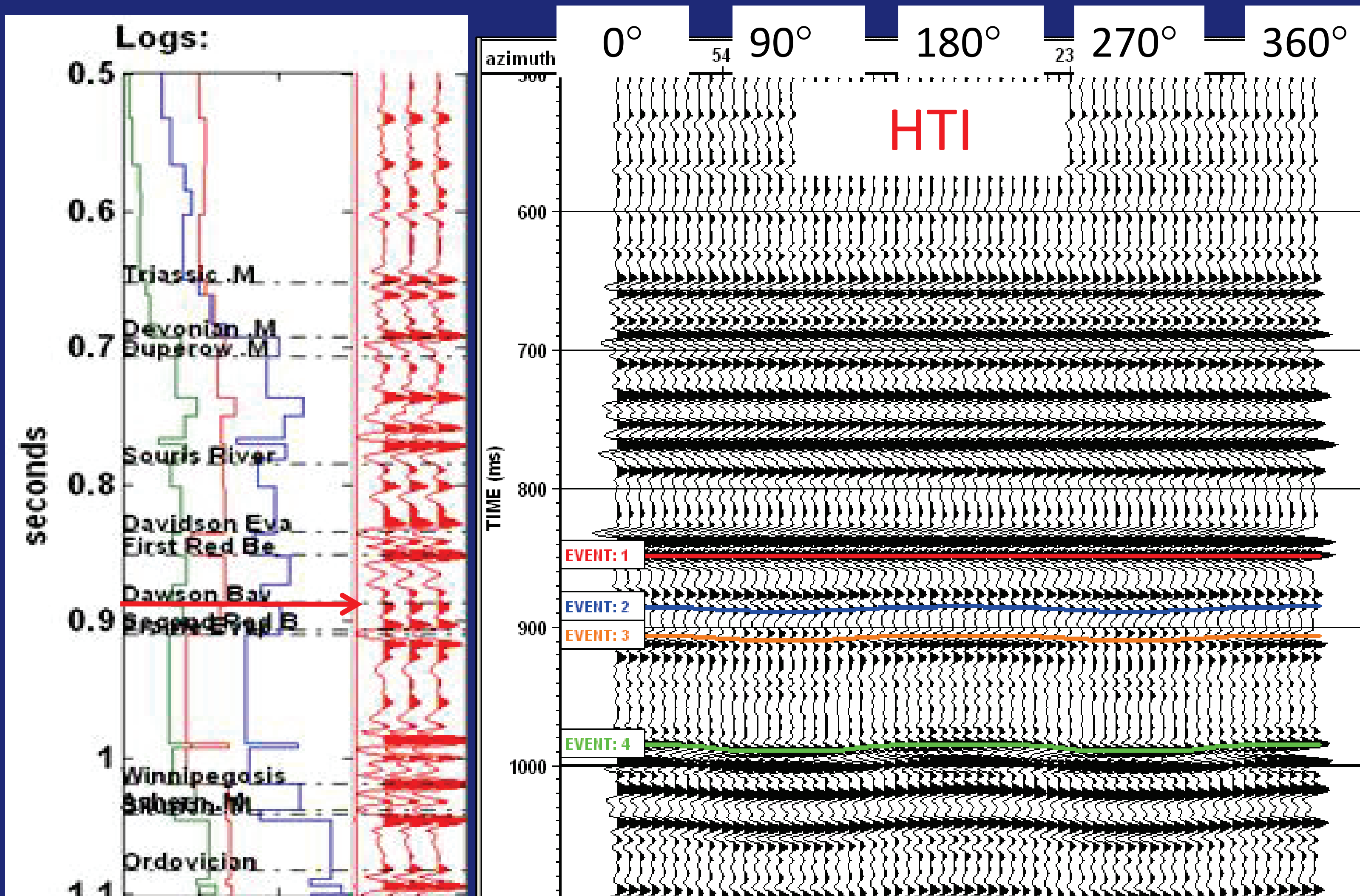


azimuth bin stack of vertical component

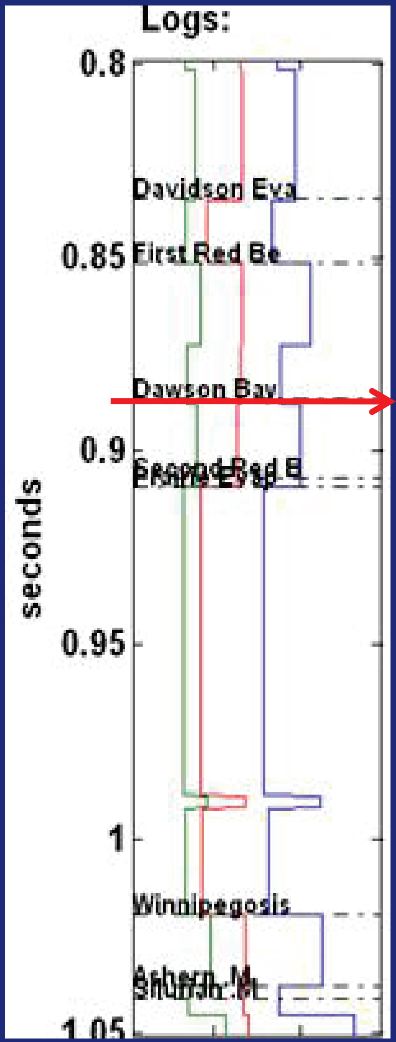


