Prestack Vp/Vs scanning and automatic PS-to-PP time mapping*

Osareni Christopher Ogiesoba
McGill University, Montreal
(formerly University of Calgary – CREWES)
and
Robert R. Stewart
CREWES

*Chris' M.Sc. Thesis, 2005

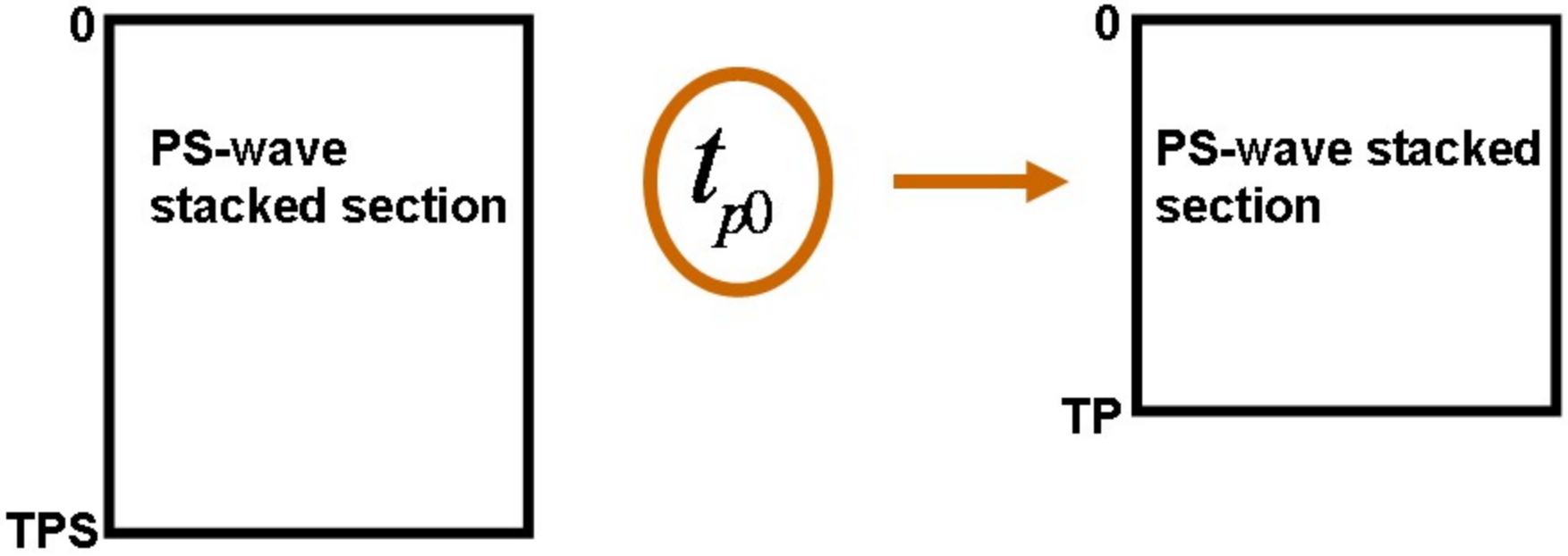
Presentation outline

- Motivations
  - We need to estimate V_{ps} and γ for processing
  - We want γ for attributes and petrophysics
  - We need PS data in PP time to correlate and interpret
- Methods: Converted-wave traveltime equation and Vp/Vs scanning algorithm
- Applied to: synthetic & real seismic data sets

$$t_{p0} = \frac{2t_{ps0}}{1+\gamma_0}$$

γ_0-function

γ_0 is defined as the average vertical velocity ratio Vp/Vs



(Prestack Vps-γ_0 scanning)

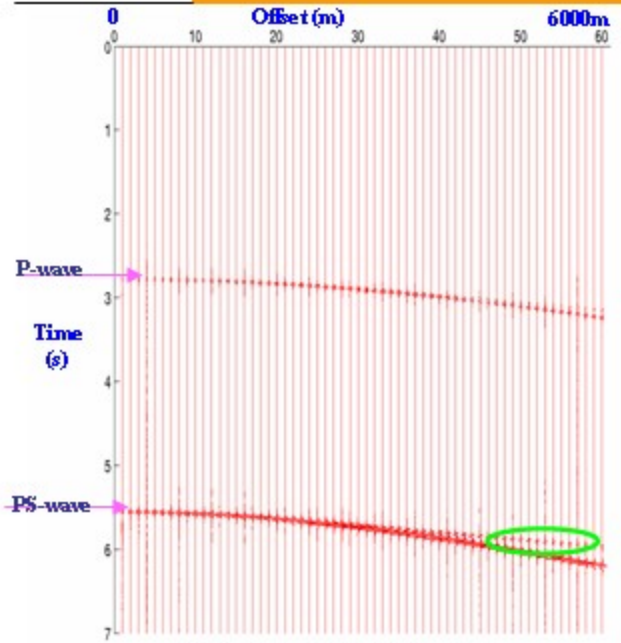
Use Thomsen's PS-wave non-hyperbolic traveltime equation with Tessmer & Behle's stacking velocity ($V_p^2 \approx \gamma_0^2 V_{ps}^2$)

$$t_{ps}^{\,2}(x) = t_{ps0}^{\,2} + \frac{x^2}{V_{ps}^{\,nmo^2}} - \left(\frac{(\gamma_0 - 1)^2}{4(\gamma_0 + 1) t_{ps0}^{\,2} V_{ps}^{\,nmo^4} + \gamma_0 (\gamma_0 - 1) V_{ps}^{\,nmo^2} x^2} \right) x^4$$

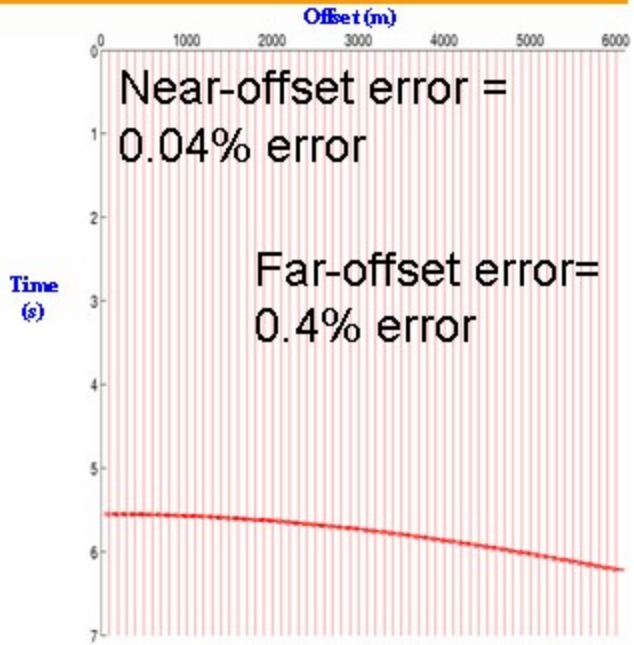
How valid is this equation?

Validity of PS traveltime equation

5000m	Thickness = 5000m Vp = 3600 m/s	Vs = 1200 m/s ρ = 2.2 gm/cc
Half space	Thickness = infinite thickness Vp = 12000 m/s	Vs = 6000 m/s ρ = 2.6 gm/cc



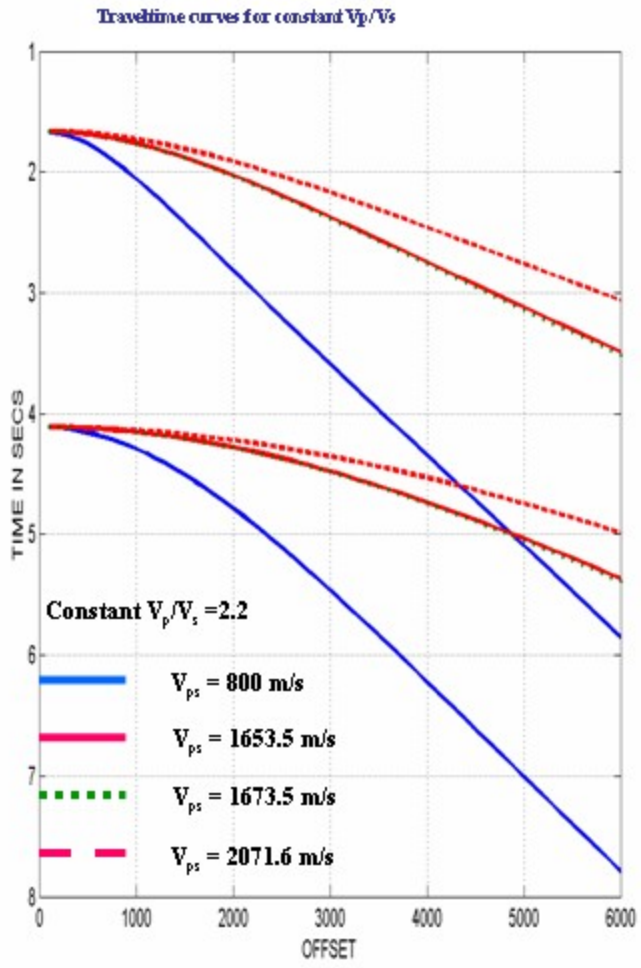
From ANIVEC

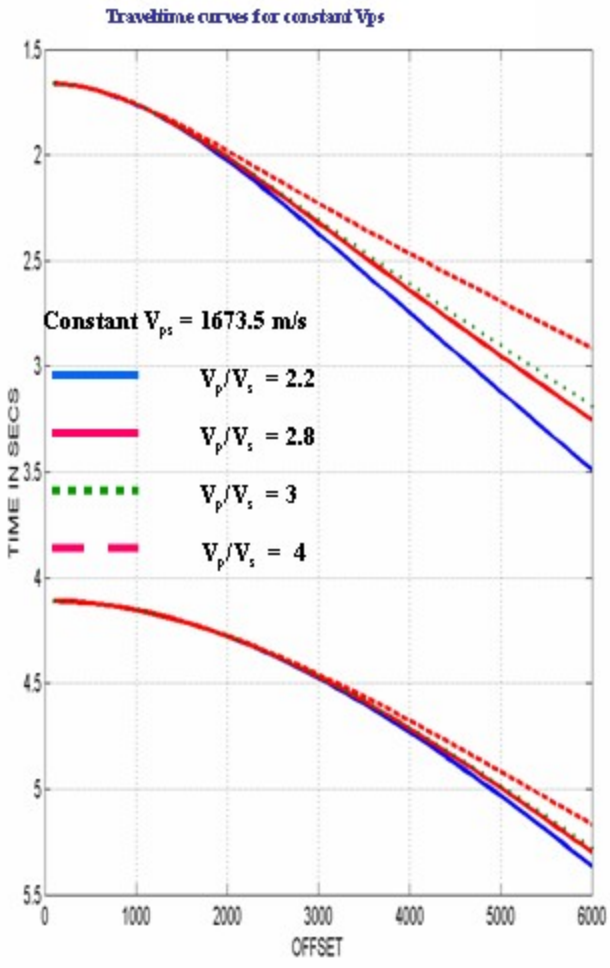


From Equation (6)

