Pressure-saturation discrimination for the underground blowout data

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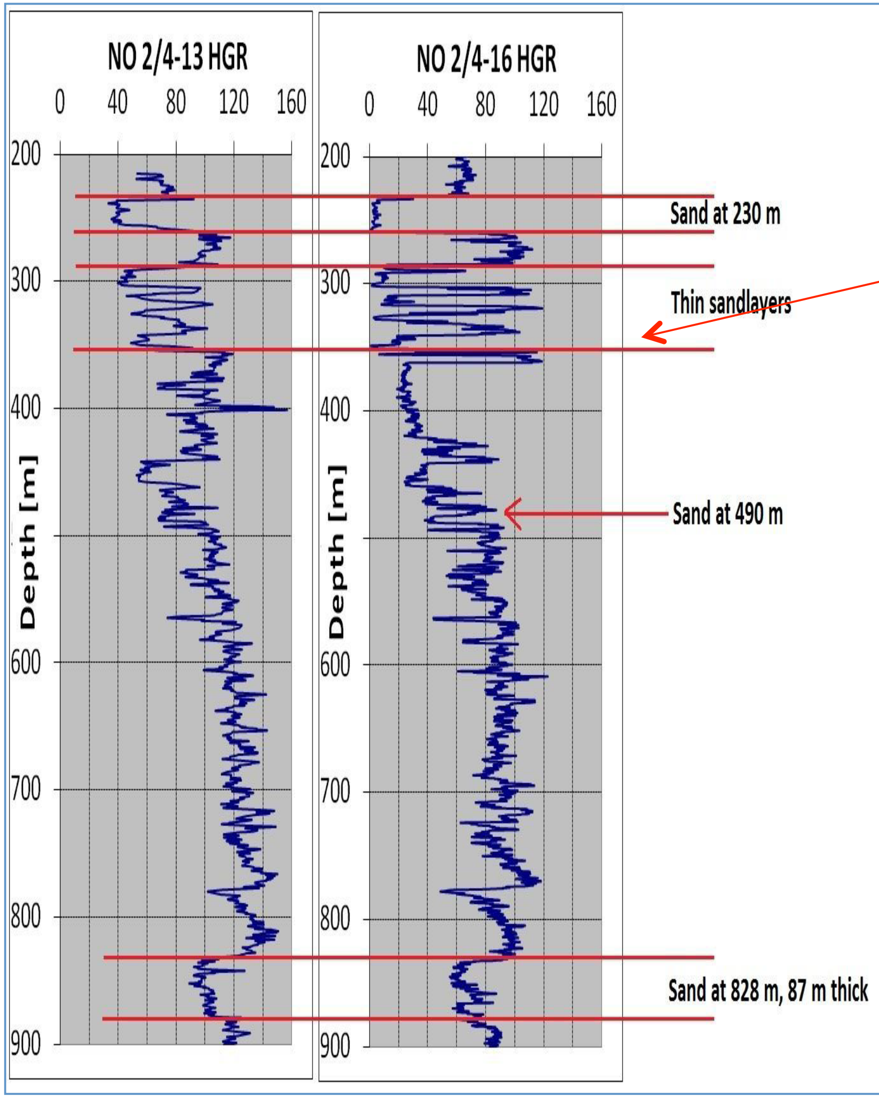
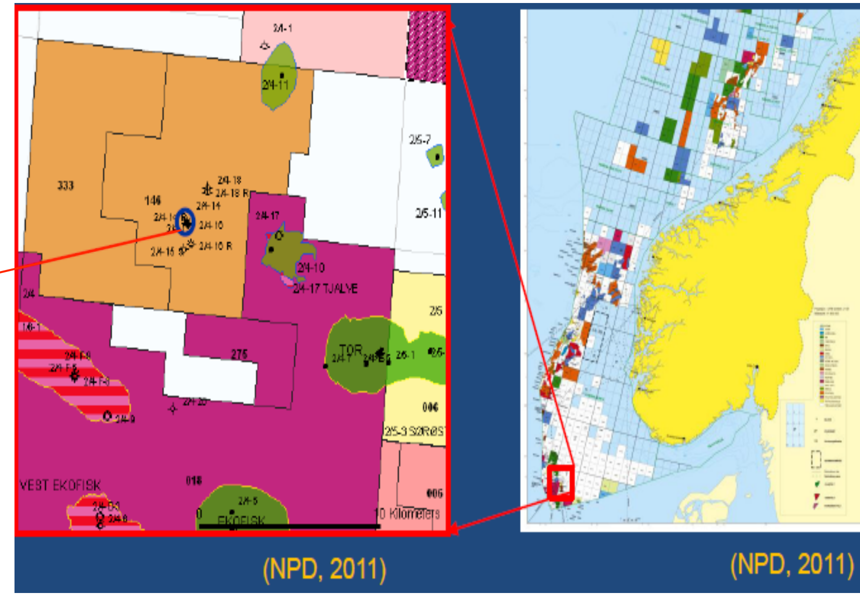
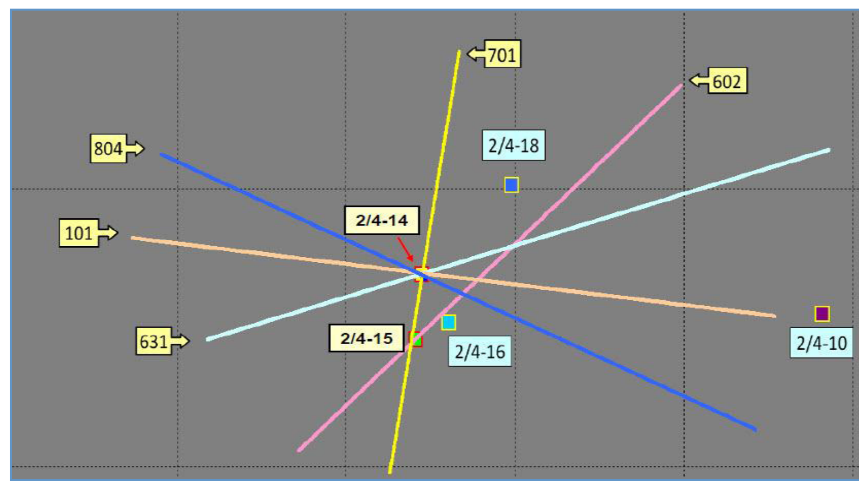
Outline

- Blowout history
- Observed Time-lapse effects
- Objectives and Challenges
- Methodology
- Results
- Uncertainties
- Conclusions

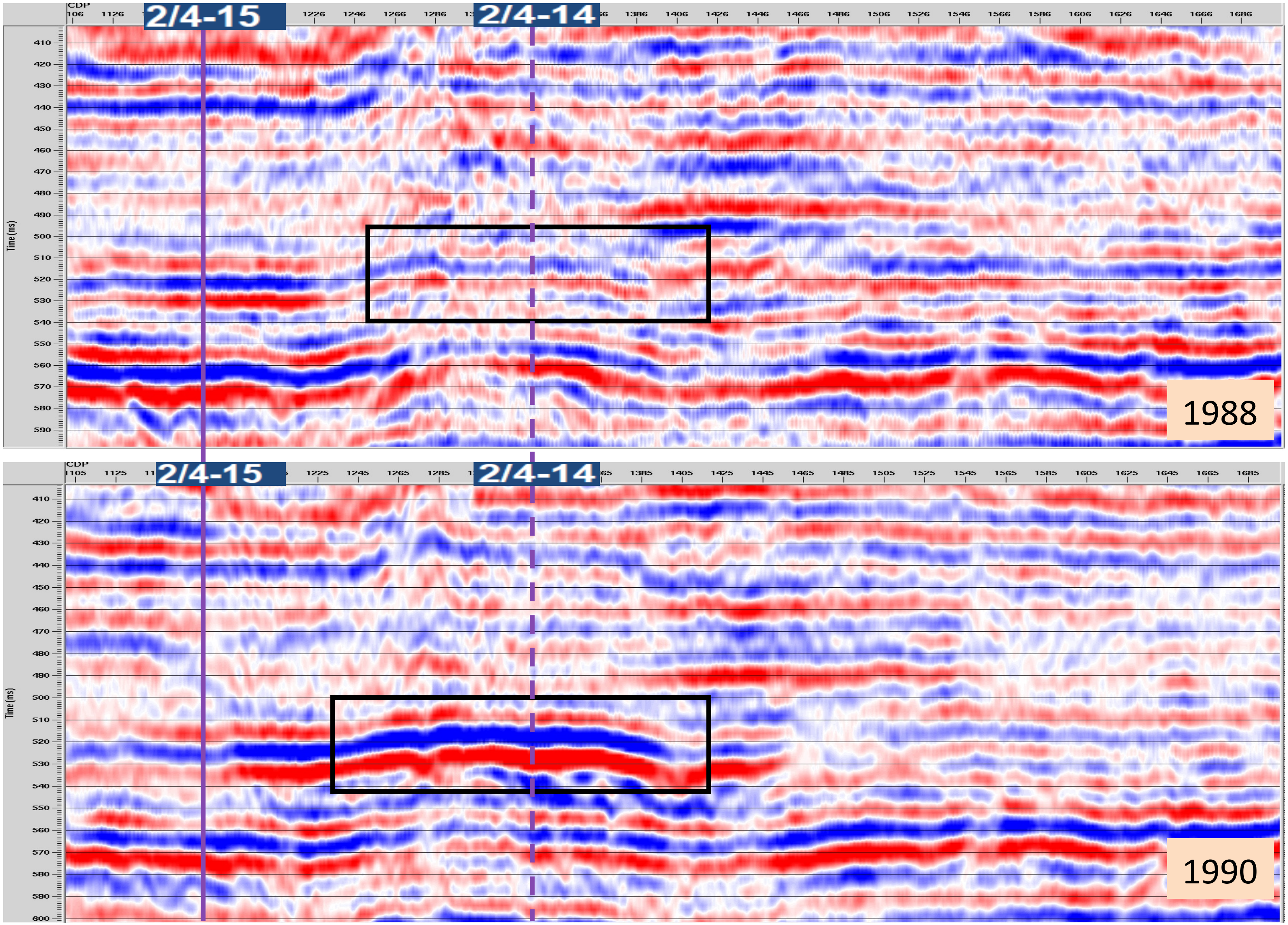
Blow out history







Observed Time-lapse effects



Main Objectives

- Discriminate pressure-saturation for gas blow out
- Explore feasibility unconsolidated rocks

Some challenges

- Don't have good well logs (Vp, Vs,Density) for AVO Calibration
- No core data is available
- Site survey data from 1988 and 1990 have significant variation in hydrophone sensitivies versus offset

