

# Gather Conditioning, Processing Impact on AVO and Rock Property Prediction



# Seismic Petrophysics The Careful Synthesis of Seismic and Well Logs

# Alpine Field North Slope, Alaska A tale of a Billion Barrels

### Bergschrund #1 Well Well Log Information as Logged



### Bergschrund #1 Well Well Log Information as Logged





#### Bergschrund #1 Well Well Log Information as Logged Phil 100 0.0 Gøs 100 0.0 Delø 100 Modeled Lime 100.6 0.0 Time Sond 100.0 0.0 Actual Gather (ms) 190.0 DT 40.0 1.6 RHOB 2.7 0.0 Shale 1000 Syn Stock 10000.0 IP 5000 000 0 DTSH 100 0 0.0 PR 0.5 Nearby 450 Gather 1600 1700 Offset Offset

### Bergschrund #1 Well Well Log Information Corrected



## Some Thoughts on Correcting the Logs

GR SP Rt Dt Rhob Nphi Cali

Raw Log Curves After Median Smoother

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RT replaces the HF part of rhob. Result is no real change.

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GR SP Rt Dt Rhob Nphi Cali

Log editing using Rt as a constraint where logs go bad.

> Previous Slide Focus



### Constraining Logs with Eigen Vectors Input = Green 3 vectors depth variant = Black GR Nphi SP Rt Dt Rhob Cali Depth (F) 14500 15000 15500 16000 16500 17000 17500





## Log Analysis Workflow



### Log Analysis Workflow



## Synthetic Tie

### Synthetic Tie Before



## Synthetic Tie

#### Synthetic Tie Before

### Synthetic Tie After



## **Typical Multi-Well Example**

### Deep Resistivity

All RT curves are in alignment



### Sonic

Multi–Well Plot dt

190 5P77\_C2\_\_\_ 40 190 40 SP78\_8\_ Depth SP77\_49\_\_\_\_-flog SP77\_C2\_ SP56\_3\_ \_-flog 20 0 20 0 SP78\_8\_ – flog 20 20 190 \$P77\_A9\_ 40 -flag (F) 40 40 40 190 40 190 40 190 SP56\_3\_\_\_\_(0) 190 SP77\_A9\_\_\_\_(0) SP78\_8\_\_\_\_(0) 190 SP77\_C2\_\_\_ (0) SP56\_3\_ L is 2 55 1 E---1 ı. 1 2000 ÷. ÷. i. ÷ 1 1 1 1 ----1 ٤. 1 : 🔫 1 1 1 1 ÷ 1 3000 1 ł 72 1 1 **e** ÷ 1 £Τ 4000 15 : --5000 6000 Γ. E ۰. 7 ÷. ÷ 700D ji, ÷ ۰. 1 ł ł ~ 1 1 s, 8000 5 1 € Æ. 1 1 900D 2 į. i. 2 ÷ 3 ÷. 1 ÷ li 1 -10000 ÷ 1 ÷. ÷ 13 15 . ÷ : 🐔 ÷ 1 1 ÷ 1 11000 5 1 **2** 1 1 1 1 1 1 1 2 1 1 1 12000 1 1 1 1 🖉 i 13000 ÷ 5 . ÷. i 7 i 1 14000 ÷ ÷. 1 1 1 **3**1 ÷ 1 1 1 ÷ 1 🗂 ÷ ÷ 1 1 1 15000 ÷ ł 1 **.** | ÷ ÷ ÷ 1 ÷ ł <u>-</u> 16000 1 ÷ 5 2. 1

### Not the case with DT

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Multi-Well Plot rhob

### Not the case with Rhob

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Multi–Well Plot fmrhob

## Initial Model for Inversion

### Rhob Raw Logs Full Bandwidth 4 Wells



Rhob Raw Logs 0 – 10 Hz 4 Wells



### Rhob FM Logs 0 – 10 Hz 4 Wells Model Normalization



### Rhob FM Logs 0 – 10 Hz 4 Wells Model Normalization

### Spectral Recursive Inversion



### Rhob, FM Logs 0 – 10 Hz 4 Wells Model Normalization

Spectral Recursive Inversion

Black Logs FM Green Inversion



## Seismic Processing for Inversion



Seismic Data Preparation

### Before Scaling

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### After Scaling

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# Model




Creating the Model

### Resulting Full Offset Stack



Velocity

# **The Perfect Model**

Gathers Near and Far Stacks Intercept (P) Gradient (G) P vs G cross plots AVO Types Lithology Inversion Velocity Inversion Density Inversion