(Prestack Vps-γ_0 scanning)

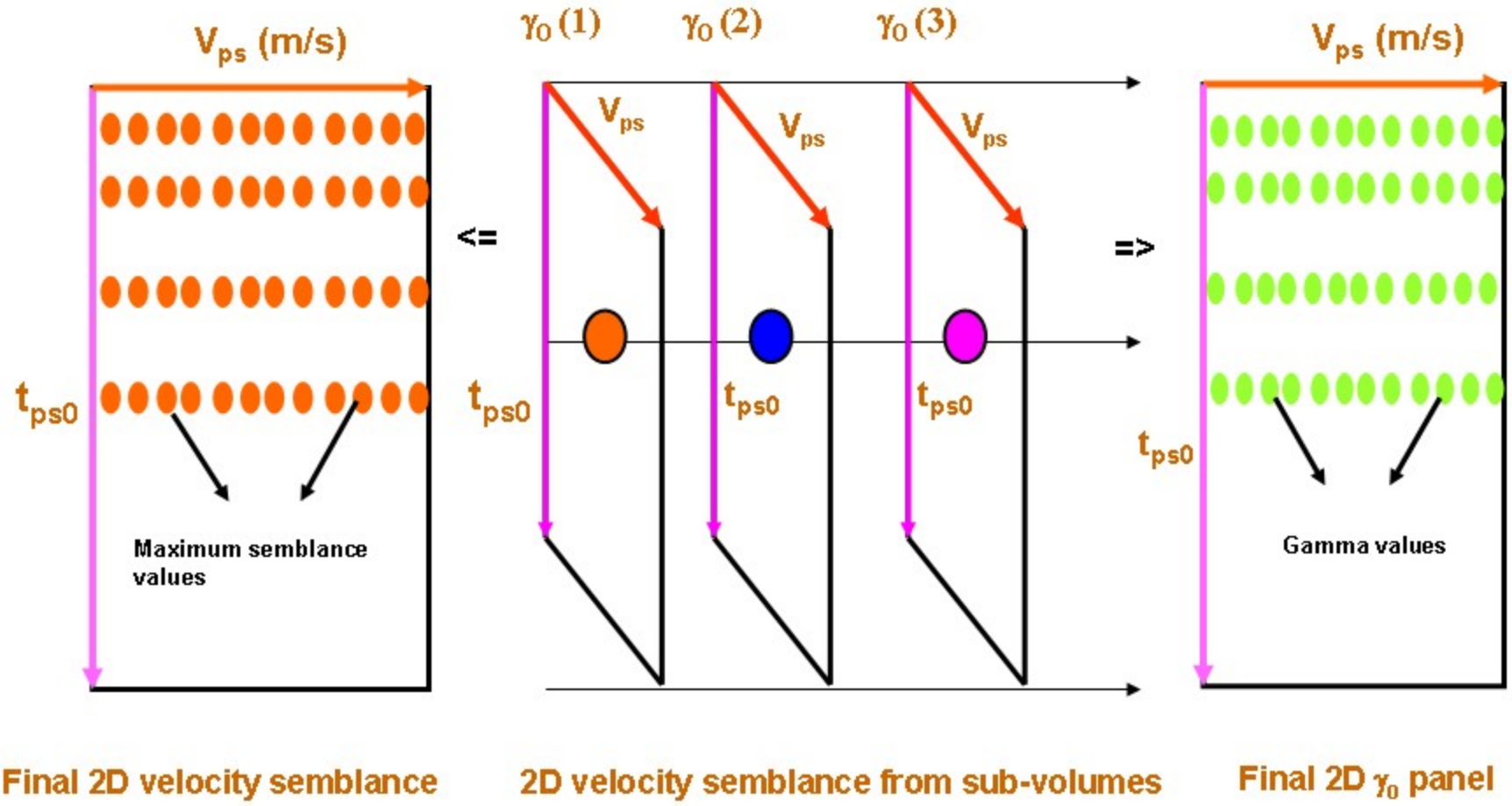
Sensitivity tests: how does moveout respond to the Variations in PS stacking velocity (Vps) and γ_0?





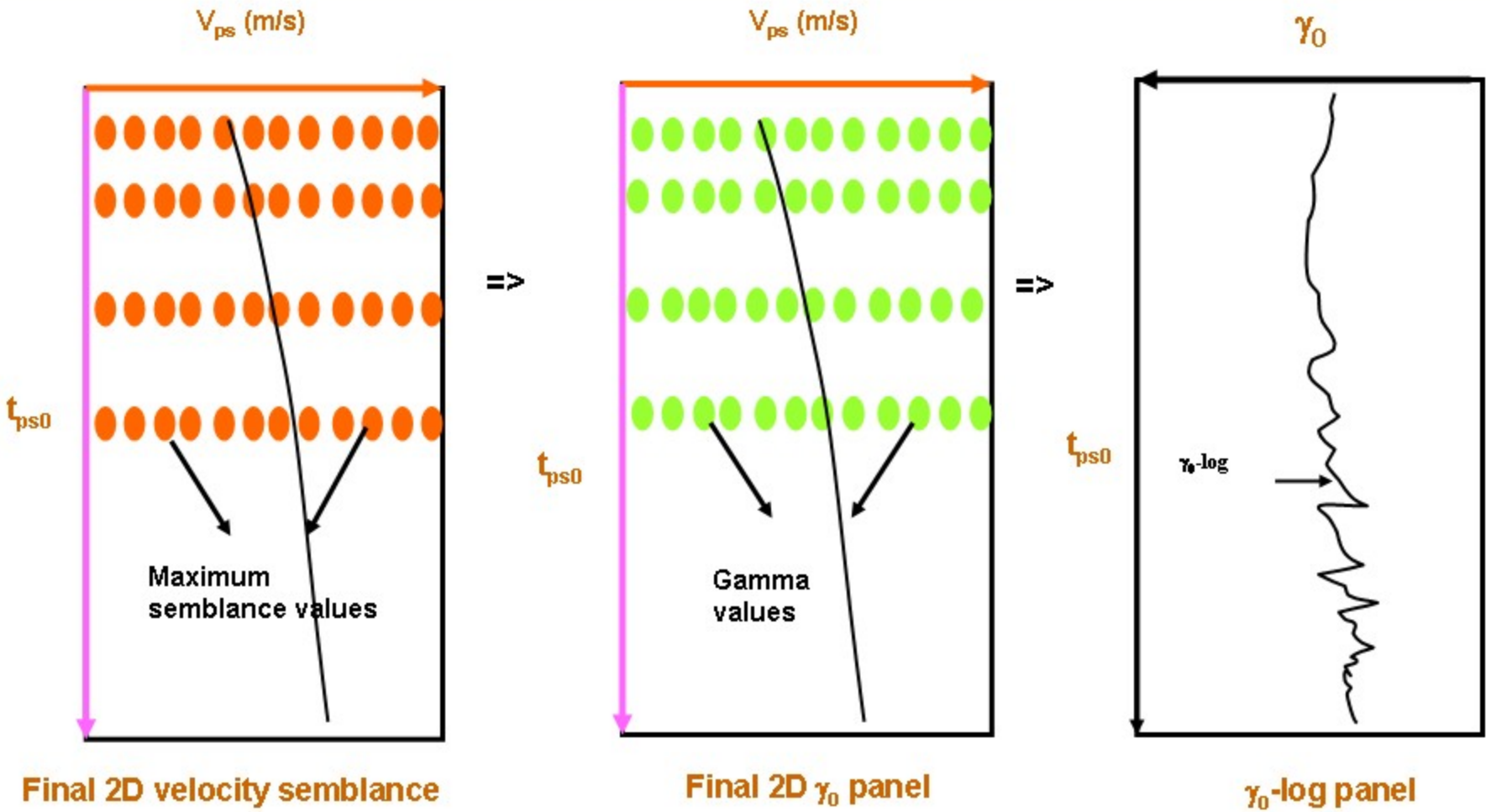
(Prestack Vps-γ_0 scanning)

Dual-parameter scanning algorithm development: the Log-type Method



(Prestack Vps-γ_0 scanning)

Dual-parameter scanning algorithm development: the Log-type Method



(Prestack Vps-γ_0 scanning)