Theory

- Reflection Coefficients can be written (Smith and Gidlow ,1987)

$$R_1(\Theta) = \frac{1}{2}\left(\frac{\Delta\rho}{\rho} + \frac{\Delta\alpha}{\alpha}\right) - \frac{2\beta^2}{\alpha^2}\left(\frac{\Delta\rho}{\rho} + \frac{2\Delta\beta}{\beta}\right)\sin^2\Theta + \frac{\Delta\alpha}{2\alpha}\tan^2\Theta$$

where, $\alpha = (\alpha_1 + \alpha_2)/2$ etc

- After fluid and pressure changes ,

$$R'_1(\Theta) = \frac{1}{2}\left(\frac{\Delta\rho'}{\rho'} + \frac{\Delta\alpha'}{\alpha'}\right) - \frac{2\beta'^2}{\alpha'^2}\left(\frac{\Delta\rho'}{\rho'} + \frac{2\Delta\beta'}{\beta'}\right)\sin^2\Theta + \frac{\Delta\alpha'}{2\alpha'}\tan^2\Theta$$

- From Rock Physics analysis

$$\frac{\Delta\alpha}{\alpha} \approx K_\alpha\Delta S + N_\alpha\Delta S^2 + L_\alpha\Delta P + M_\alpha\Delta P^2$$

$$\frac{\Delta\beta}{\beta} \approx K_\beta\Delta S + N_\beta\Delta S^2 + L_\beta\Delta P + M_\beta\Delta P^2$$

$$\frac{\Delta\rho}{\rho} \approx K_\rho\Delta S$$

(Landrø,2001)

Theory

- If we consider conventional AVO intercept and gradient formula,

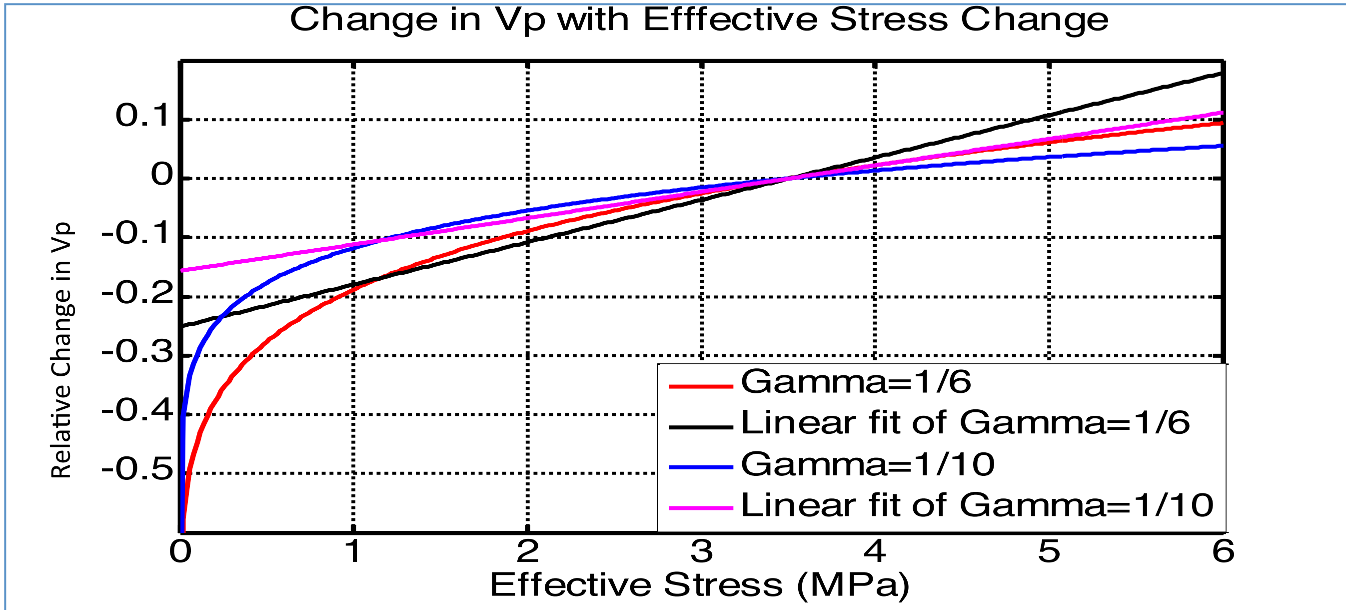
$$\Delta R_0 \approx \frac{1}{2}(K_\alpha \Delta S + N_\alpha \Delta S^2 + K_\rho \Delta S + L_\alpha \Delta P + M_\alpha \Delta P^2)$$

$$\Delta G \approx \frac{1}{2}(K_\alpha \Delta S + N_\alpha \Delta S^2 + L_\alpha \Delta P + M_\alpha \Delta P^2) - \frac{4\beta^2}{\alpha^2}(L_\beta \Delta P + M_\beta \Delta P^2)$$

(Landrø,2001)

Note: If $\beta / \alpha \Rightarrow 0,$ the discrimination power is reduced as last term in ΔG is of less importance => expect more uncertainty as β / α decreases.