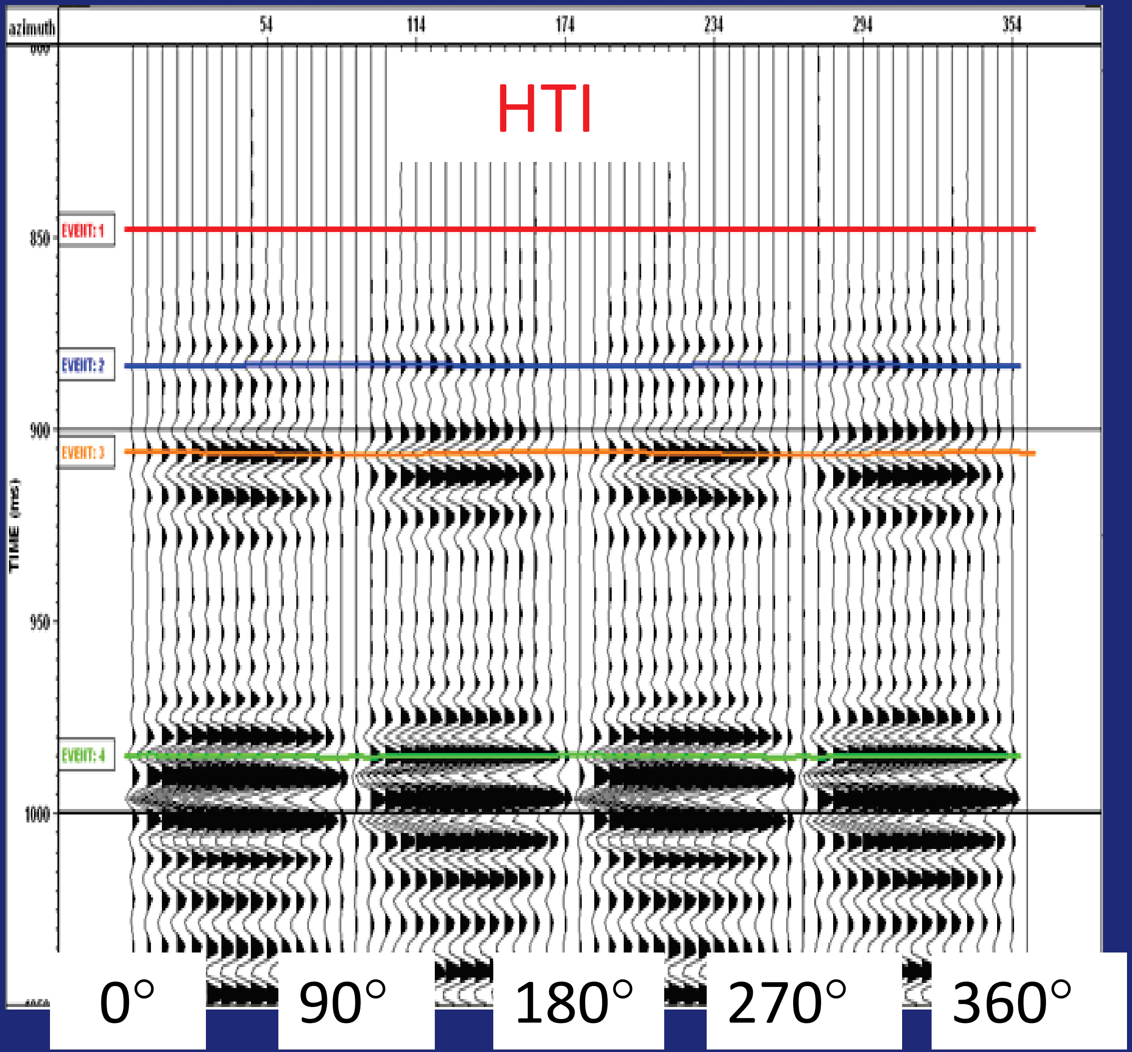


azimuth bin stack of radial component

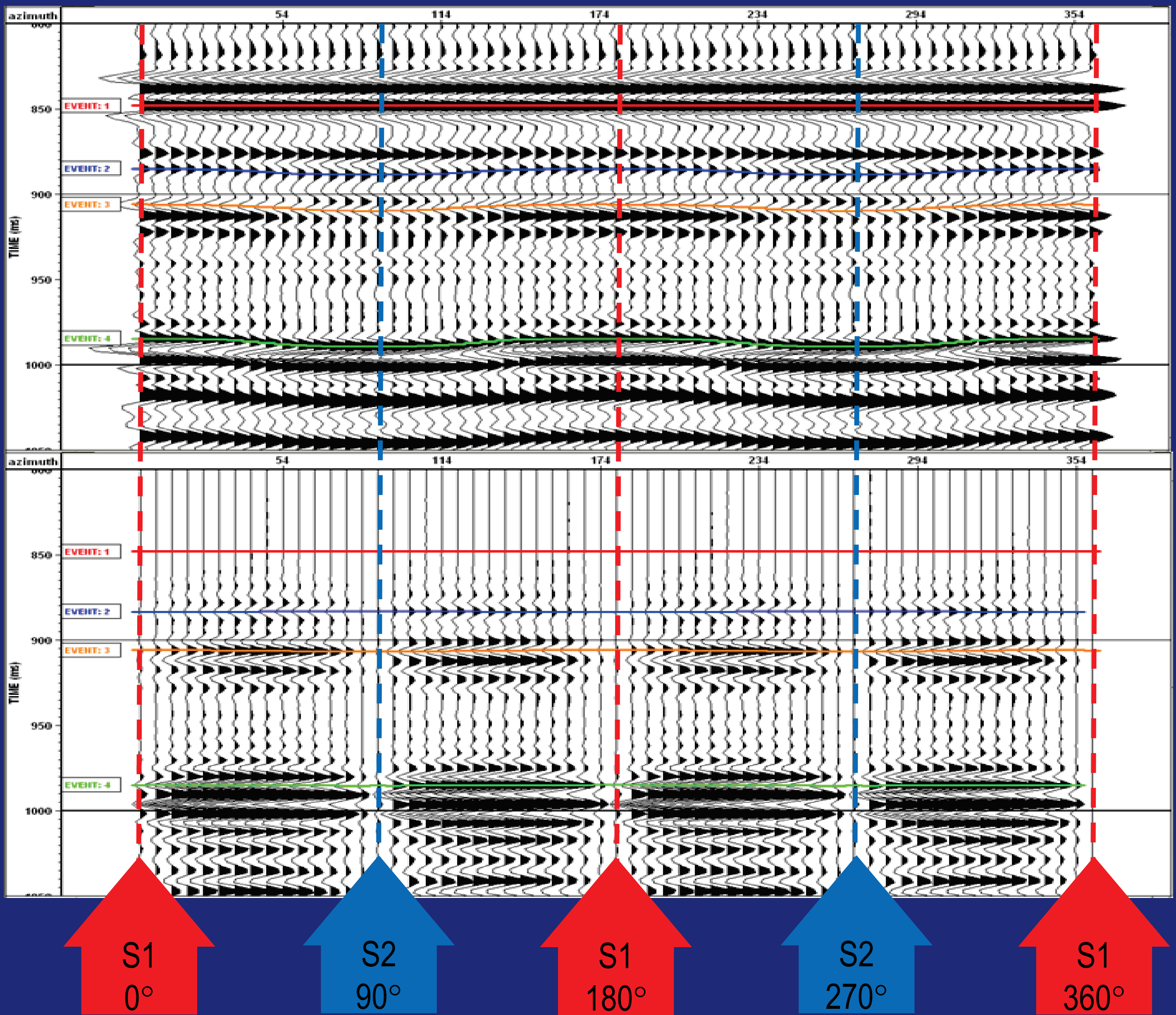