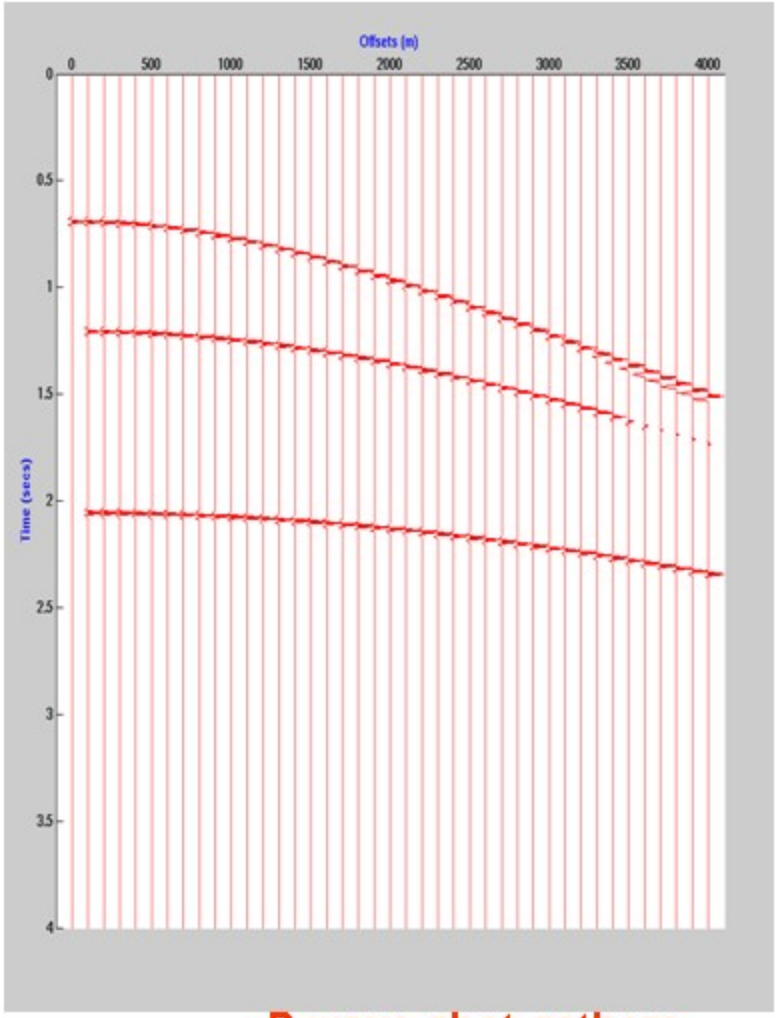
Multi-layer isotropic model

1000m	Thickness = 1000m Vp = 3000 m/s	Vs = 1395 m/s ρ = 2.5 gm/cc
900m	Thickness = 900m Vp = 3500 m/s	Vs = 1636 m/s ρ = 2.52 gm/cc
1700m	Thickness = 1700m Vp = 4000 m/s	Vs = 1878 m/s ρ = 2.54 gm/cc

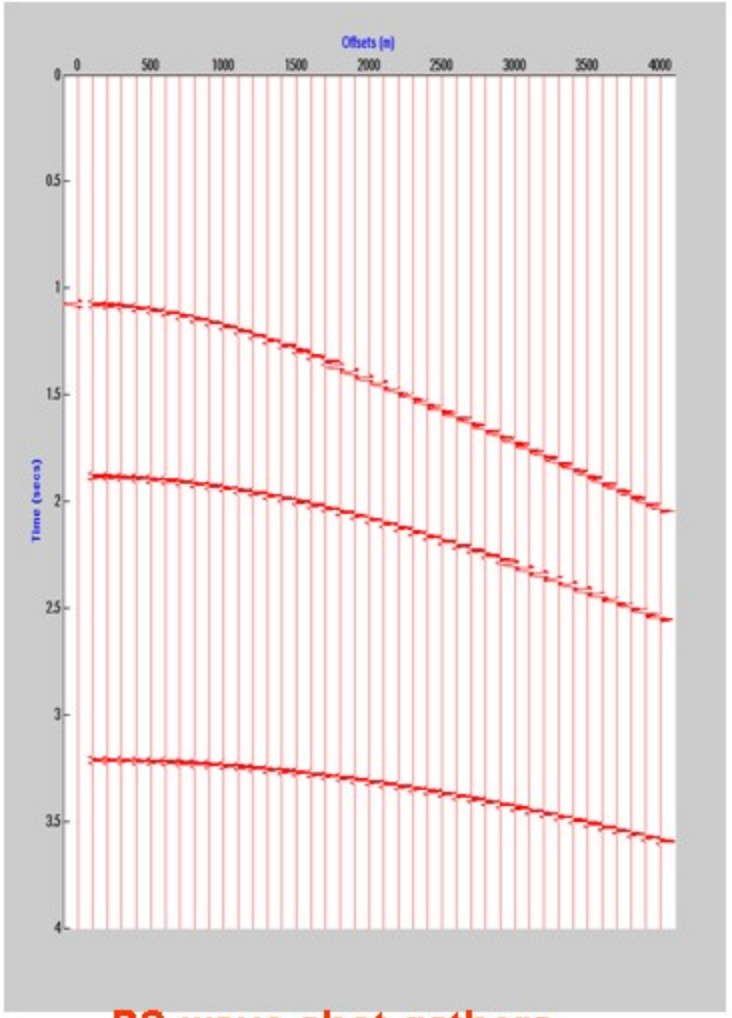
$$V_{psrms} = \left[\frac{t_{pav} V_{prms}^{\ 2} + t_{sav} V_{srms}^{\ 2}}{t_{ps}} \right]^{0.5} \qquad (8)$$

(Prestack Vps-γ_0 scanning)

Multi-layer isotropic model



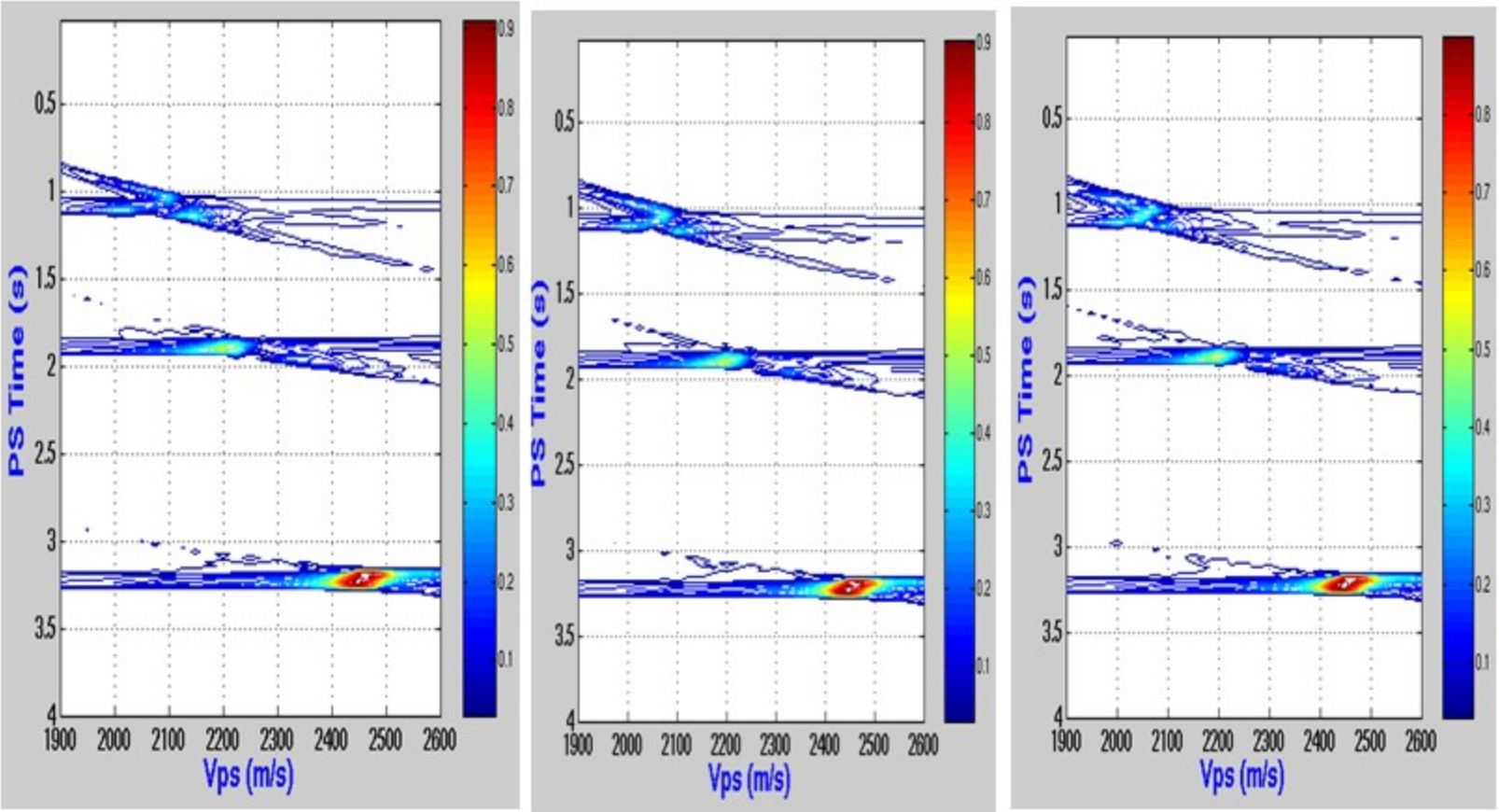
P-wave shot gathers



PS-wave shot gathers

(Prestack Vps-γ_0 scanning)