Rock Physics Analysis

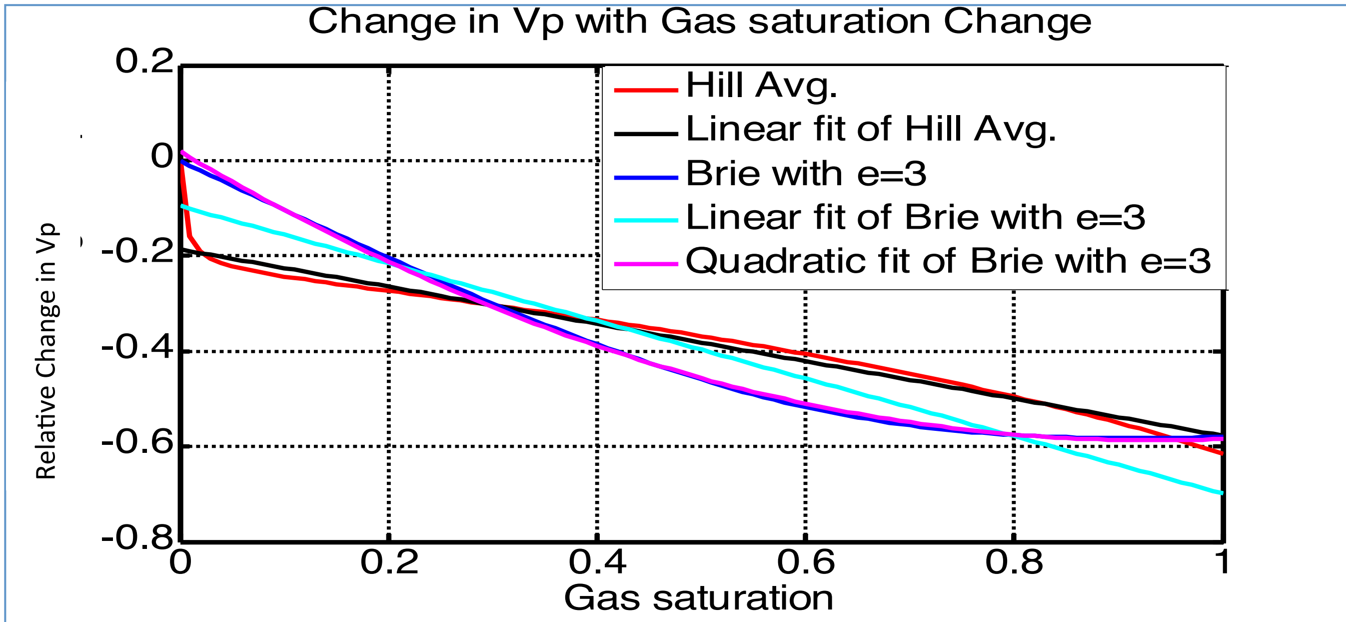


For gamma=1/10,

$$L_\alpha = L_\beta = 0.062$$

For gamma=1/6,

$$L_\alpha = L_\beta = 0.097$$



Linear fit Hill Avg. ,

$$K_\alpha = -0.394$$

Linear fit of Brie e=3,

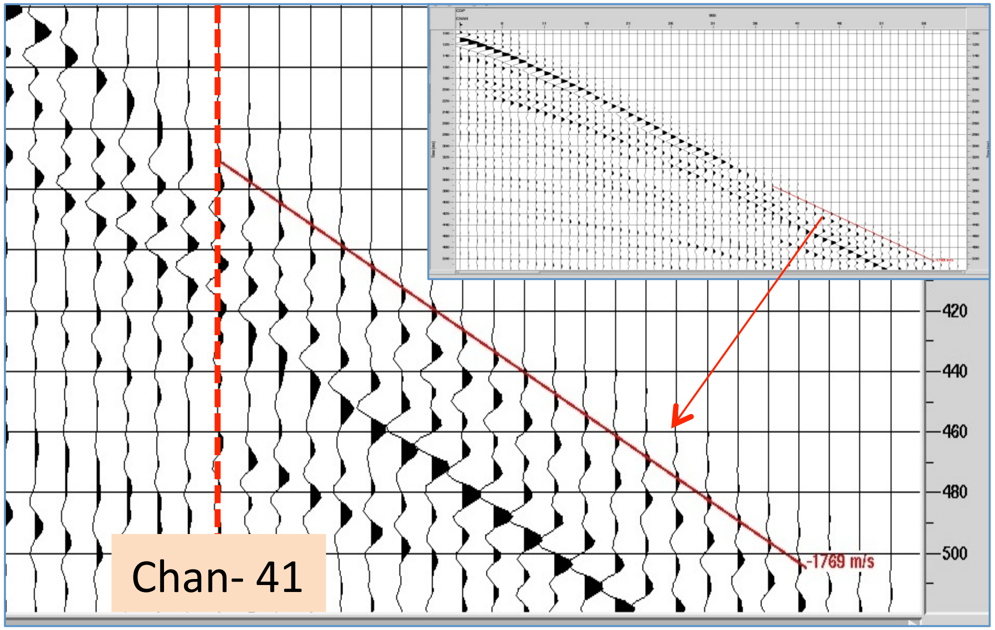
$$K_\alpha = -0.601$$

Quadratic fit of Brie e=3,

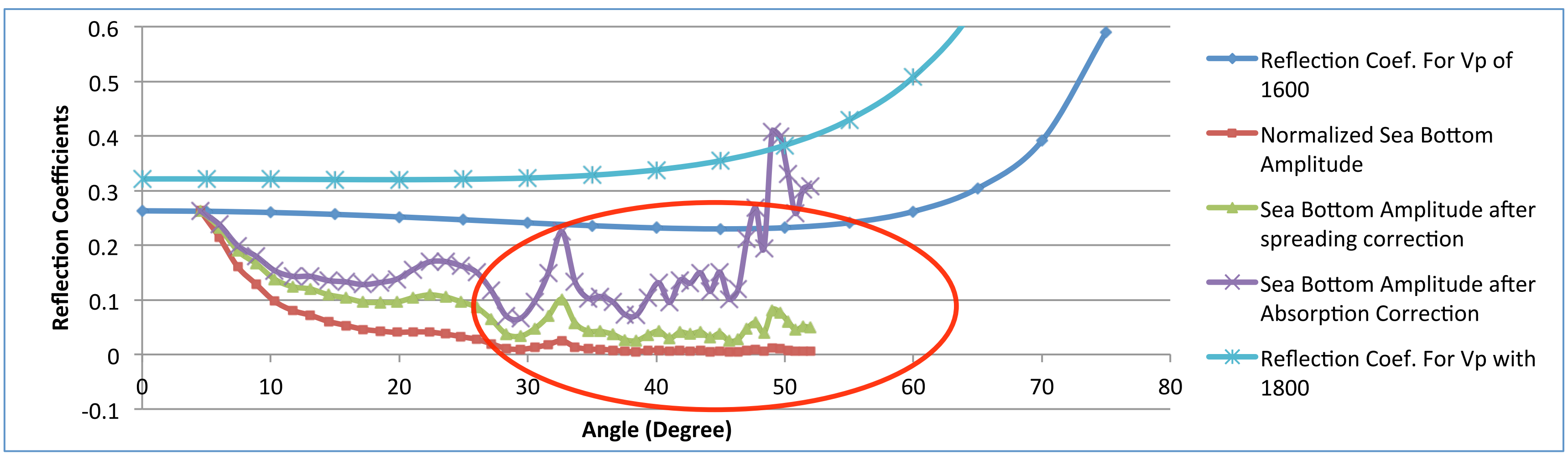
$$K_\alpha = -1.288$$

$$N_\alpha = 0.687$$

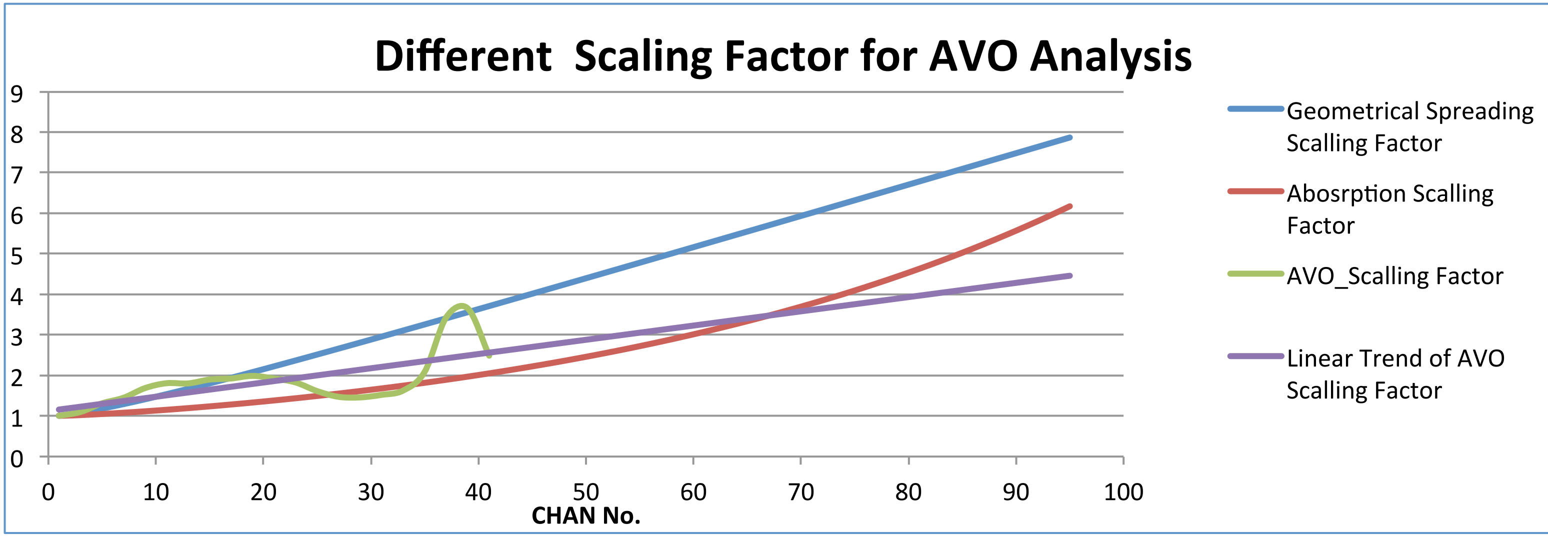
AVO Analysis-- calibration



	Vp (m/s)	Vs (m/s)	ρ (g/cc)
Sea-Water	1500	0	1
Sea Bottom	1600	375	1.6

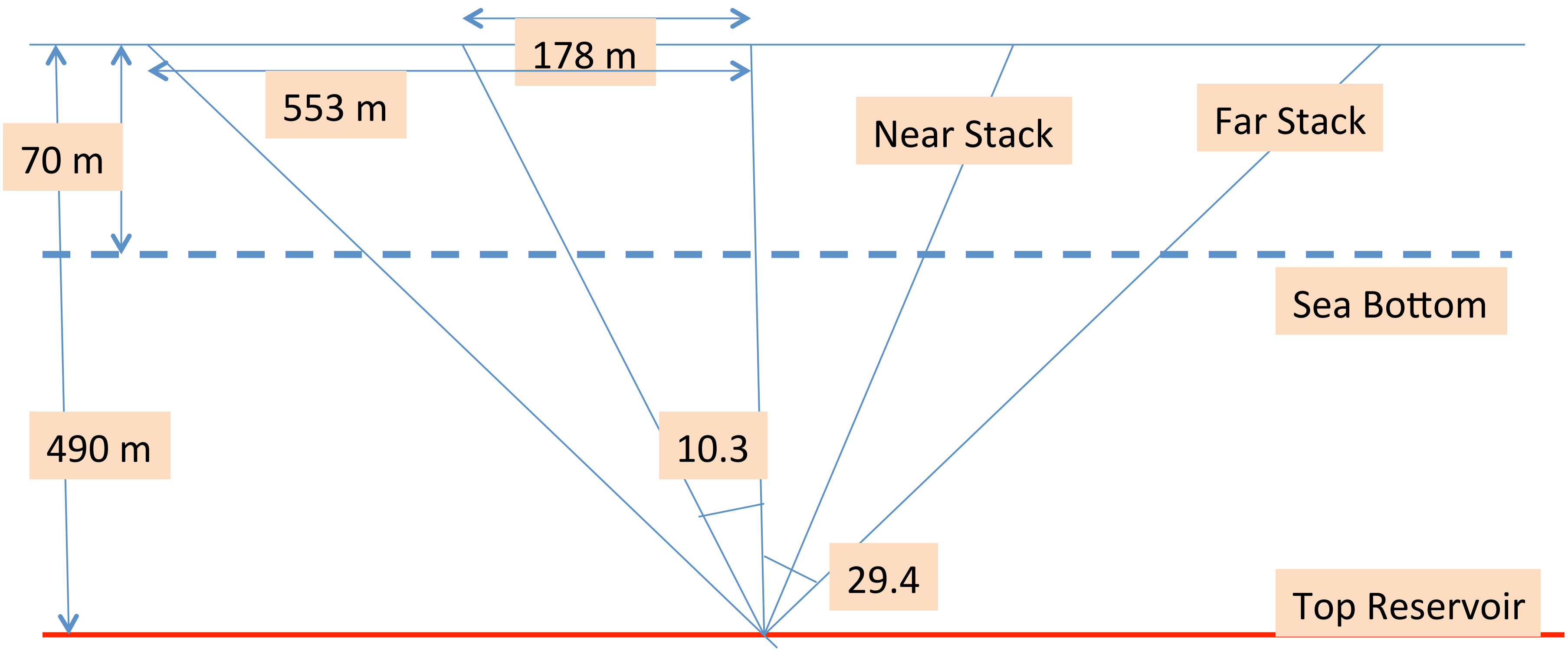


AVO Analysis-- calibration



Scaling Factor	Near Stack Data (1-17)	Far Stack Data (31-47)
Global Scaling (1988)	1.41*10^-11	1.41*10^-11
Global Scaling (1990)	5.30*10^-9	5.30*10^-9
Geometrical Spreading	1.013	1.145
Absorption	1.022	1.265
AVO Scaling	1.7	2.5