azimuth bin stack of transverse component

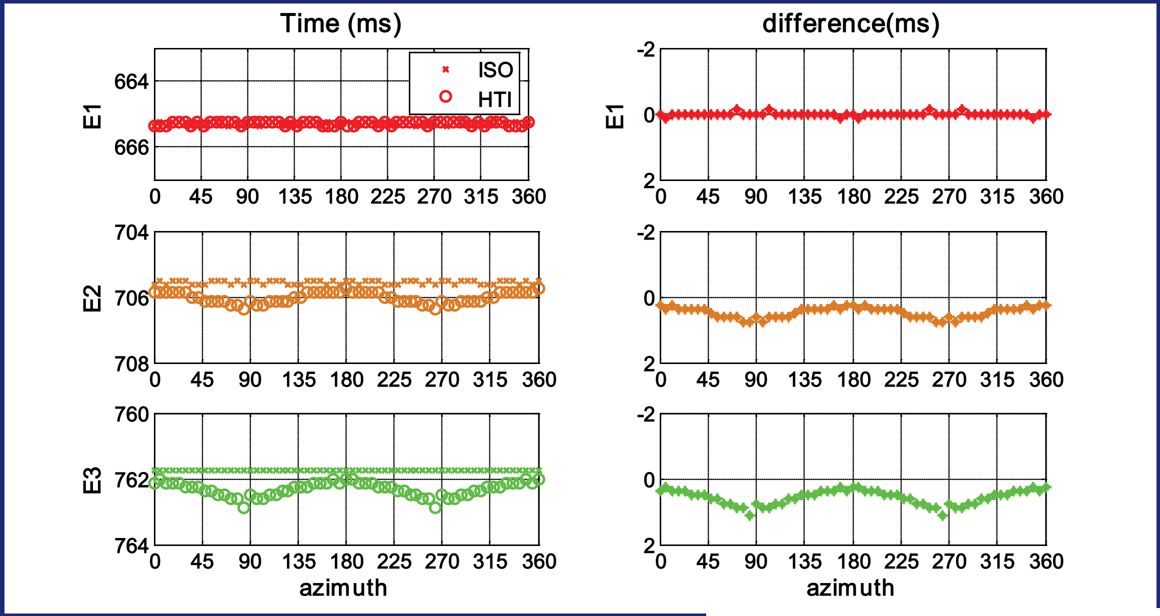