Application: Log-type Method
Multi-layer isotropic model



Sub-volume 1: Vp/Vs = 2.01

Sub-volume 4: Vp/Vs = 2.085

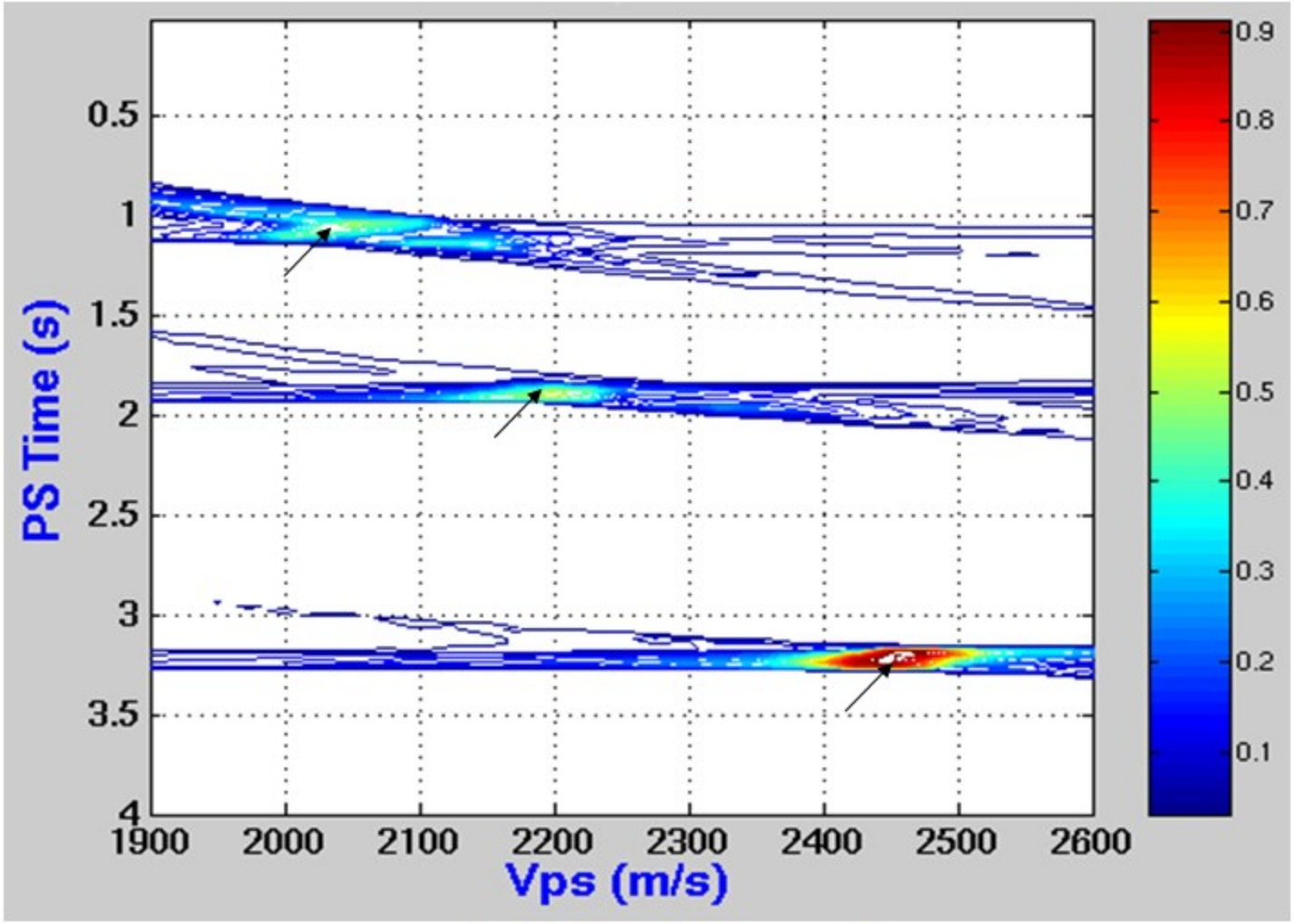
Sub-volume 6: Vp/Vs = 2.135

Divided into 10 sub-volumes
Vp/Vs from 2 to 2.26 at intervals 0f 0.005

(Prestack Vps-γ_0 scanning)

Application: Log-type Method

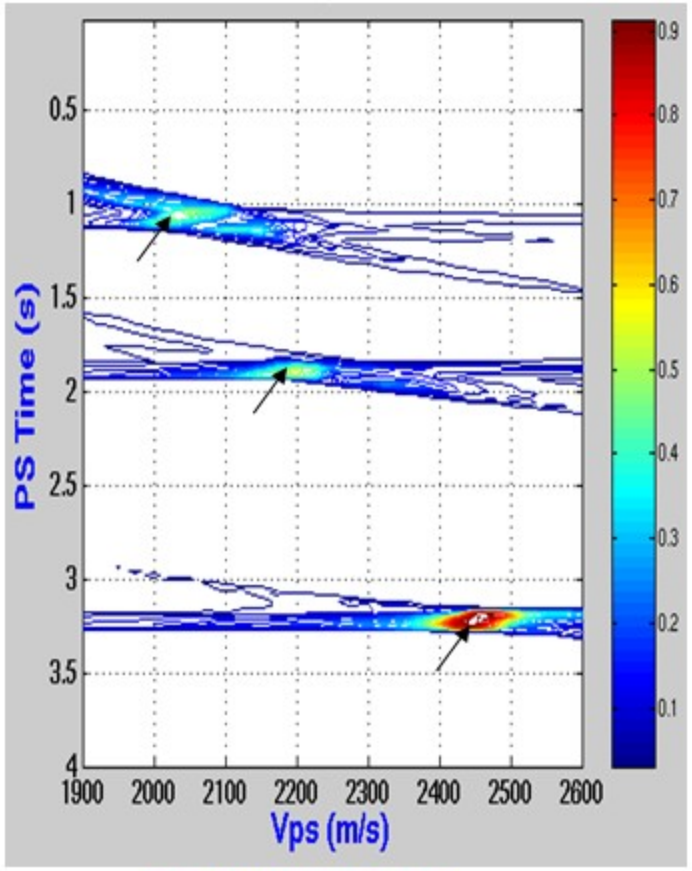
Multi-layer isotropic model



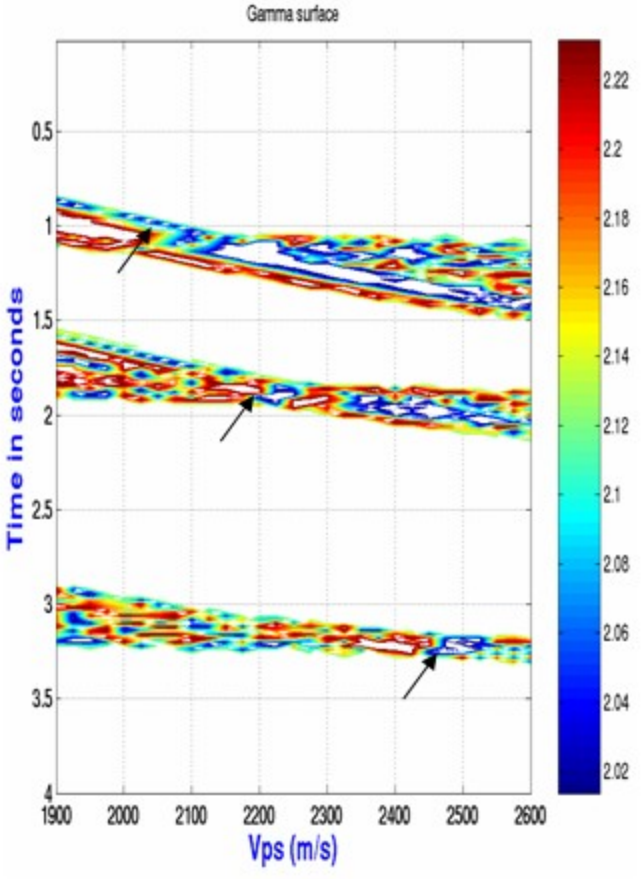
Final 2D velocity semblance

(Prestack Vps-γ_0 scanning)

Application: Log-type Method
Multi-layer isotropic model



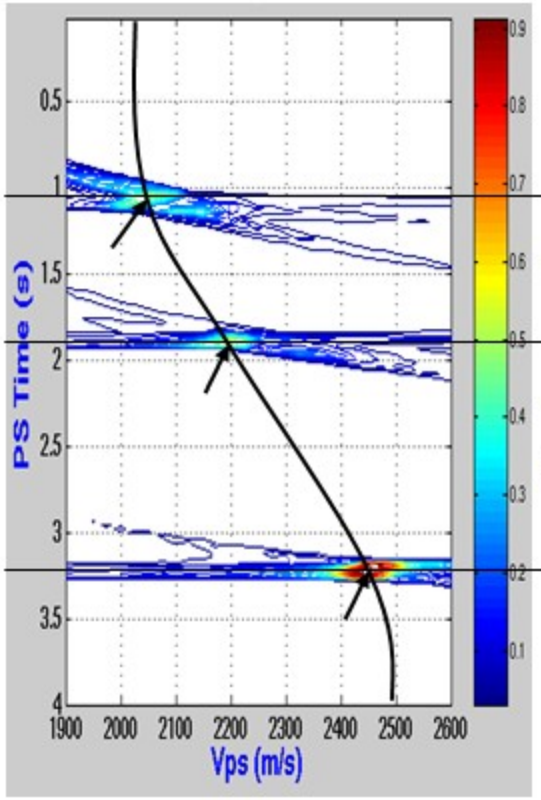
Final 2D semblance



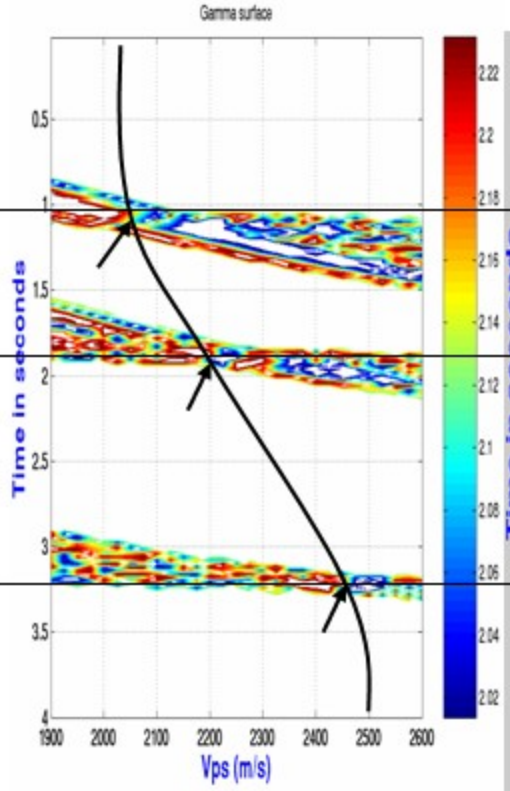
γ_0 2D contour

(Prestack Vps-γ_0 scanning)