# Single Trace Scaler

# Perfect Model

### Every 20th gather

Line	2dmodel-dec.sgy	
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#### P Stack



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# Single trace scaler

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#### P Stack



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### Single trace scaler

Cross Plot of P vs G Color is Porosity





#### Single trace scaler

Cross Plot of P vs G Color is Lithology Shale is Green Sand is Yellow Oil is Red



# 1000ms AGC Scaler

# Perfect Model

### Every 20th gather

Line	2dmodel-dec.sgy	
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1600		
1700		
1800		
1900		
2000		
2100		
2200		
2300		
2400		
2500		
2600		
2700		
2800	**************************************	

#### P Stack



2dmodel-gl.sgy	
	0 90 10
1200	
1300	
1400	
	*****
1600	
2000	
2200 -	*****
	******
2400	
2500	
2800	
2700	
	98000000000000

# AGC Scaler

# Every 20th gather

Line	2dmodel-dec.sgy	<b>F</b>
1	20 40 40 4050 4050 6080 6080 8000 8000	E
1000		N
1100		
1200		
1300		
1400		
1500		
1600		
1700		
1800		
1900		
2000		
2100		
2200		
2300		
2400	······································	
2500	······································	
2600		
2700		
2800	//////////////////////////////////////	

#### P Stack



2dmodel-gl.sgy	
	10
1000	
1100	
1200	, 
1300	
1400	
1500	
1600	
1700	
1000	
2100	
2200	
2300	
2400	
2600	
2700	







# AGC Scaler

CDP's 1 - 100 and times 1000 to 2700 Scaler = age, Factor = 1,Cale = 1.05

Cross Plot of P vs G Color is Lithology Shale is Green Sand is Yellow Oil is Red



**Inverted Space** 

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# **NMO Stretch**

# Perfect Model

### Every 20th gather

Line	2dmodel-dec.sgy	
1	20 40 40 4060 4060 6060 6060 8000 8000	
1000		N
1100		
1200		_
1300		
1400		
1500		
1600		
1700		
1800		
1900		
2000		
2100		
2200		
2300		
2400		
2500		
2600		
2700		
2800	**************************************	

#### P Stack



2dmodel-gl.sgy	
	0 90 10
1200	
1300	
1400	
	****
1600	
2000	
2200 -	*****
	******
2400	
2500	
2800	
2700	
	98888888888888888888888888888888888888

# NMO Stretch

### Every 20th gather

Line	2dmodel-dec.sgy	
1	20 40 40 4060 4060 6080 6080 8000	
1000		N
1100	Exercise Exercise Exercises Exercises Exercises	
1200	THE CONTRACT CONTRACT CONTRACT CONTRACT	
1300		
1400		
1500		
1600		
1700		
1800		
1900		
2000	**************************************	
2100		
2200	······································	
2300		
2400		
2500		
2600		
2700		
2800	A	

### P Stack



	2dmodel-gl.sgy
1000	
1100 -	
1200 -	
1300 -	
1400 -	
1500 -	
1600 -	
1700 -	***************************************
1800 -	
1900 -	
2000 -	
2100 -	
2200 -	
2300 -	
2400 -	
2500 -	
2600 -	
2700 -	
2800 -	



# NMO Stretch

Cross Plot of P vs G Color is Porosity CDP's 1 - 100 and times 1000 to 2700 Scaler = none, Factor = 1,Cale = 0.85





# NMO Stretch

Cross Plot of P vs G Color is Lithology Shale is Green Sand is Yellow Oil is Red

1060 -5 -3 846 120 636 OIL 5 110 424 100 212 90 SAND 80 O -2 70 -212 60 2010 -424 50 35 - 1 -636 SHALE 20 -848 10 З 1 -845 -636 -212 212 424 636 648 1060 Lithology -424 σ Ρ