Shear-wave polarization analysis



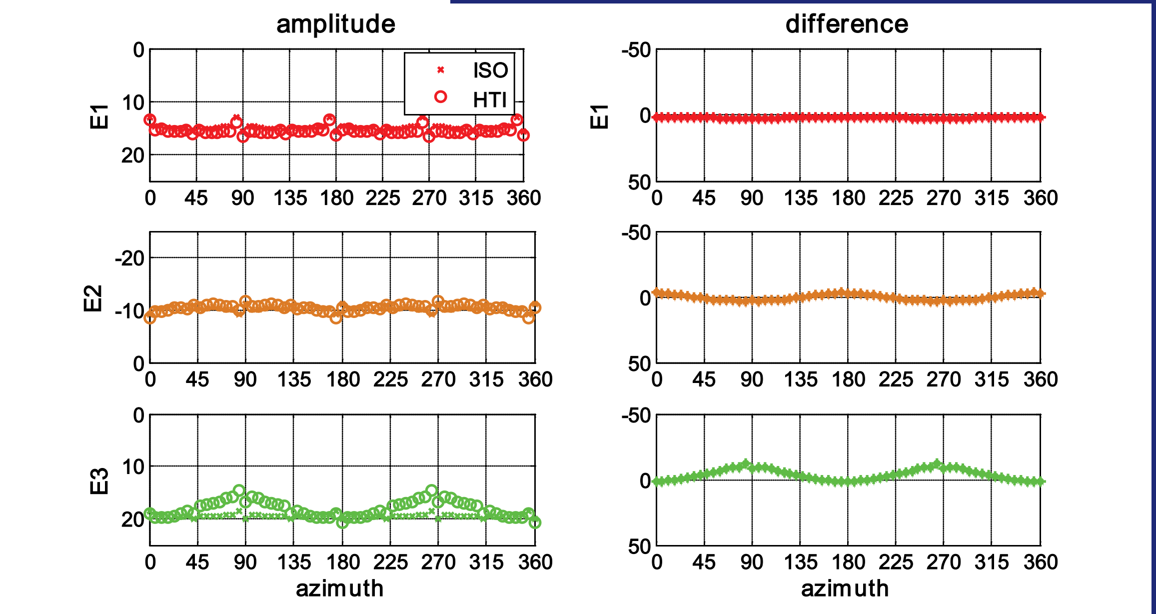
Time and amplitude changes (vertical component)