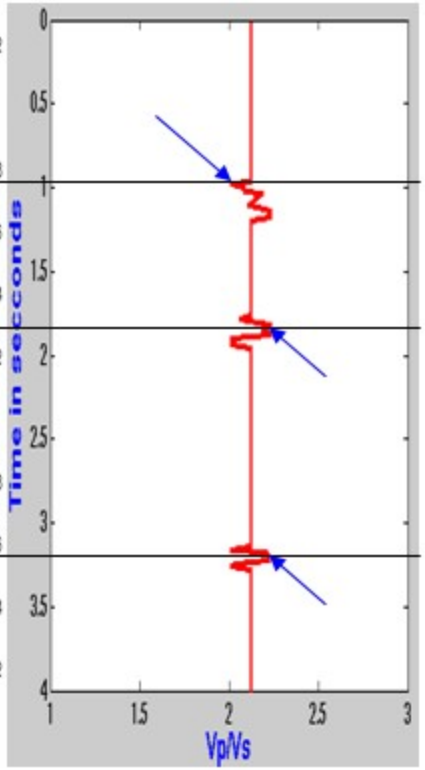
Application: Log-type Method
Multi-layer isotropic model



Final 2D semblance



γ_0 2D contour



γ_0-time log

(Prestack Vps-γ_0 scanning)

Application: Log-type Method

Multi-layer case error analysis

Horizon	Scanned γ_0	Input γ_0	Difference	% Difference
1	2.1600	2.15	+0.01	+0.5
2	2.230	2.15	+0.08	+4.0
3	2.2100	2.14	+0.07	+3.0

Horizon	Scanned Vps(m/s)	Input Vps(m/s)	Difference	% Difference
1	2040	2046	+4(m/s)	-0.3
2	2200	2203	-3(m/s)	-0.1
3	2450	2450	0	0

(Prestack Vps-γ_0 scanning)

Application: PS-to-PP time mapping
Multi-layer case error analysis

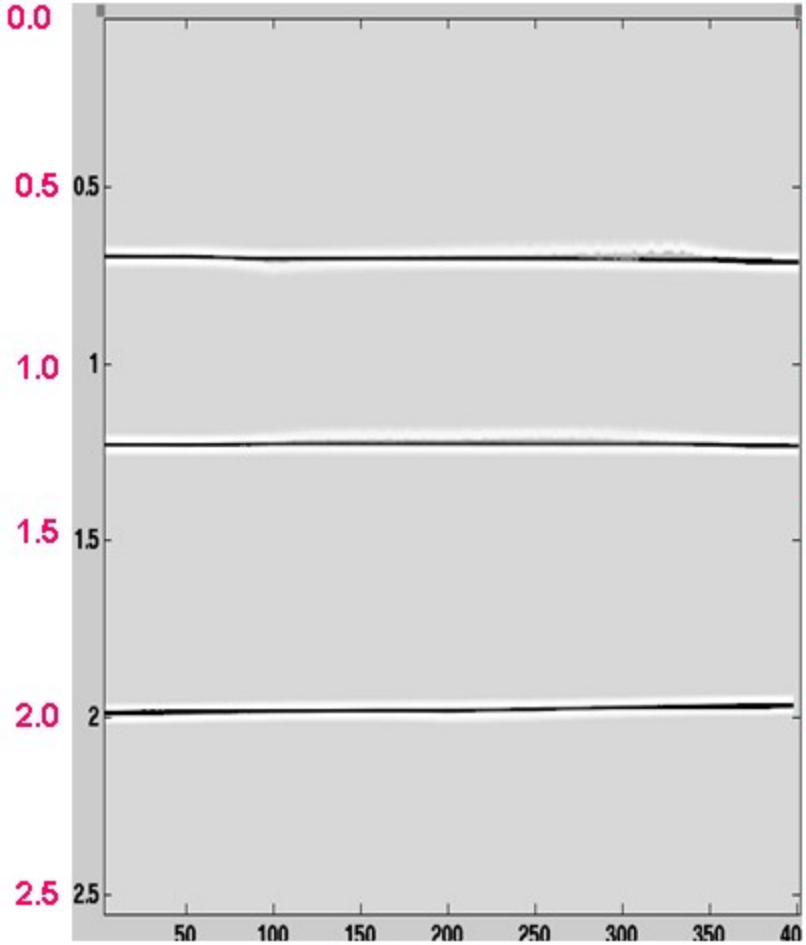
$t_{ps\ 0}$	Scanned γ_0	$t_{p0} = (2 * t_{ps\,0}) / (1 + \gamma_0)$	$t_{p\ 0}$ from PP data
1.05	2.160	0.6650	0.6667
1.8574	2.230	1.1500	1.1808
3.1877	2.210	1.9861	2.0308

Horizon	Derived P-wave times	Actual P-wave time	Difference	% Difference
1	0.6650	0.6666	-0.0016	-0.2
2	1.1500	1.1808	-0.0308	-3
3	1.9861	2.0308	-0.0447	-2

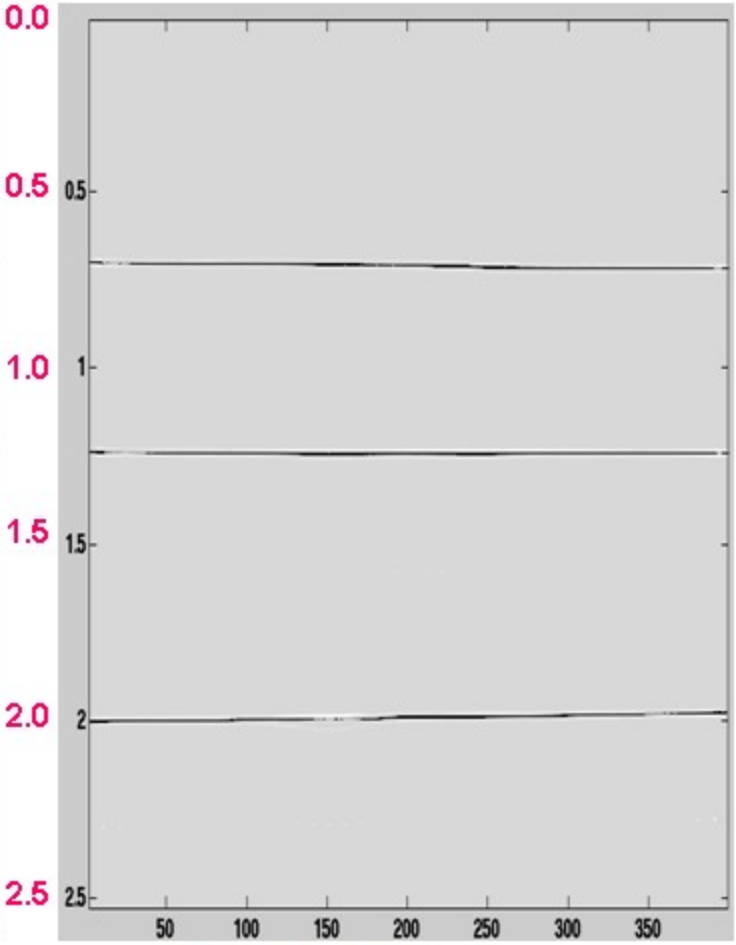
(Prestack Vps-γ_0 scanning)

Application: PS-to-PP time mapping

Multi-layer isotropic model:



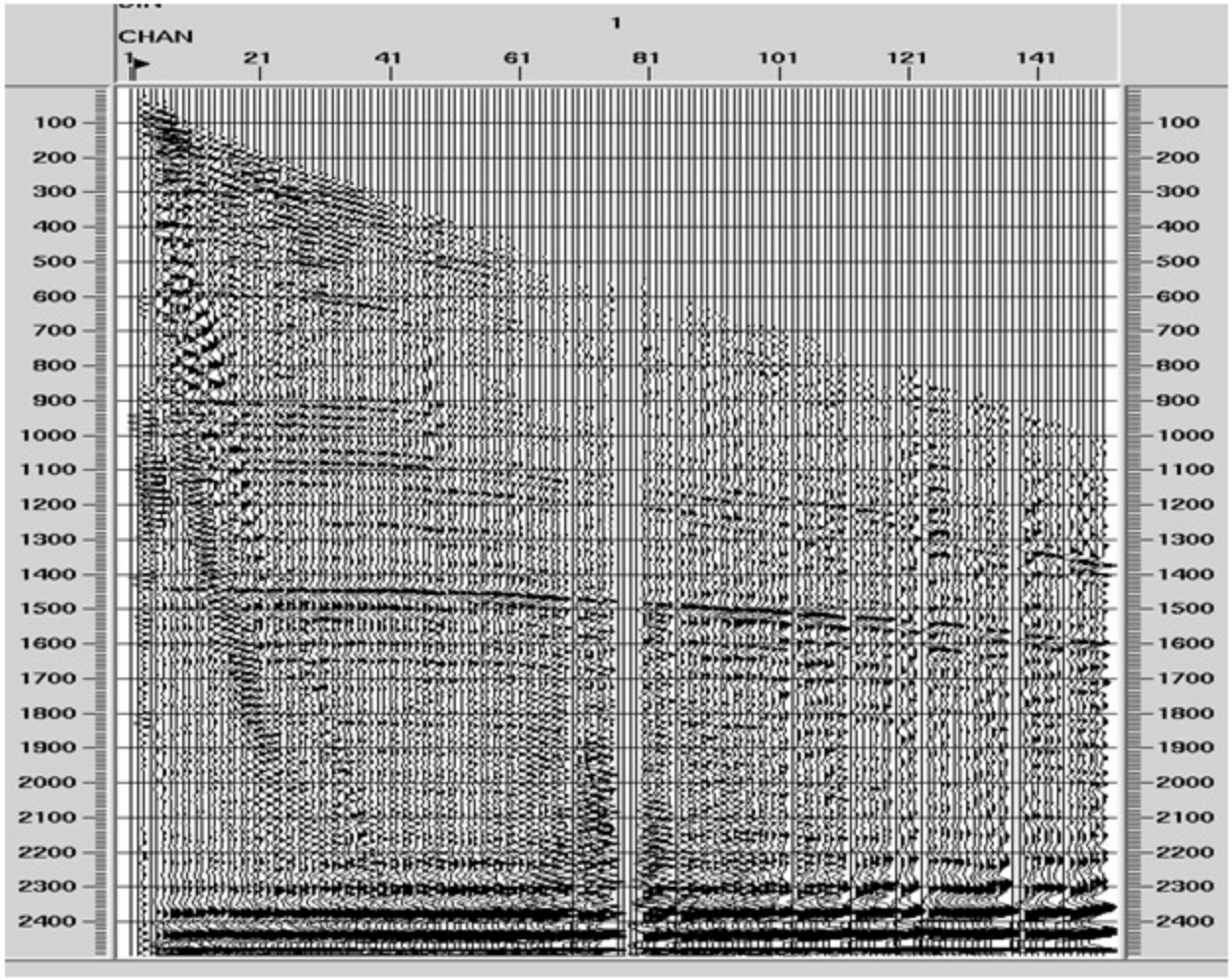
PP stacked data



PS stacked data after transformation to PP times

(Prestack Vps-γ_0 scanning)