General Information



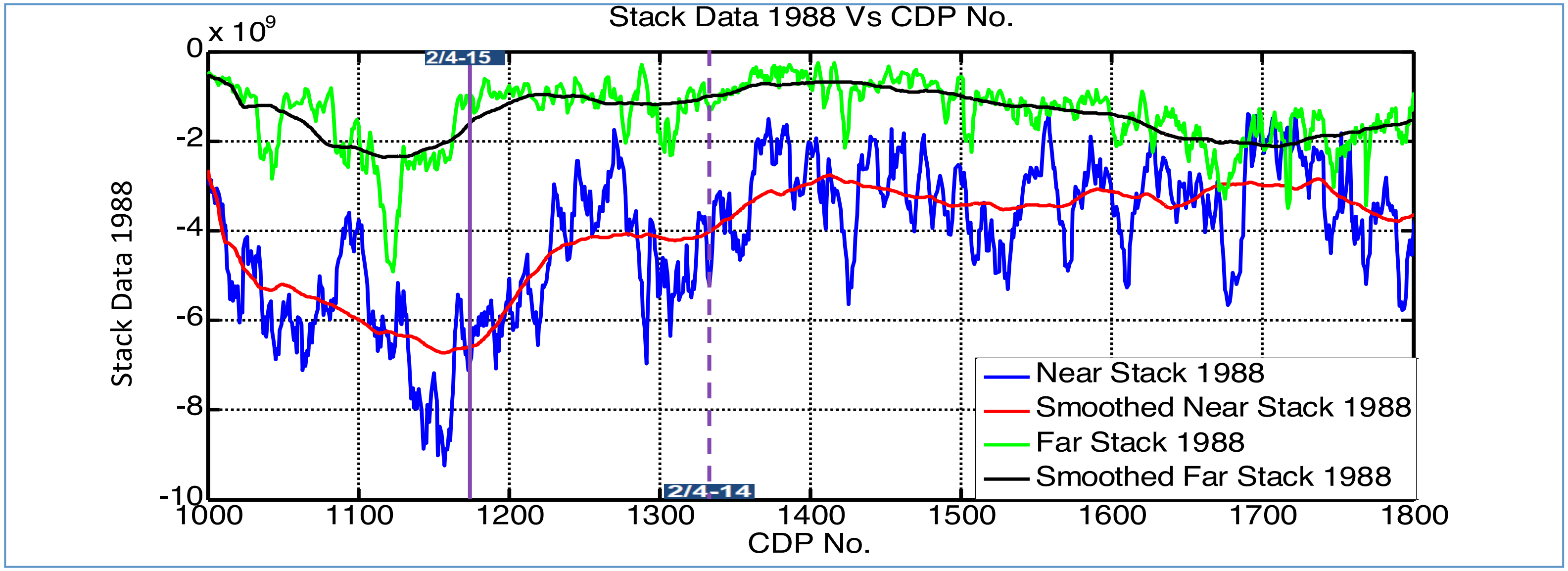
Trace interval is =12.5 m

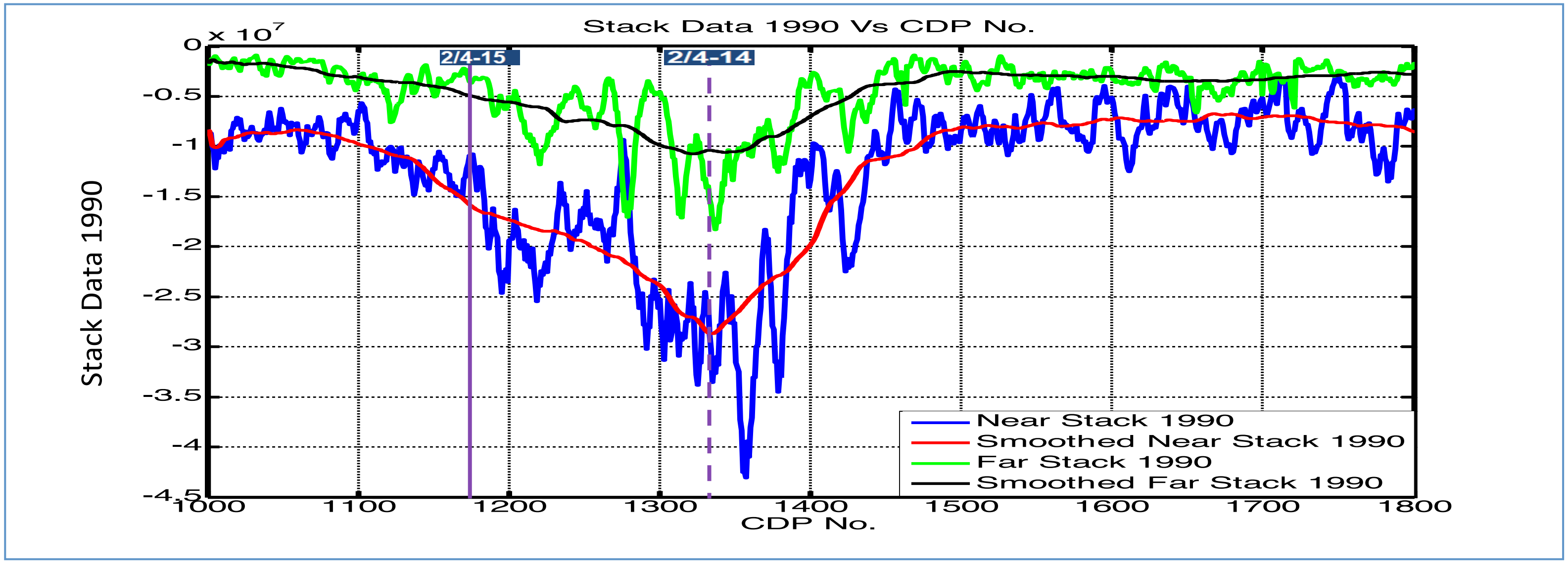
Near offset =78 m

No. of channels= 95

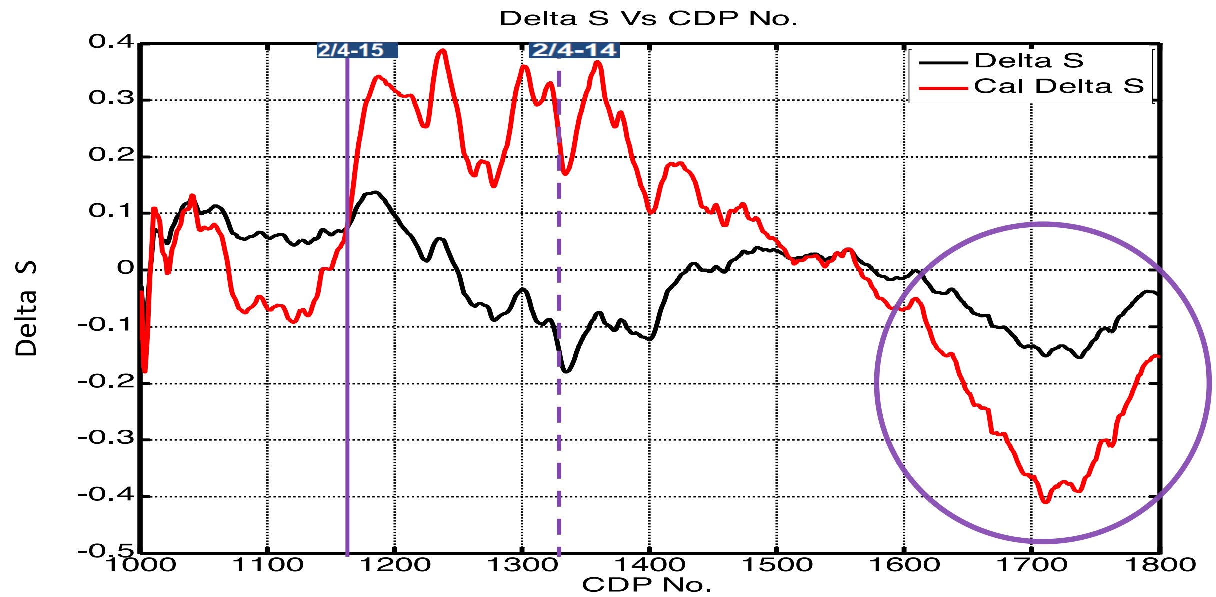
Initial Effective Stress is around 3.5 MPa (Assuming hydrostatic trend)

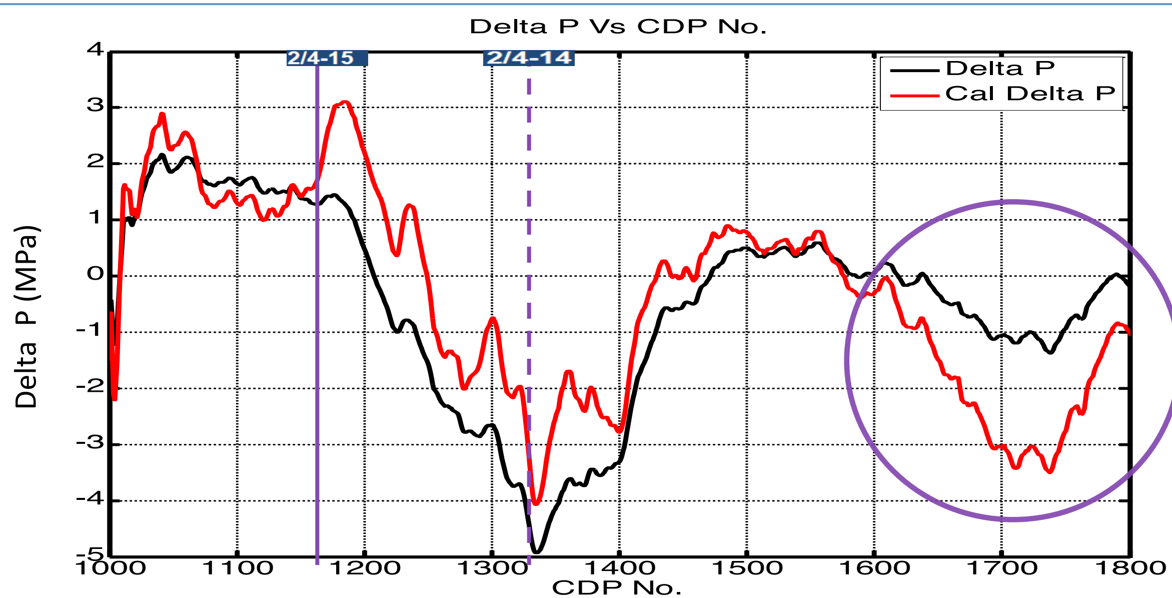
Results


Stack Data 1988 Vs CDP No.
x 10^9
Stack Data 1988
0
-2
-4
-6
-8
-10
2/4-15
2/4-14
1000
1100
1200
1300
1400
1500
1600
1700
1800
CDP No.
Near Stack 1988
Smoothed Near Stack 1988
Far Stack 1988
Smoothed Far Stack 1988


Stack Data 1990 Vs CDP No.
x 10^7
Stack Data 1990
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
2/4-15
2/4-14
1000
1100
1200
1300
1400
1500
1600
1700
1800
CDP No.
Near Stack 1990
Smoothed Near Stack 1990
Far Stack 1990
Smoothed Far Stack 1990

Results





Here,

$$K_\alpha = -0.394$$

$$K_\beta = 0.077$$

$$K\rho = -0.138$$

$$L_\alpha = L_\beta = 0.062$$

$$\frac{V_s}{V_p} = 0.5$$

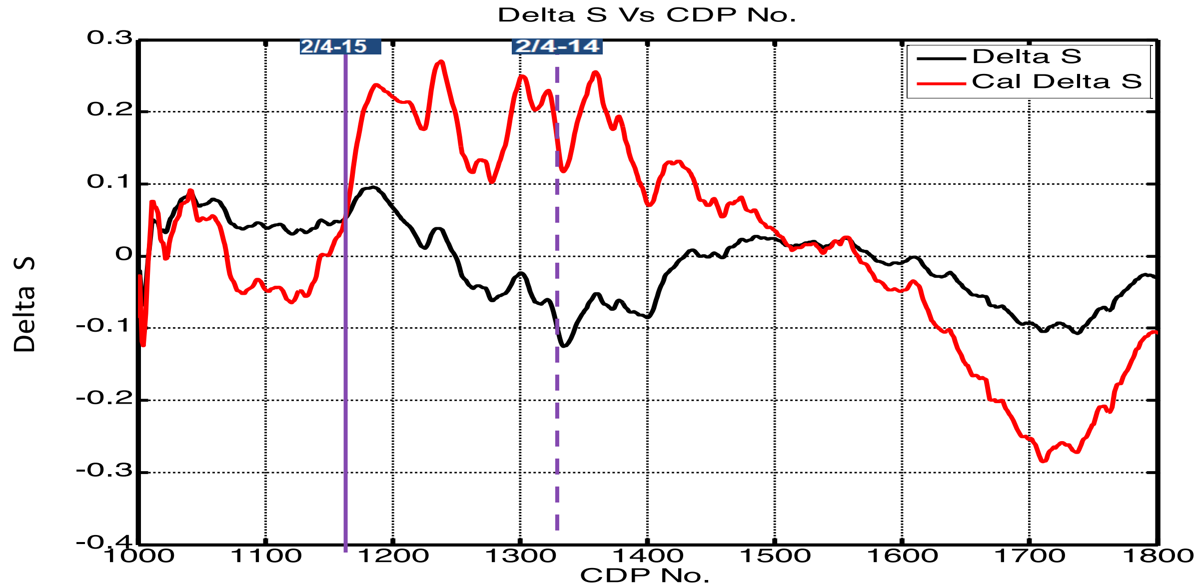
$$\Delta P = 13.7\Delta R_0 - 18.5\Delta G$$