**Inverted Space** 

CDP's 1 - 100 and times 1000 to 2700 Scaler = none, Factor = 1,Cale = 0.85

# Automatic High Resolution NMO

# Perfect Model

### Every 20th gather

Line	2dmodel-dec.sgy	
1	20 40 40 4060 4060 6060 6060 8000 8000	
1000		N
1100		
1200		_
1300		
1400		
1500		
1600		
1700		
1800		
1900		
2000		
2100		
2200		
2300		
2400		
2500		
2600		
2700		
2800		

#### P Stack



2dmodel-gl.sgy	
	0 90 10
1200	
1300	
1400	
	****
1600	
	*****
2000	
2200 -	*****
	******
2400	
2500	
2800	
2700	

# High Resolution RNMO

# Every 20th gather

Line	2dmodel-dec.sgy	<b>S</b>
1	20 40 40 4050 4050 6050 6050 8000 8000	
1000		N
1100		
1200	מוווווו <b>זוווווווו זווווווו זווווווו זווווווו זוווווו</b>	
1300		
1400		
1500		
1600		
1700		
1800		
1900		
2000		
2100		
2200		
2300		
2400		
2500		
2600		
2700		
2800		

#### P Stack



	2dmodel-gl.sgy
1000	
1100	
1200	
1300	
1400	······································
1500	
1600	
1700	
1800	
1900	
2000	
2100	
2200	
2300	
2400	
2500	
2600	
2700	
2800	



High Resolution RNMO

Cross Plot of P vs G Color is Porosity CDP's 1 - 100 and times 1000 to 2700 Scaler = none, Factor = 1,Calc = 1.61





### High Resolution RNMO

Cross Plot of P vs G Color is Lithology Shale is Green Sand is Yellow Oil is Red



CDP's 1 - 100 and times 1000 to 2700 Scaler = none, Factor = 1,Calc = 1.64

# AGC, NMO Stretch

# Perfect Model

### Every 20th gather

Line	2dmodel-dec.sgy	
1	20 40 40 4060 4060 6060 6060 8000 8000	
1000		N
1100		
1200		_
1300		
1400		
1500		
1600		
1700		
1800		
1900		
2000		
2100		
2200		
2300		
2400		
2500		
2600		
2700		
2800		

#### P Stack



2dmodel-gl.sgy	
	0 90 10
1200	
1300	
1400	
	****
1600	
	*****
2000	
2200 -	*****
	******
2400	
2500	
2800	
2700	

# AGC, NMO Stretch

### Every 20th gather

Line	2dmodel-dec.sgy	
1	20 40 40 4060 4060 6080 6080 8000 8000	<b>F</b> AM
1000		<b>N</b>
1100		
1200		
1300		
1400		
1500		
1600		
1700		
1800	<u> </u>	
1900		
2000		
2100		
2200		
2300	Summer  Summer<	
2400		
2500		
2600		
2000		
2700		
2800		

#### P Stack



	2dmodel-gl.sgy
1000	
1100	
1200	
1300	
1400	
1500	
1600	
1700	
1800	
1900	
2000	
2100	
2200	
2300	
2400	
2500	
2600	
2700	
2800	***************************************



# AGC, NMO Stretch

Cross Plot of P vs G Color is Porosity CDP's 1 - 100 and times 1000 to 2700 Scaler = agc, Factor = 1,Cale = 1.08




# AGC, NMO Stretch

Cross Plot of P vs G Color is Lithology Shale is Green Sand is Yellow Oil is Red



CDP's 1 - 100 and times 1000 to 2700 Scaler = age, Factor = 1,Cale = 1.08

# 1000ms AGC Scaler Then Apply Offset Scaler to Correct

# Perfect Model

# Every 20th gather

Line	2dmodel-dec.sgy	
1	20 40 40 4060 4060 6060 6060 8000 8000	
1000		N
1100		
1200		_
1300		
1400		
1500		
1600		
1700		
1800		
1900		
2000		
2100		
2200		
2300		
2400		
2500		
2600		
2700		
2800		

#### P Stack



2dmodel-gl.sgy	
	0 90 10
1200	
1300	
1400	
	****
1600	
	*****
2000	
2200 -	*****
	******
2400	
2500	
2800	
2700	