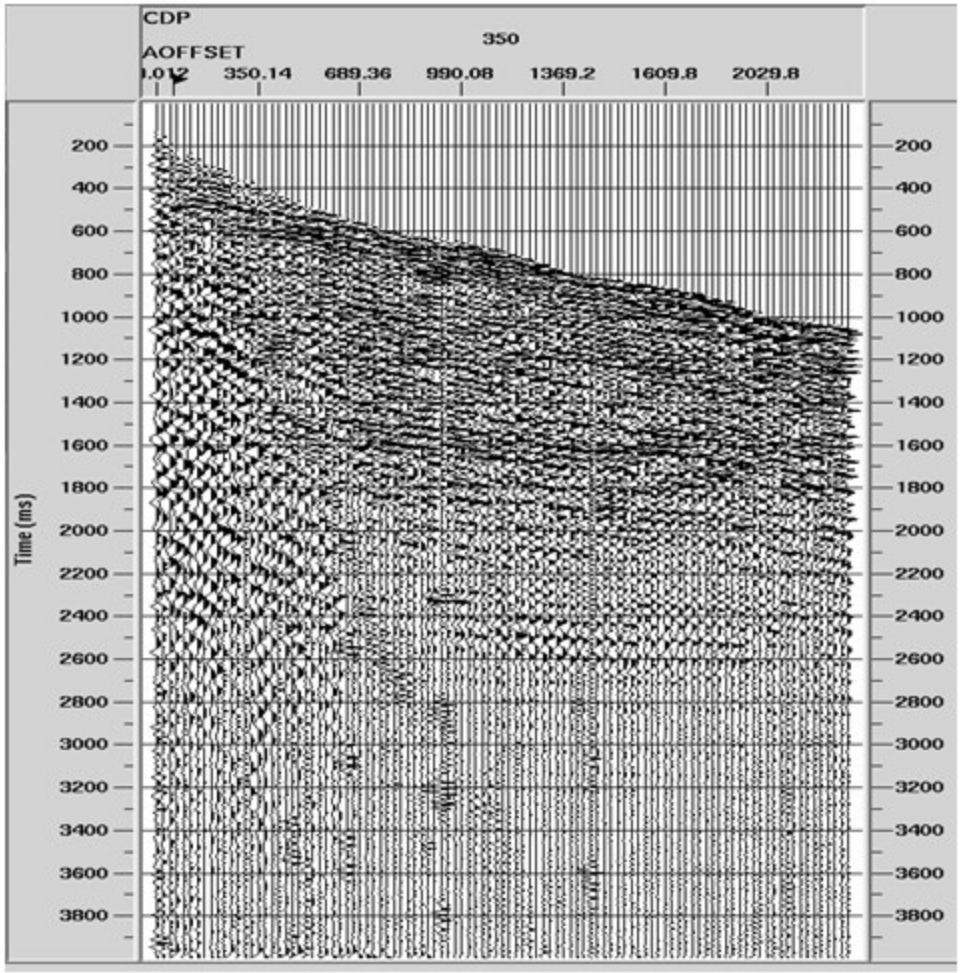
Application: Real data case:
Blackfoot Oil Field: Processing in Promax



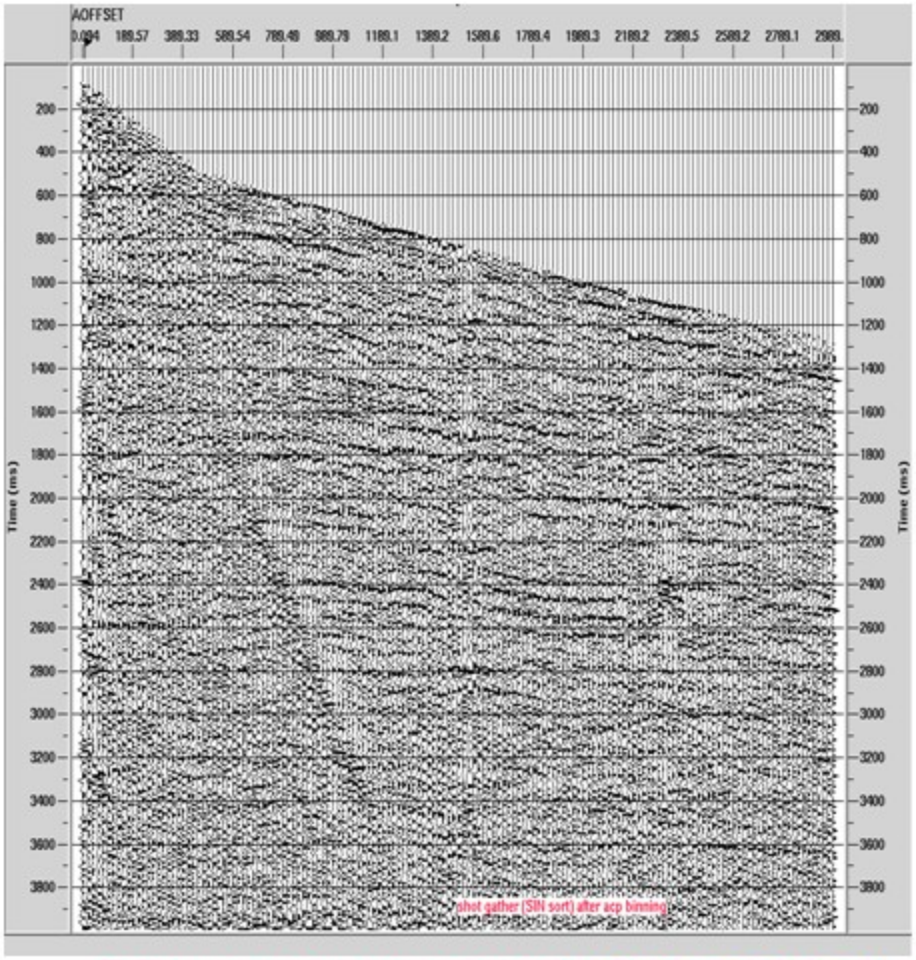
P-wave shot gather

(Prestack Vps-γ_0 scanning)

Application: Real data case
Blackfoot Oil Field: Processing in Promax



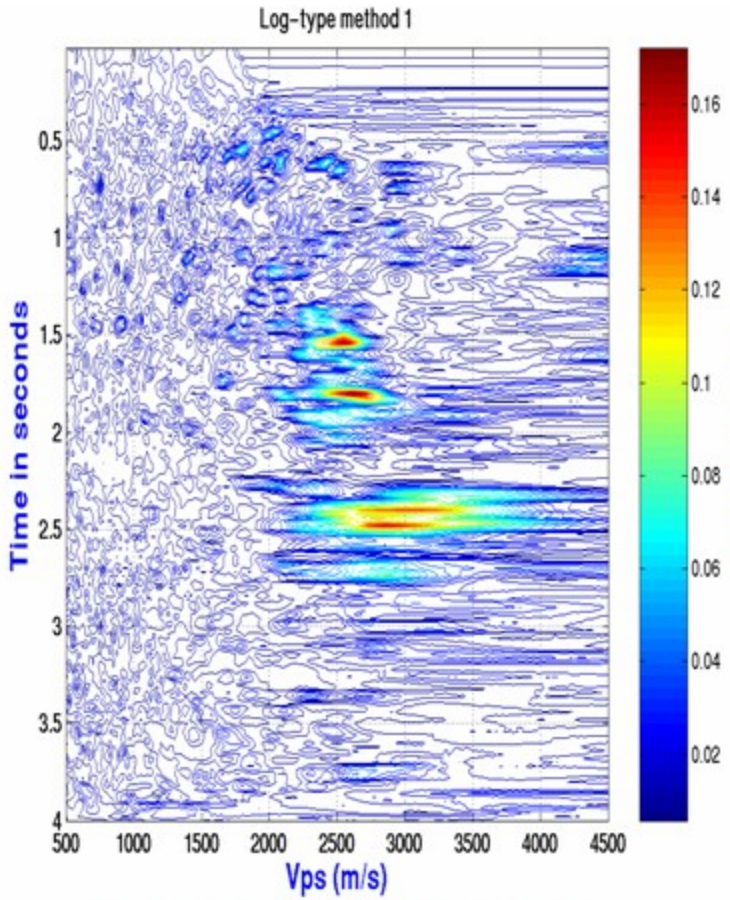
Seismic ACP gather 350 (At well 09-08 loc.)



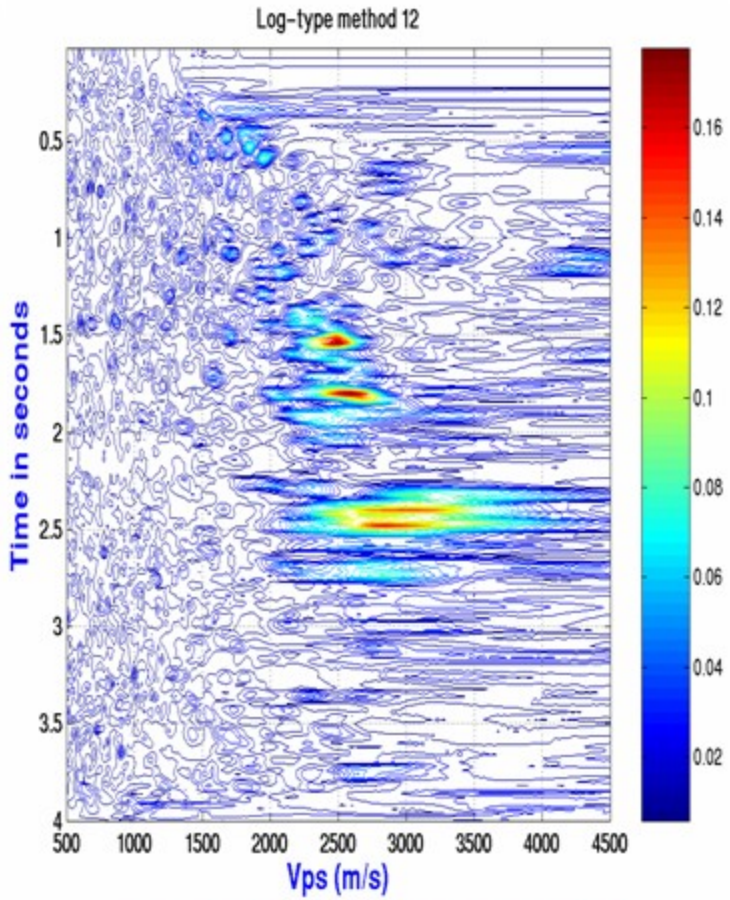
PS-wave shot gather (First shot loc.)