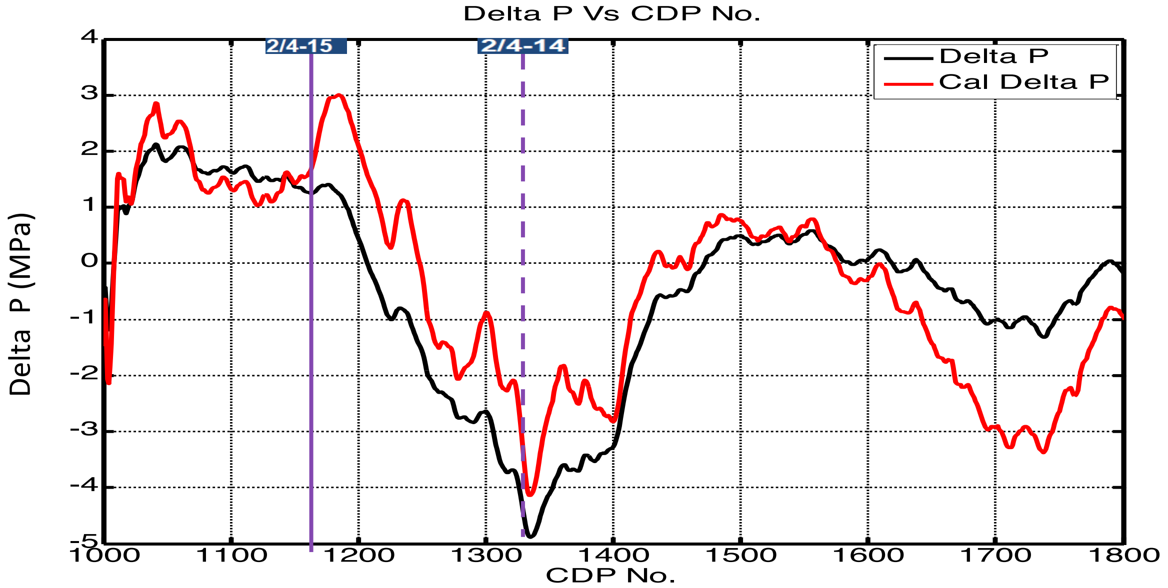
$$\Delta S = -2.16(\Delta R_0 + \Delta G)$$

Gamma=1/10

Hill Avg.

Results





Here,

$$K_\alpha = -0.601$$

$$K_\beta = 0.077$$

$$K\rho = -0.138$$

$$L_\alpha = L_\beta = 0.062$$

$$\frac{V_s}{V_p} = 0.5$$

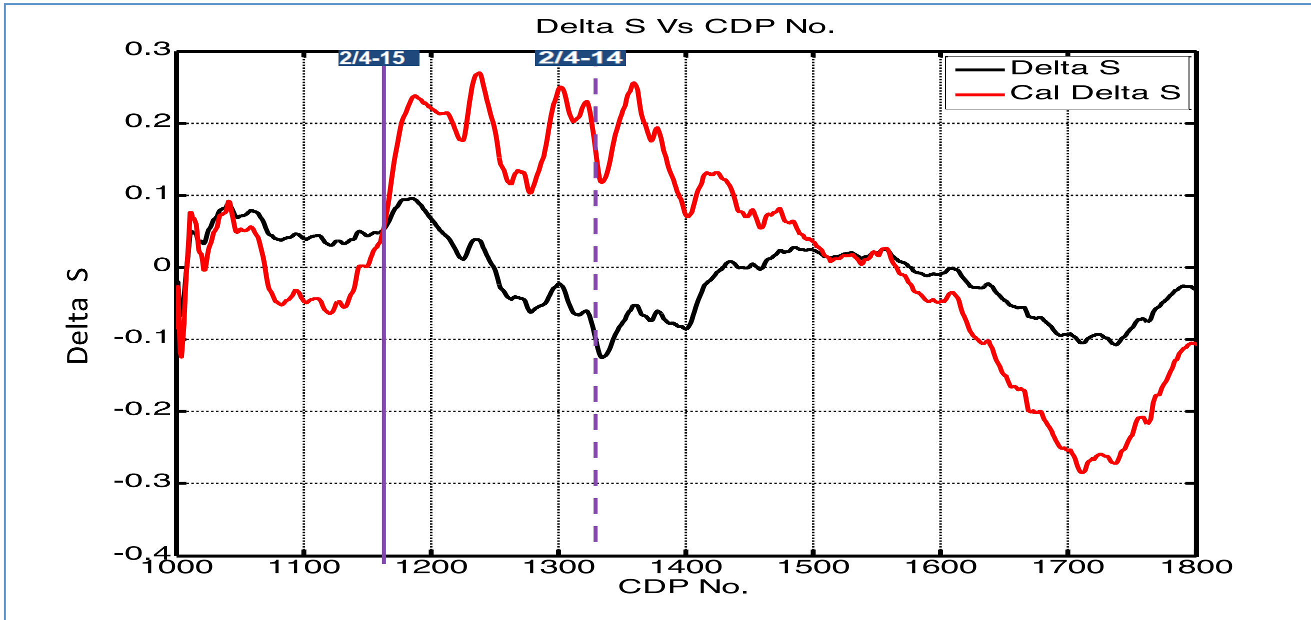
$$\Delta P = 14.5\Delta R_0 - 17.8\Delta G$$

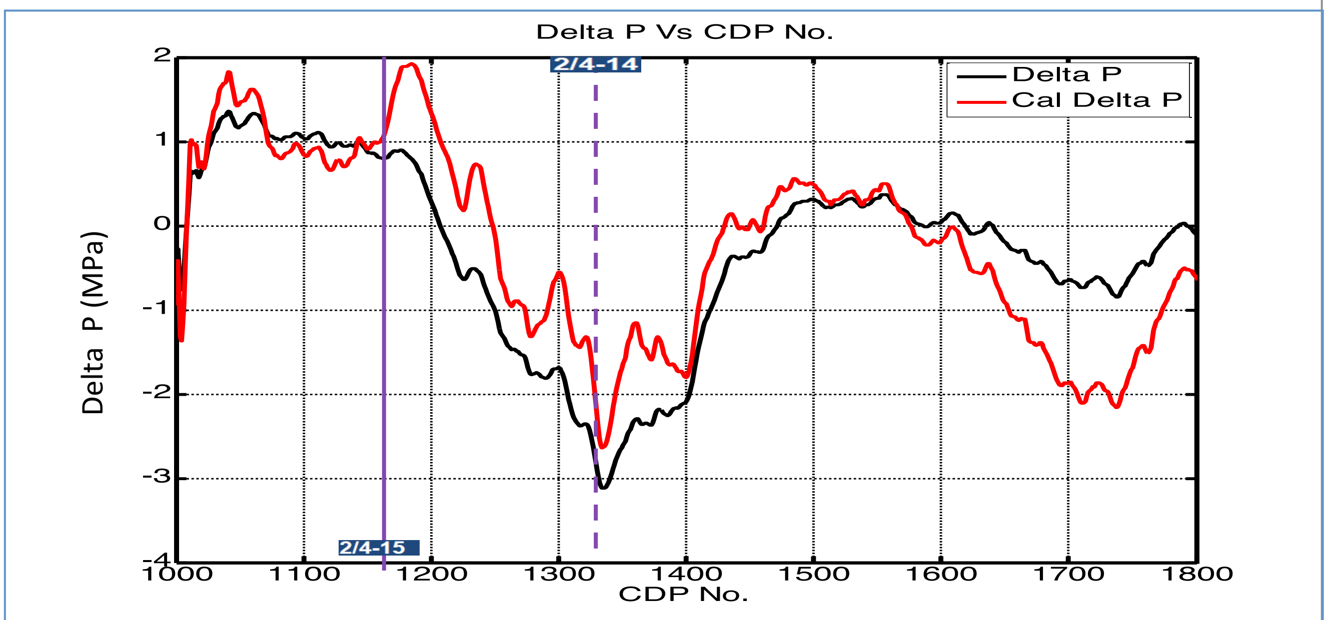
$$\Delta S = -1.5(\Delta R_0 + \Delta G)$$

Gamma=1/10

Brie with e=3 linear Trend

Results





Here,

$$K_{\alpha} = -0.601$$

$$K_{\beta} = 0.077$$

$$K\rho = -0.138$$

$$L_{\alpha} = L_{\beta} = 0.097$$

$$\frac{V_s}{V_p} = 0.5$$

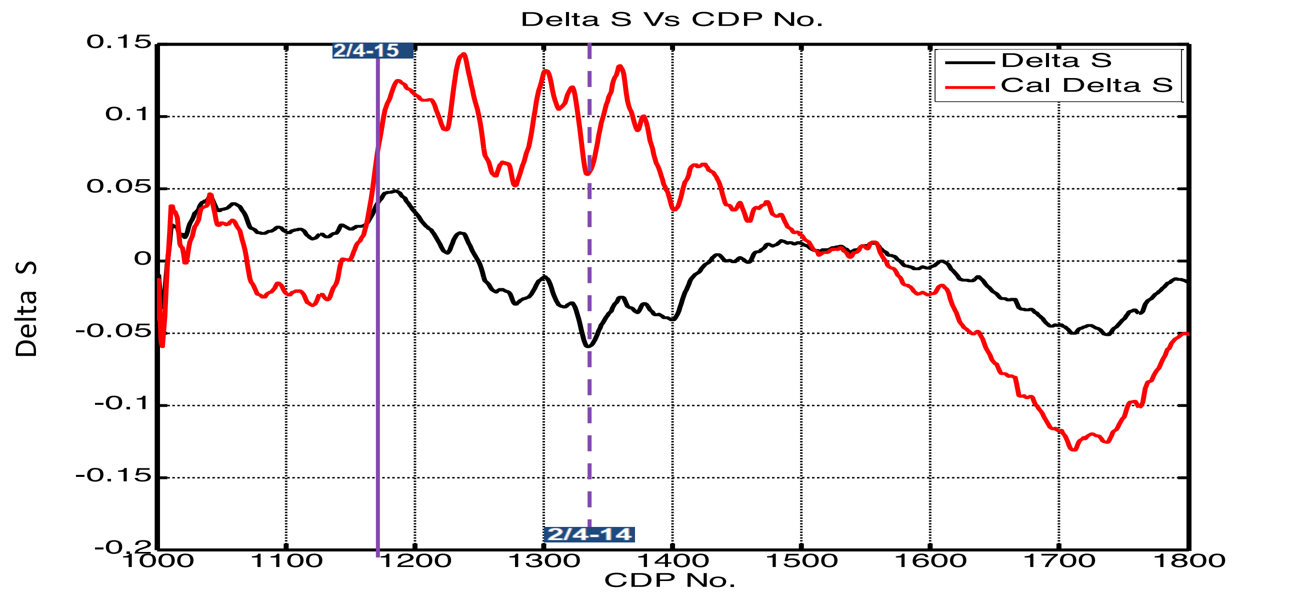
$$\Delta P = 9.2\Delta R_0 - 11.4\Delta G$$