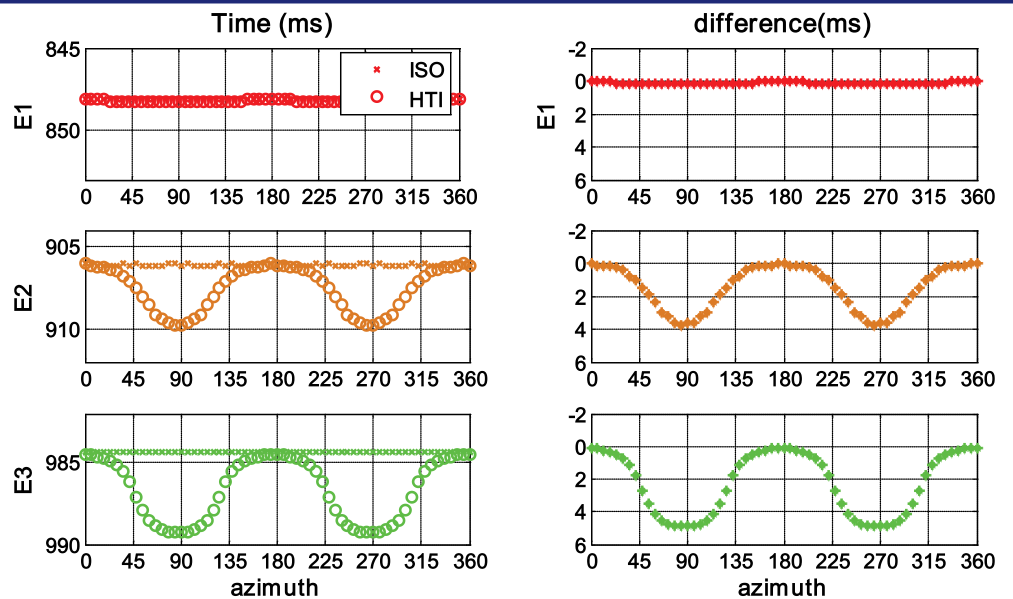
1.1ms

3.2%

12.2%



Time and amplitude changes (radial component)



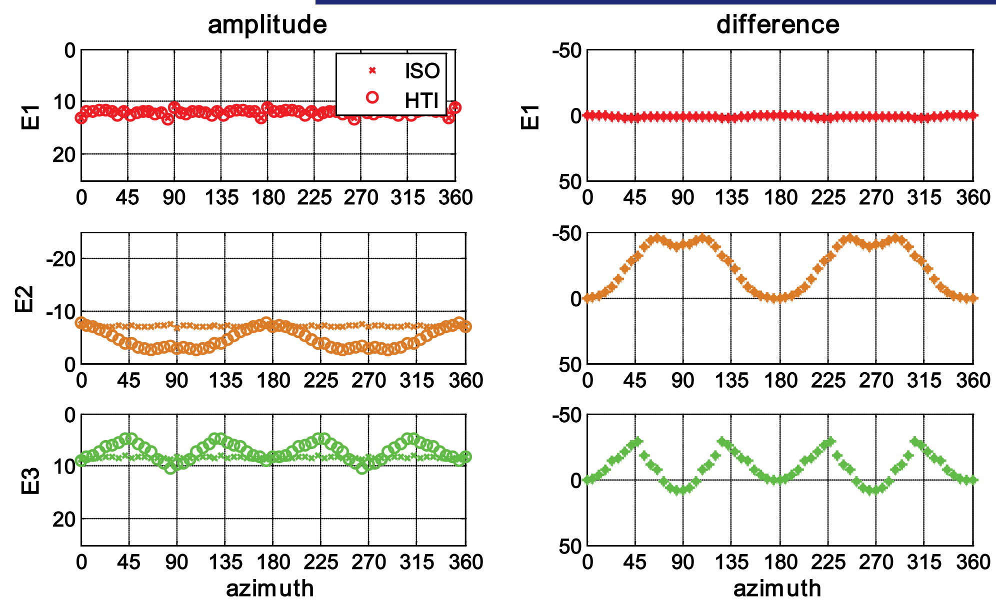
3.75ms

4.9ms

2.2%

46%

30%



Conclusions

- Visible seismic velocity anisotropy on both vertical and horizontal components
- Stronger effects on horizontal component
- Distinct shear-wave splitting, and polarization of fast and slow shear waves is consistent with the crack orientation
- Apparent time-shift and amplitude changes by anisotropic layer on both vertical and radial components
- The time-shift on the radial component is up to 5ms, the amplitude change is up to 46%

Acknowledgements

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