(Prestack Vps-γ_0 scanning)

Application: Log-type Method (ACP gather)
Blackfoot Oil Field



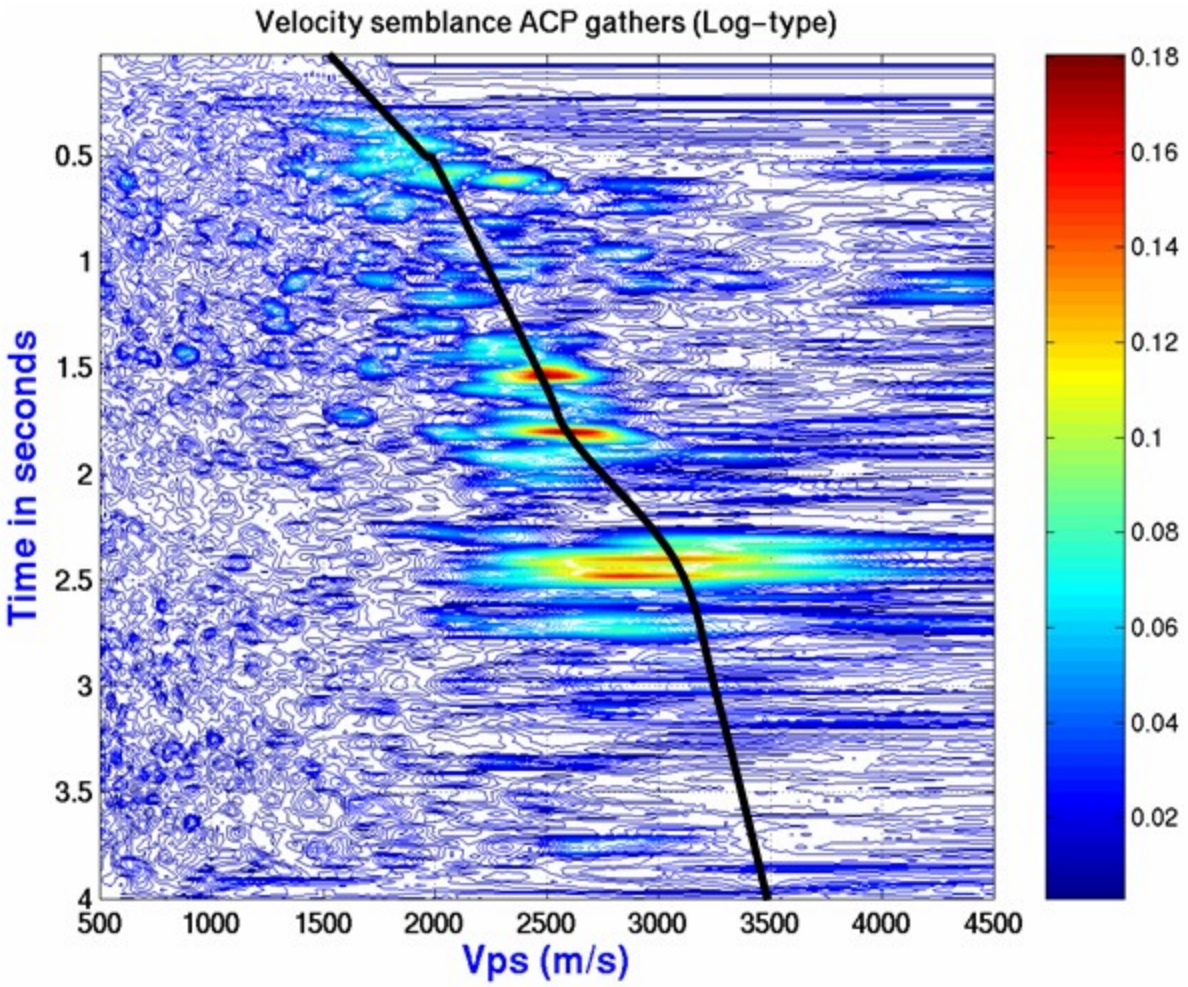
Sub-volume 1 (Vp/Vs = 1.55)



Sub-volume 11 (Vp/Vs = 2.8)

(Prestack Vps-γ_0 scanning)

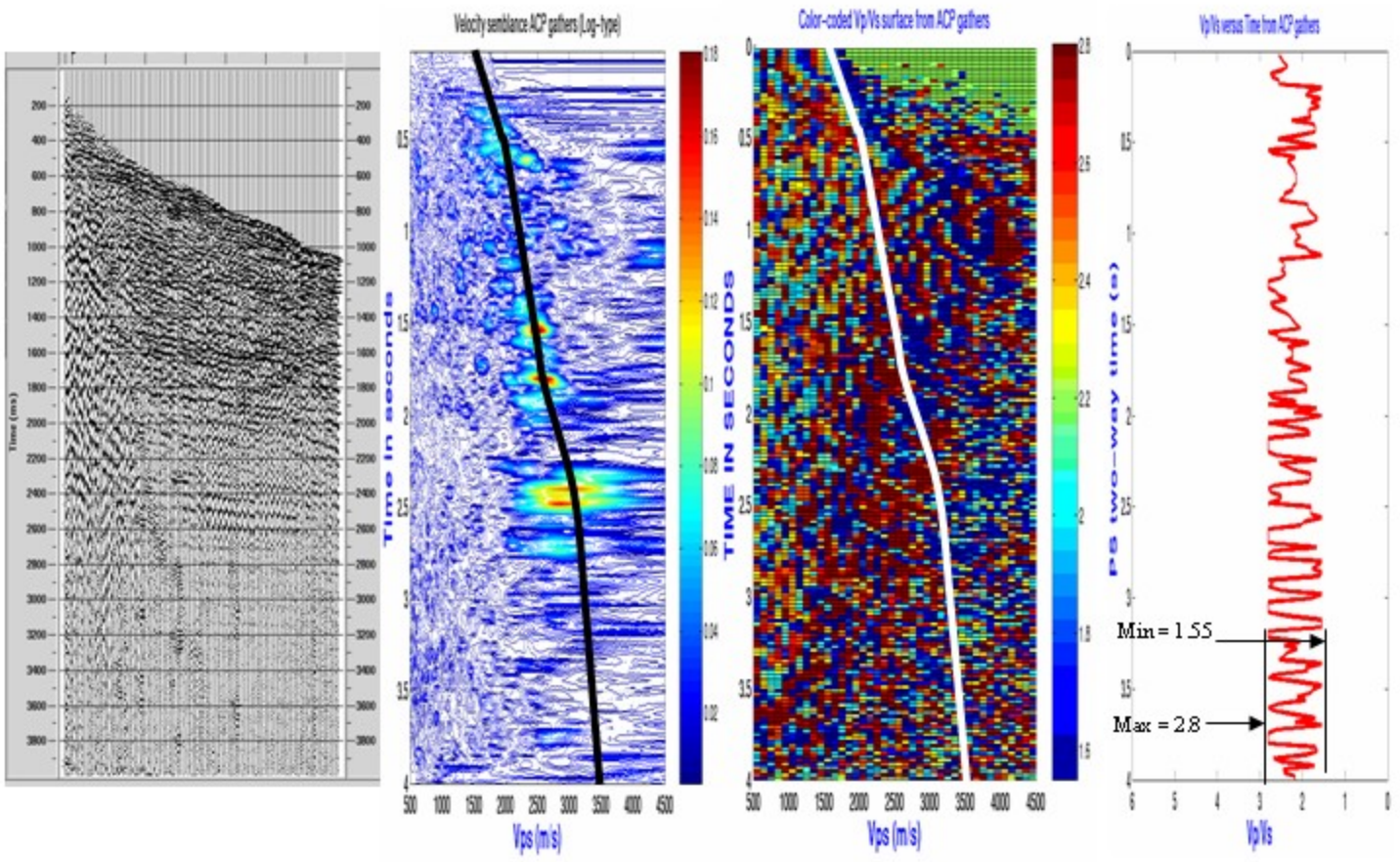
Application: Log-type Method (ACP gather)
Blackfoot Oil Field



Final 2D velocity semblance

(Prestack Vps-γ_0 scanning)