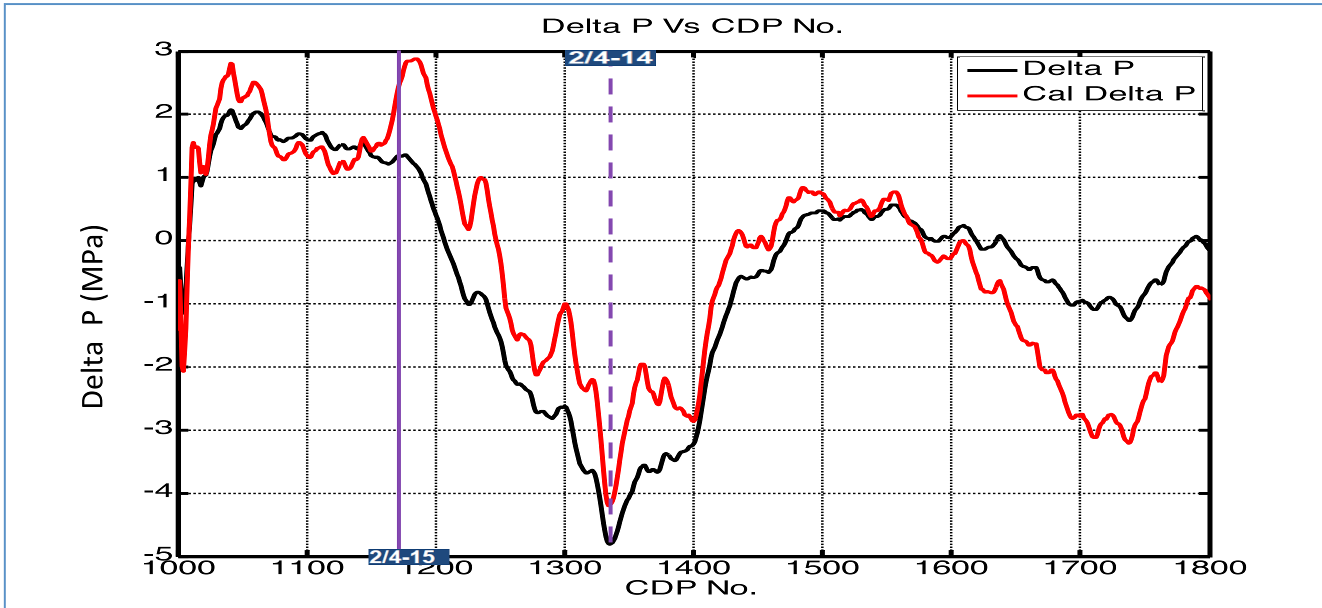
$$\Delta S = -1.5(\Delta R_0 + \Delta G)$$