#### AGC Scaler + Offset Scaler

### Every 20<sup>th</sup> gather



#### P Stack



2dmodel-gl.sgy	
10 20 30 40 50 60 70 80 90 1000	
1200	
1300	Ш П
1400	
1600	**
2000	
2200	
2300 +++++++++++++++++++++++++++++++++++	
2400	
2800	趔
2700	
	∭





AGC Scaler + Offset Scaler

Cross Plot of P vs G Color is Porosity CDP's 1 – 100 and times 1000 to 2700 Scaler = agc, Factor = 1.64,Calc = 1.67





# AGC Scaler

CDP's 1 - 100 and times 1000 to 2700 Scaler = age, Factor = 1,Cale = 1.05

Cross Plot of P vs G Color is Lithology Shale is Green Sand is Yellow Oil is Red



**Inverted Space** 

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# AGC Scaler + Offset Scaler

Cross Plot of P vs G Color is Lithology Shale is Green Sand is Yellow Oil is Red



**Inverted Space** 

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# NMO Stretch Then Filter Back to Far Offset Frequency Content

# Perfect Model

# Every 20th gather

Line	2dmodel-dec.sgy	
1	20 40 40 4060 4060 6060 6060 8000 8000	
1000		N
1100		
1200		_
1300		
1400		
1500		
1600		
1700		
1800		
1900		
2000		
2100		
2200		
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2400		
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2700		
2800		

#### P Stack



2dmodel-gl.sgy	
	0 90 10
1200	
1300	
1400	
	****
1600	
	*****
2000	
2200 -	*****
	******
2400	
2500	
2800	
2700	

# NMO Stretch

# Every 20th gather

Line	2dmodel-dec.sgy	
1	20 40 40 4060 4060 6080 6080 8000	
1000		N
1100	Exercise Exercise Exercises Exercises Exercises	
1200	THE CONTRACT CONTRACT CONTRACT CONTRACT	
1300		
1400		
1500		
1600		
1700		
1800		
1900		
2000	**************************************	
2100		
2200	······································	
2300		
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2500		
2600		
2700		
2800	A	

# P Stack



	2dmodel-gl.sgy
1000	
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1200	
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1400	
1500	
1600	
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1800	
1900	
2000	
2100	
2200	
2300	
2400	
2500	
2600	
2700	
2800	

### NMO Stretch then Filter Back

#### Every 20<sup>th</sup> gather



#### P Stack



	2dmodel-gl.sgy
1000	
1100	
1200	
1300	
1400	
1500	
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1700	
1800	
1900	
2000	
2100	
2200	
2300	
2400	
2500	
2600	
2700	
2800	



# NMO Stretch

Cross Plot of P vs G Color is Porosity CDP's 1 - 100 and times 1000 to 2700 Scaler = none, Factor = 1,Cale = 0.85



NMO Stretch then Filter Back

Cross Plot of P vs G Color is Porosity CDP's 1 - 100 and times 1000 to 2700 Scaler = none, Factor = 1,Calc = 1.52





# NMO Stretch

Cross Plot of P vs G Color is Lithology Shale is Green Sand is Yellow Oil is Red

1060 -5 -3 846 120 636 OIL 5 110 424 100 212 90 SAND 80 O -2 70 -212 60 2010 -424 50 35 - 1 -636 SHALE 20 -848 10 З 1 -845 -636 -212 212 424 636 648 1060 Lithology -424 σ Ρ

**Inverted Space** 

CDP's 1 - 100 and times 1000 to 2700 Scaler = none, Factor = 1,Cale = 0.85

# NMO Stretch then Filter Back

CDP's 1 - 100 and times 1000 to 2700 Scaler = none, Factor = 1,Cale = 1.52

Cross Plot of P vs G Color is Lithology Shale is Green Sand is Yellow Oil is Red

-5 -3 76 120 67 OIL 5 110 38 100 90 19 SAND 80 O ß -4 -2 70 -19 60 -38 50 mm 35 - 1 -67 SHALE 20 -76 10 З 1 -76 -19 19 76 Lithelogy -57 - 38 σ 25 57 95 Ρ

**Inverted Space** 

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