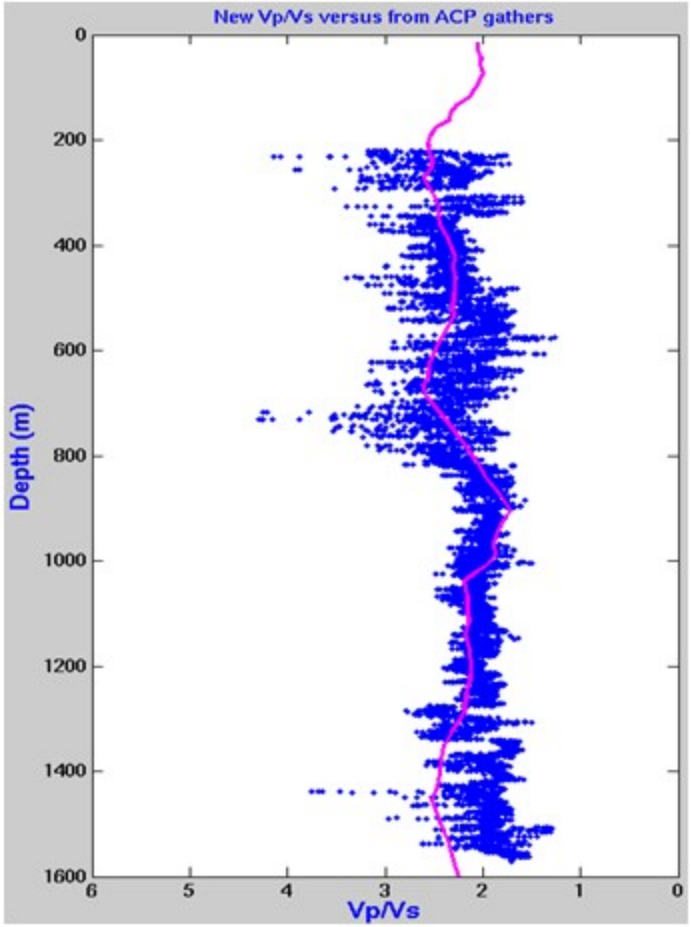
Application: Log-type Method (ACP gather)
Blackfoot Oil Field



Seismic ACP gather 350 | Final 2D semblance | Color-coded γ_0 panel | γ_0 –time log

(Prestack Vps-γ_0 scanning)

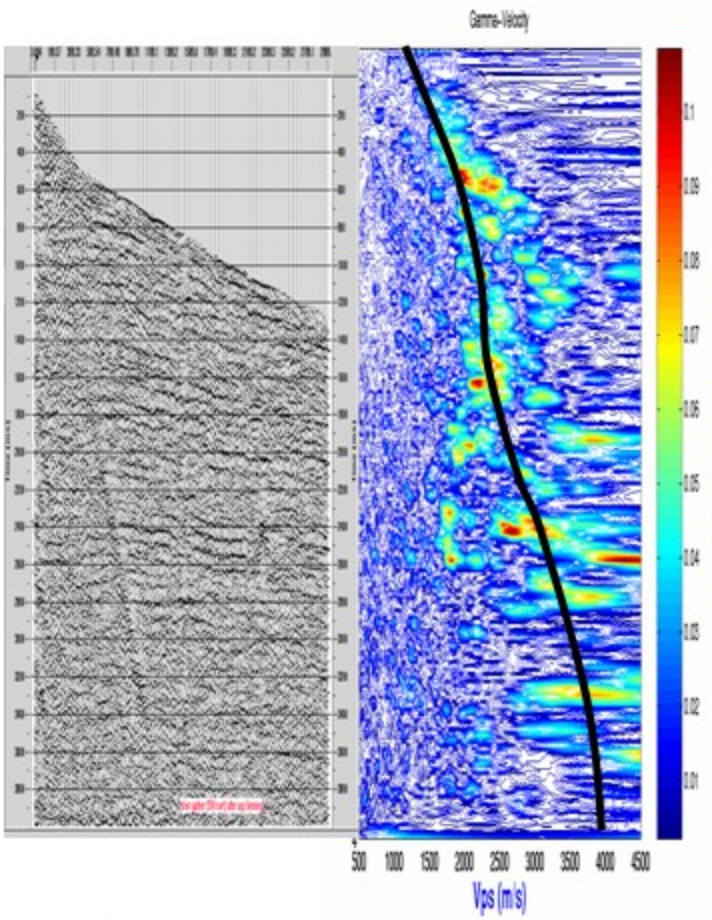
Application: Log-type Method (ACP gather)
Blackfoot Oil Field



Comparison of the Vp/Vs log from the Log-type Method and the Vp/Vs log from Well-09-08.

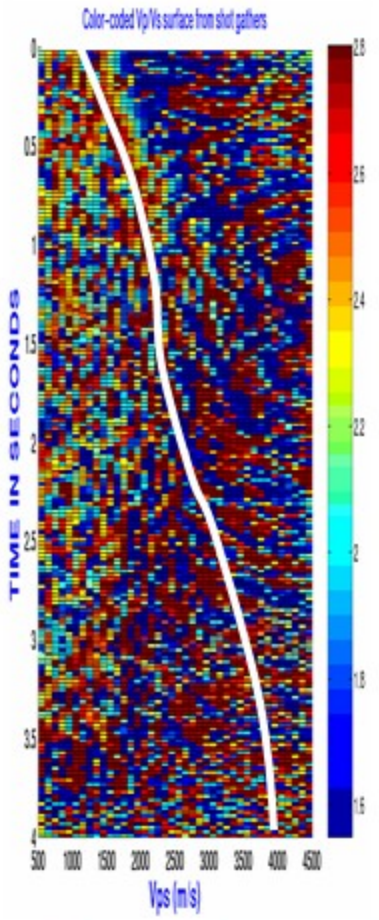
(Prestack Vps-γ_0 scanning)

Application: Log-type Method (Shot gather)
Blackfoot Oil Field

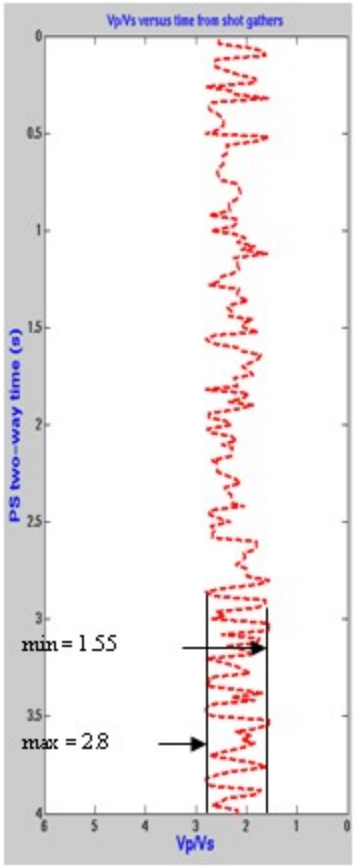


Shot gather

Final 2D semblance



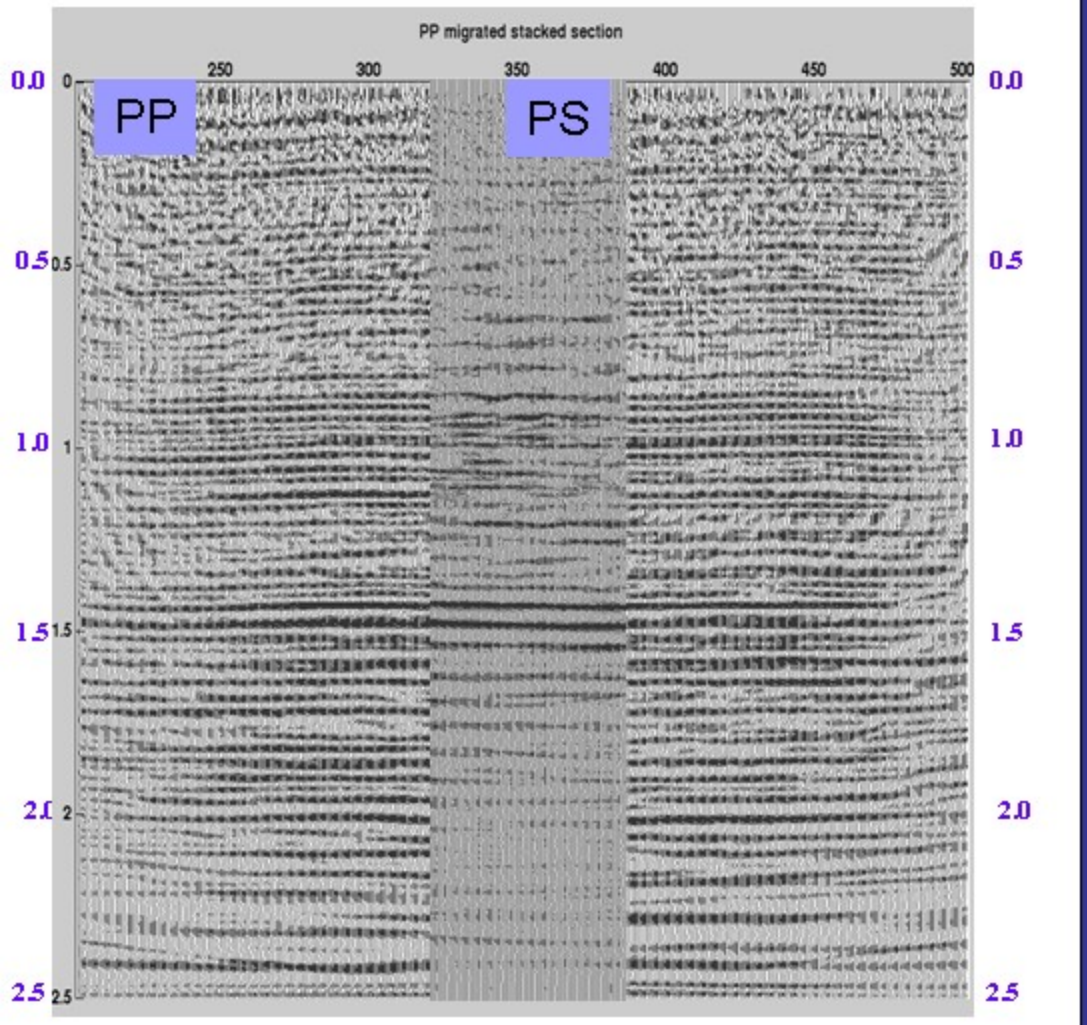
Color-coded γ_0 panel



γ_0 –time log

(Prestack Vps-γ_0 scanning)

Application: Blackfoot Oil Field
PS-to-PP time mapping



(Prestack Vps-γ_0 scanning)

Conclusions

Vp/Vs (γ_0) can be derived from prestack data via moveout analysis using a PS non-hyperbolic traveltime equation from Thomsen (1999) and Tessmer and Behle (1988).

Based on the derived equation, the Log-type scanning method was developed to search for the stacking velocities and γ values

The method can automatically map PS data into PP time

The algorithms showed considerable promise when applied to synthetic and the Blackfoot data sets