Gamma=1/6

Brie with e=3 linear Trend

Results





Here,

$$K_\alpha = -1.288$$

$$N_\alpha = 0.687$$

$$K_\beta = 0.077$$

$$K\rho = -0.138$$

$$L_\alpha = L_\beta = 0.062$$

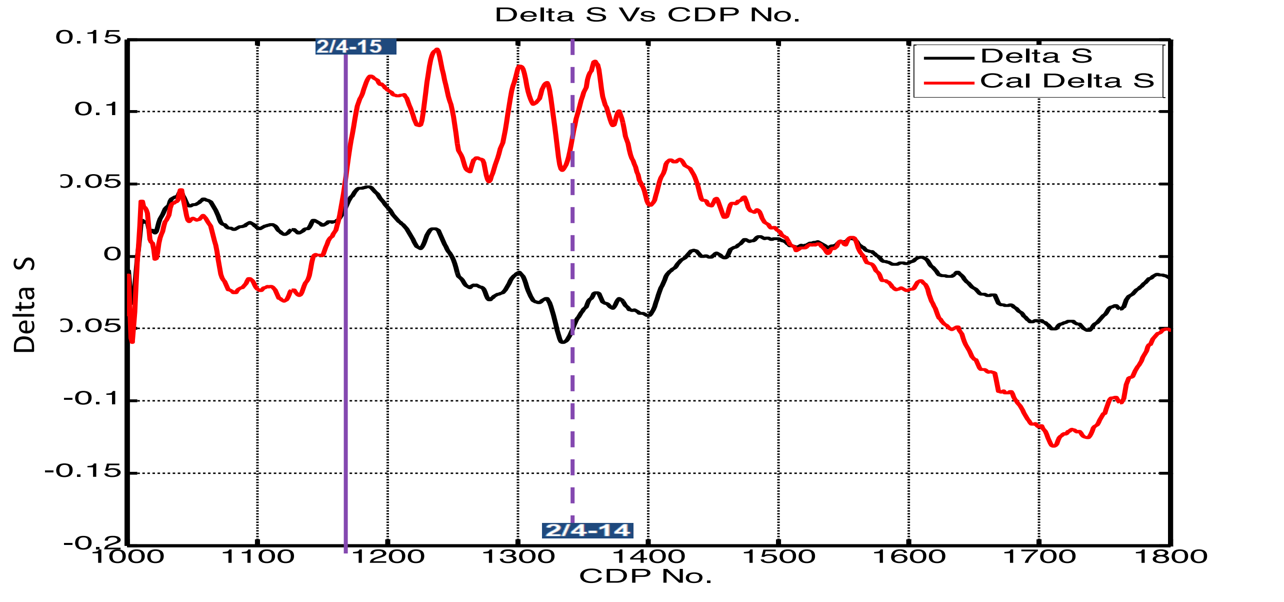
$$\frac{V_s}{V_p} = 0.5$$

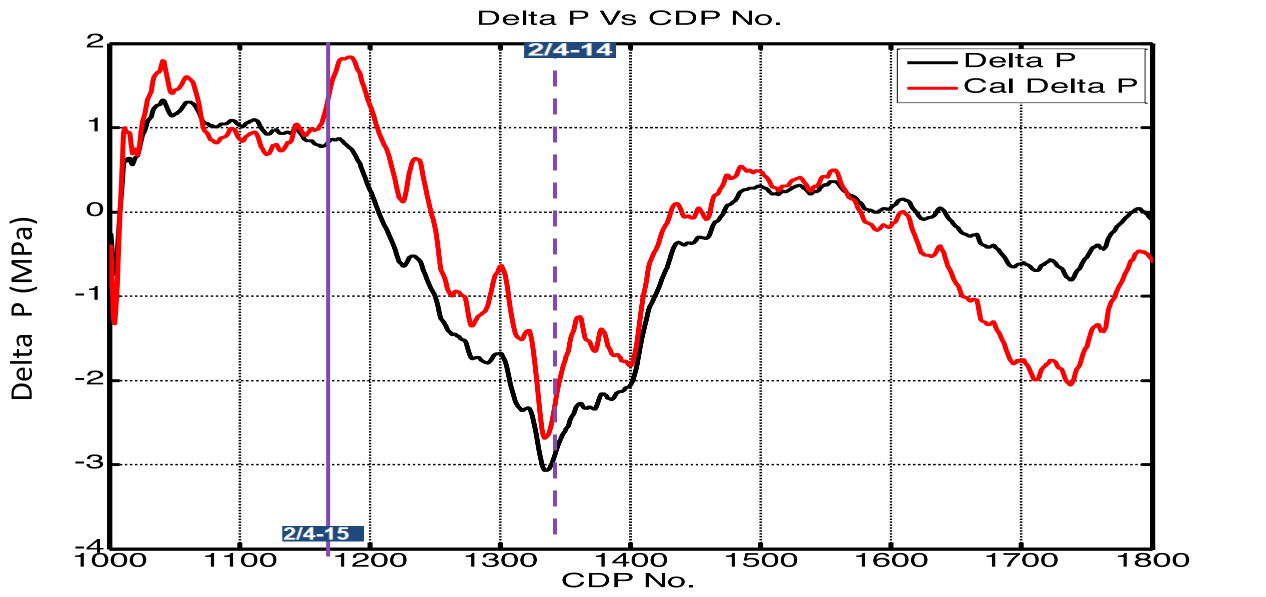
Gamma=1/10

Brie with e=3

quadratic trend

Results





Here,

$$K_\alpha = -1.288$$

$$N_\alpha = 0.687$$

$$K_\beta = 0.077$$

$$K\rho = -0.138$$

$$L_\alpha = L_\beta = 0.097$$

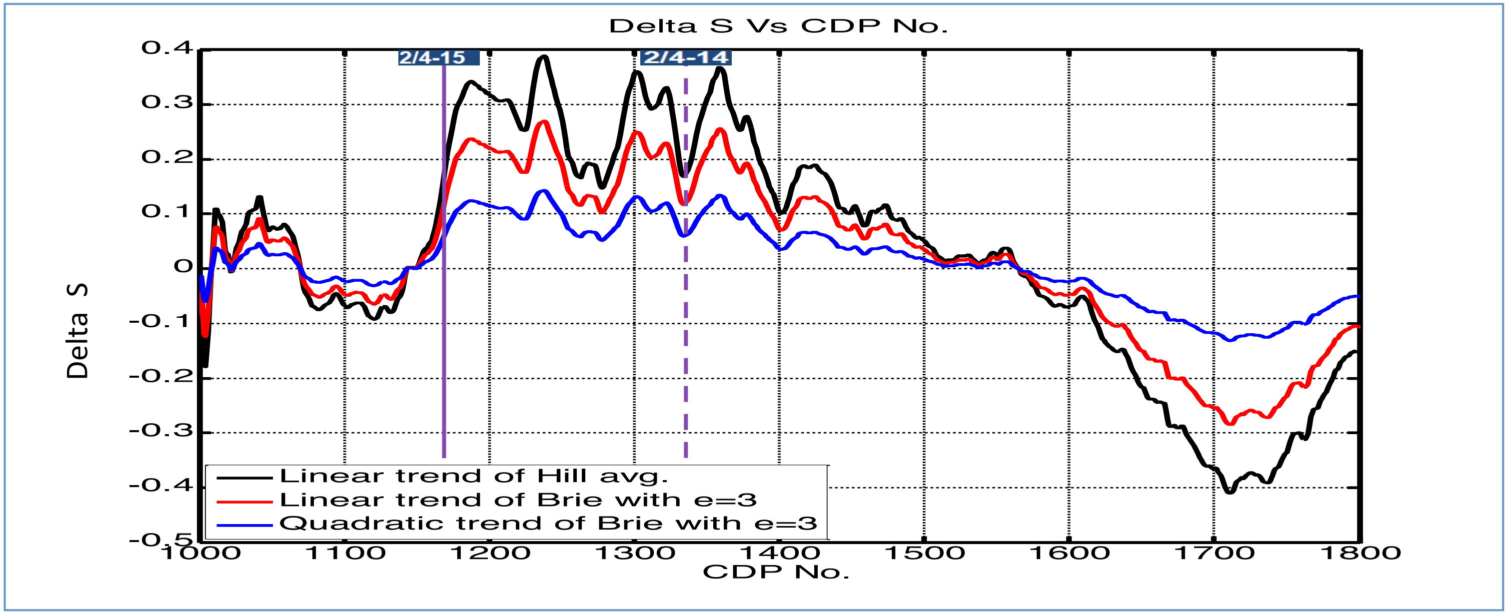
$$\frac{V_s}{V_p} = 0.5$$

Gamma=1/6

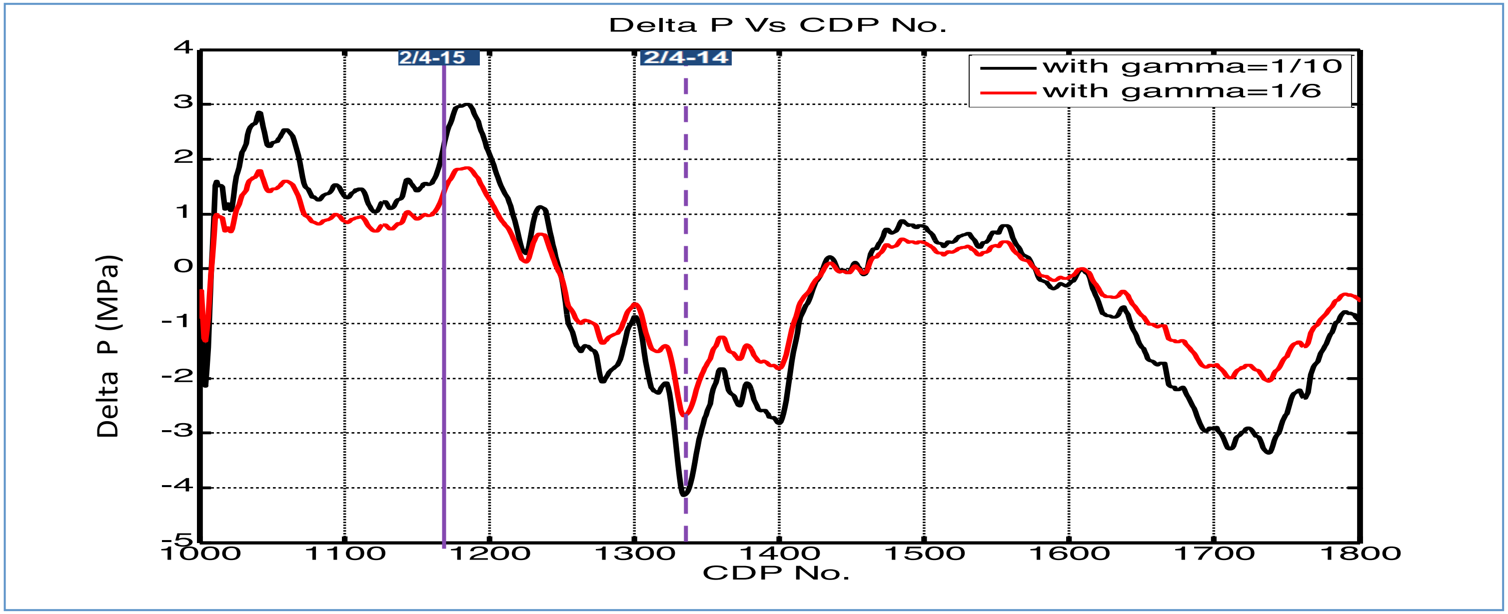
Brie with e=3

quadratic trend

Results

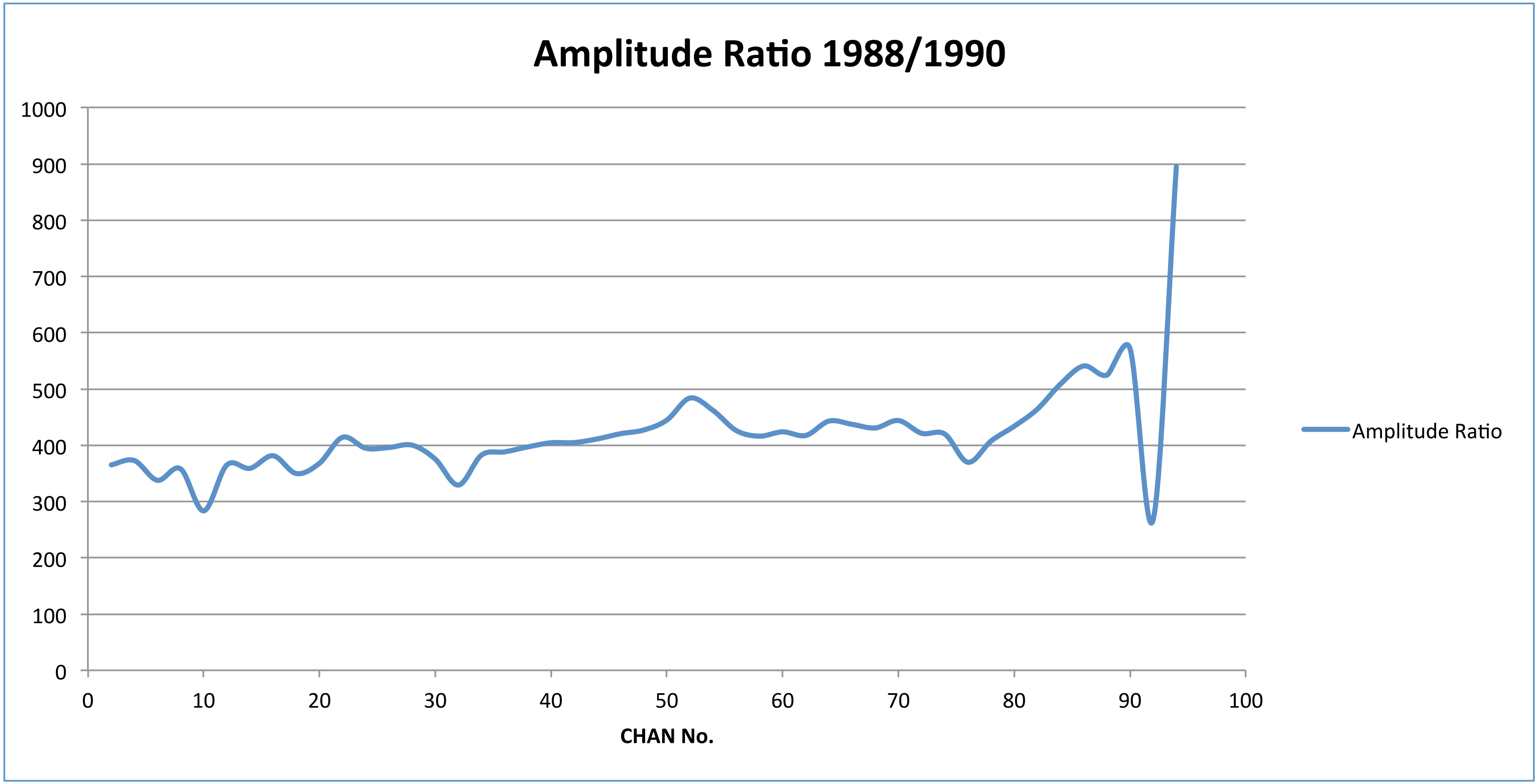


Delta S Vs CDP No.
2/4-15
2/4-14
Delta S
CDP No.
Linear trend of Hill avg.
Linear trend of Brie with e=3
Quadratic trend of Brie with e=3



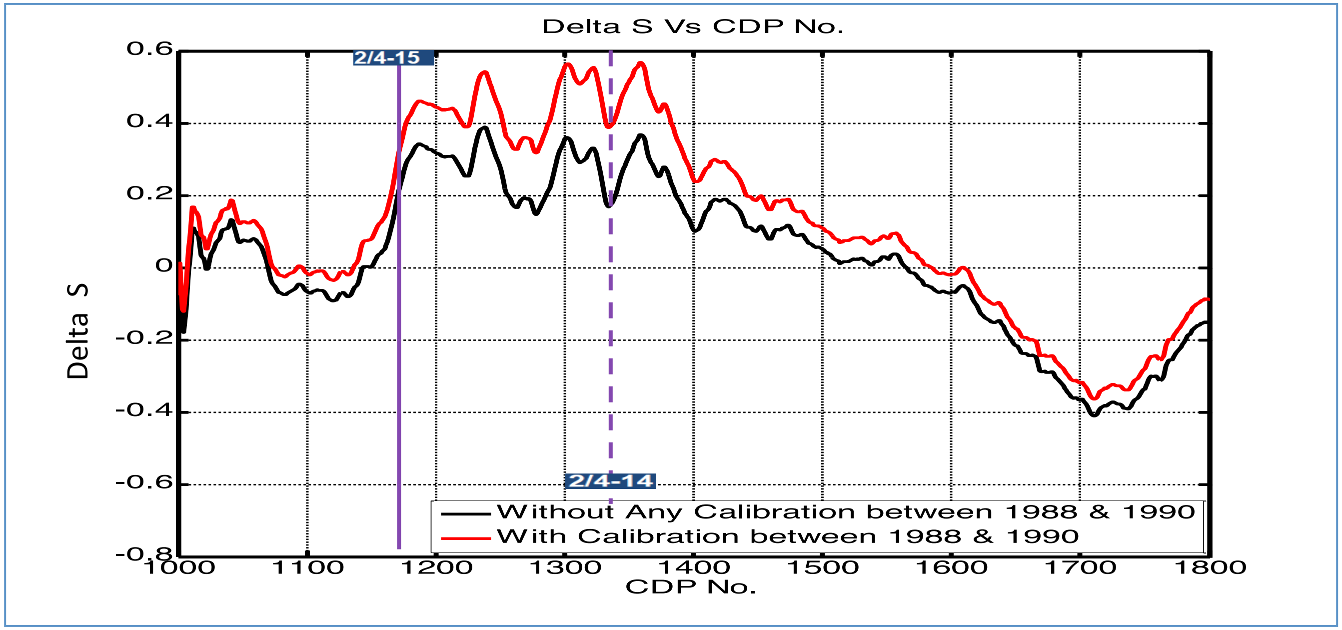
Delta P Vs CDP No.
2/4-15
2/4-14
Delta P (MPa)
CDP No.
with gamma=1/10
with gamma=1/6

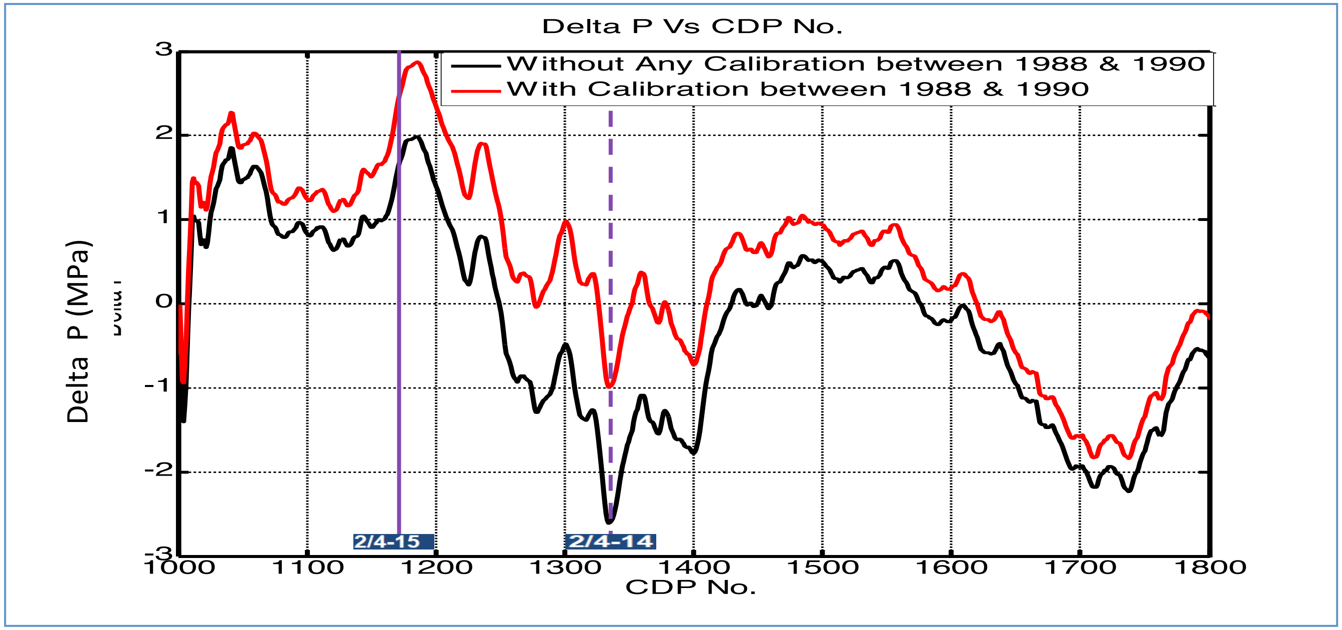
Calibration of channel sensitivities, 1988 and 1990 data



RMS window: 400-1000 ms

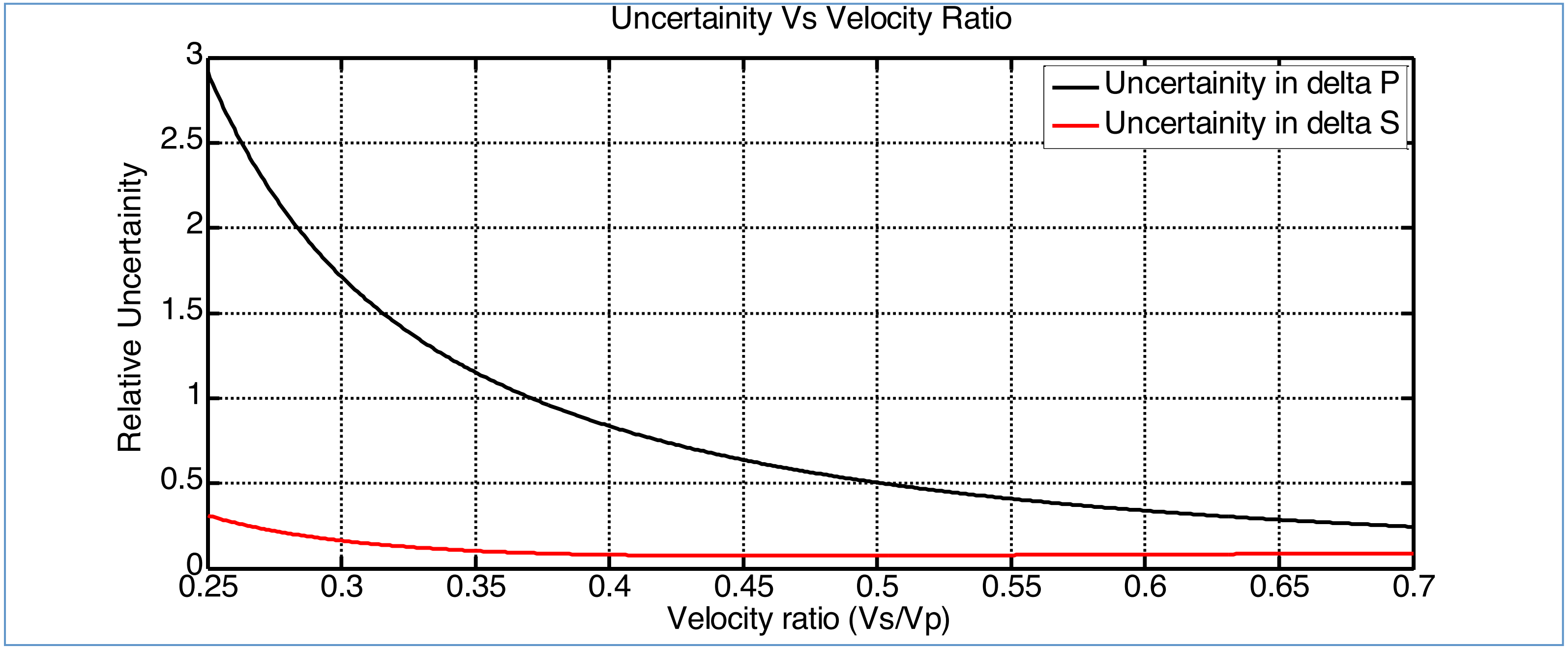
Results


Delta S Vs CDP No.
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Delta S
2/4-15
2/4-14
Without Any Calibration between 1988 & 1990
With Calibration between 1988 & 1990
1000
1100
1200
1300
1400
1500
1600
1700
1800
CDP No.

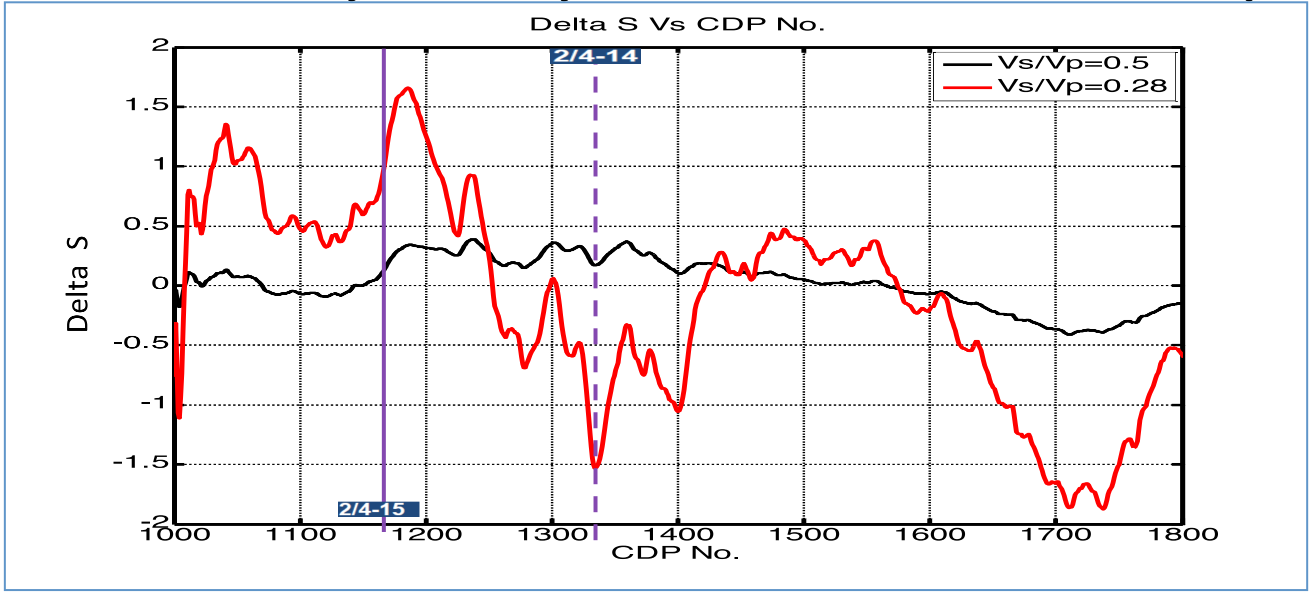

Delta P Vs CDP No.
3
2
1
0
-1
-2
-3
Delta P (MPa)
Without Any Calibration between 1988 & 1990
With Calibration between 1988 & 1990
2/4-15
2/4-14
1000
1100
1200
1300
1400
1500
1600
1700
1800
CDP No.

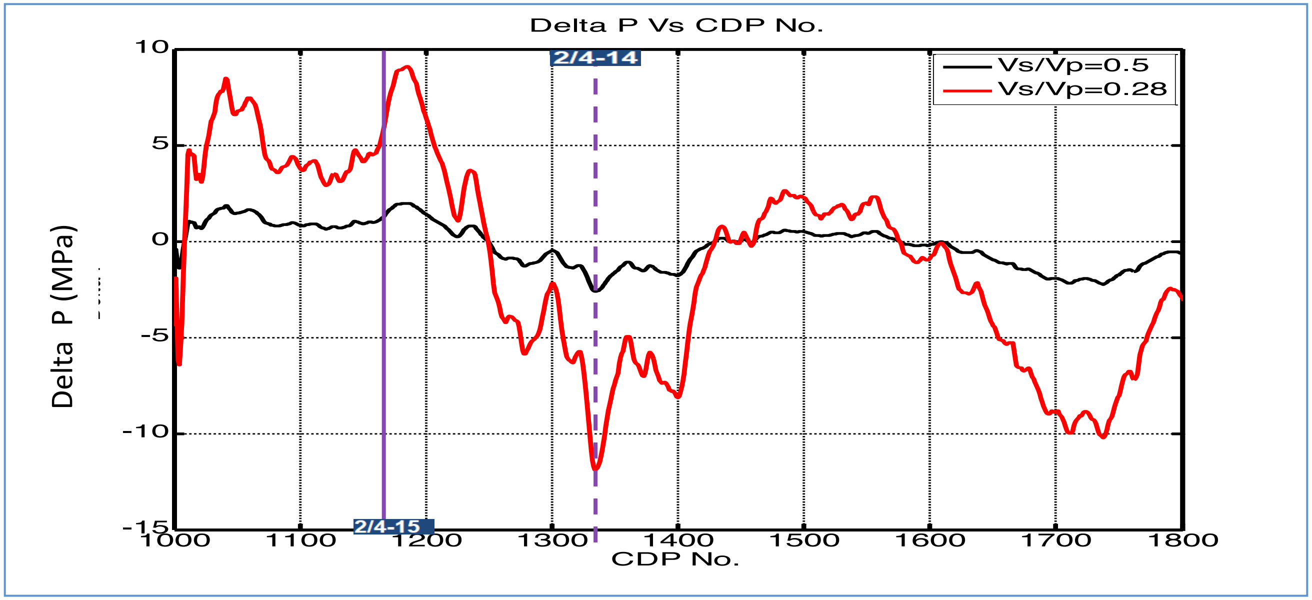
Uncertainty Analysis

K_α	δK_α	L_α	δL_α	K_ρ	δK_ρ	ΔR_0	$\delta \Delta R_0$	ΔG	$\delta \Delta G$
-0.394	0.01	0.097	0.005	-0.138	0.005	-0.175	0.04	-0.18	0.03



Uncertainty Analysis-Real Data Example





Discussions & Conclusions

- Analysis highly dependent on rock physics parameters
- We have used Vs/Vp ratio of 0.5, however, in real case it should be lower. But it makes the pressure fluid discrimination highly unstable
- Estimated saturation and pressure values are reasonable, however, the algorithm gives high pressure and saturation changes outside the area between the wells
- Uncertainty in pressure-saturation estimation increases as reservoir depth decreases
- AVO-calibration and sensitivity calibration is a challenge for time lapse site survey data

Acknowledgements

- Total E&P Norge for sponsoring my research
- Statoil , Total and their partners for providing the data
- The sponsors of the Rose Consortium

Thank You

Rock Physics Analysis