



Shale Core Analysis

Endeavour Operating Corporation
Federal 5-24-8-101
Mesa County, Colorado

CL File No.: DEN-130026

Date: December 06, 2013

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Core Analysis

077 - 08832-01



Shale Core Analysis

		As received			Dry & Dean Stark Extracted Conditions ⁽²⁾					
Sample	Depth (ft)	Bulk Density (g/cc)	Matrix Permeability ⁽¹⁾ (mD)	Gas-filled Porosity (%)	Gas Saturation (%)	Grain Density (g/cc)	Matrix Permeability ⁽⁵⁾ (mD)	Porosity (%)	Oil Saturation ⁽³⁾ (%)	Water Saturation ⁽⁴⁾ (%)
1 GRI	5918.55-5919.37	2.580	1.99E-07	1.49	27.8	2.684	1.26E-04	5.35	4.3	67.9
2 GRI	5921.60 - 5922.25	2.574	2.74E-07	1.25	21.7	2.683	3.76E-04	5.75	11.9	66.4
3 GRI	5925.15 - 5925.75	2.580	3.14E-07	1.45	24.5	2.695	1.19E-04	5.92	11.4	64.1
4 GRI	5928.00-5928.65	2.595	5.85E-08	0.85	17.1	2.687	9.65E-05	4.97	5.6	77.3
5 GRI	5931.00 - 5931.60	2.587	5.67E-08	0.96	17.7	2.688	1.10E-04	5.42	8.7	73.6
6 GRI	5933.30 - 5933.90	2.584	3.51E-07	1.26	22.6	2.690	2.40E-04	5.57	4.5	73.0
7 GRI	5937.00-5937.75	2.574	9.65E-08	1.14	21.7	2.673	8.19E-05	5.28	3.7	74.6
8 GRI	5939.65 - 5940.25	2.588	2.00E-07	1.12	19.5	2.697	3.39E-04	5.76	7.4	73.1
9 GRI	5943.20 - 5943.75	2.593	1.89E-07	1.29	23.8	2.698	1.87E-04	5.45	8.6	67.6
10 GRI	5946.00-5946.65	2.577	1.34E-07	1.30	26.8	2.670	4.83E-05	4.84	5.3	67.9
11 GRI	5948.90 - 5949.65	2.582	1.78E-07	1.23	25.3	2.676	2.59E-04	4.87	14.1	60.6
12 GRI	5951.85 - 5952.45	2.616	4.02E-08	0.82	20.9	2.691	4.20E-05	3.93	18.7	60.5
13 GRI	6293.15 - 6293.95	2.514	4.69E-07	1.63	22.1	2.652	3.94E-04	7.37	8.7	69.2
14 GRI	6295.55 - 6296.20	2.477	3.39E-06	2.19	25.5	2.640	6.51E-04	8.59	11.6	62.9
15 GRI	6299.60-6300.22	2.499	5.59E-07	1.60	21.2	2.637	2.49E-04	7.53	4.6	74.2
16 GRI	6301.85 - 6302.45	2.549	1.75E-08	0.63	10.9	2.650	1.73E-04	5.80	1.1	88.0
17 GRI	6305.25-6305.88	2.511	1.50E-07	1.25	18.1	2.635	3.19E-04	6.88	3.0	78.9
18 GRI	6307.65 - 6308.30	2.512	2.08E-06	2.32	28.8	2.668	4.10E-04	8.06	1.3	69.9
19 GRI	6310.00-6310.60	2.488	3.51E-07	1.46	23.9	2.599	1.14E-04	6.10	4.5	71.5
20 GRI	6313.90 - 6314.55	2.536	1.14E-06	1.93	28.4	2.668	1.63E-04	6.79	7.2	64.4
21 GRI	6317.10-6317.75	2.526	2.64E-07	1.57	22.8	2.655	1.43E-04	6.91	3.6	73.6
22 GRI	6320.45 - 6321.20	2.566	1.13E-07	0.96	17.8	2.665	8.32E-05	5.38	10.1	72.1
23 GRI	6323.10-6323.75	2.520	1.02E-07	1.10	14.4	2.656	3.03E-04	7.63	3.6	82.0
24 GRI	6326.00 - 6326.65	2.516	5.32E-07	1.84	22.1	2.672	3.54E-04	8.33	1.9	76.0
25 GRI	6329.40-6330.05	2.539	8.78E-08	1.11	16.7	2.660	2.21E-04	6.65	5.2	78.1
26 GRI	6331.30 - 6331.90	2.517	2.93E-07	1.66	22.9	2.653	2.19E-04	7.26	10.3	66.8
27 GRI	6335.00-6335.60	2.523	4.48E-07	1.77	24.9	2.658	2.15E-04	7.13	6.3	68.8
28 GRI	6338.40 - 6339.00	2.516	1.71E-06	2.13	28.6	2.660	1.80E-04	7.45	3.4	68.1
29 GRI	6341.65-6342.25	2.534	9.05E-08	0.99	14.7	2.654	1.87E-04	6.71	5.4	79.8
30 GRI	6343.90 - 6344.55	2.534	5.42E-07	1.74	24.4	2.669	1.37E-04	7.12	4.3	71.3

Footnotes:

- (1) Matrix Permeability is an effective Kg determined from pressure decay results on the fresh, crushed, 20/35 mesh size sample.
(2) Dean Stark extracted sample (20/35 mesh size) dried at 110 °C. Porosity and saturations are relative to total interconnected pore space.

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Shale Core Analysis

Sample	Depth (ft)	As received				Dry & Dean Stark Extracted Conditions ⁽²⁾			
		Bulk Density (g/cc)	Matrix Permeability ⁽¹⁾ (mD)	Gas-filled Porosity (%)	Gas Saturation (%)	Grain Density (g/cc)	Matrix Permeability ⁽⁵⁾ (mD)	Porosity (%)	Oil Saturation ⁽³⁾ (%)

(3) Oil volume computed assuming an oil density of 0.818 g/cc

(4) Water volume corrected assuming a brine concentration of 50,000 ppm NaCl with an ambient density of 1.032 g/cc

(5) Matrix Permeability is an absolute Kg determined from pressure decay results on the clean and dry 20/35 mesh size sample.

Reference: "Development of Laboratory and Petrophysical Techniques for Evaluating Shale Reservoirs", GRI-95/0466, Gas Research Institute, April 1996



Shale Core Analysis Protocol

SAMPLE PREPARATION

Approximately 300g of sample was removed from each core section by making a longitudinal slice with a band saw, using chilled nitrogen as the blade lubricant. Each sample was weighed to ± 0.001 g and the bulk volume by mercury immersion was measured to ± 0.01 cc. These initial measurements were performed to determine natural sample density (Bulk Density).

Each 300g sample was processed using a mechanical rock crusher and sieved through 20 and 35 US mesh sieve screens. The material retained on the 35-mesh screen was separated into a Dean Stark sub-sample (~100g) and a permeability sub-sample (~50g). These procedures were performed while minimizing exposure time and evaporative losses. These sample splits were sealed in airtight vials pending analysis. Any sample remnants were collected and preserved for future use.

MEASUREMENTS

Matrix Permeability:

Matrix permeability was determined by monitoring pressure decay as defined in the "Advances in Shale Analyses Report, D.L. Luffel, 1993". The permeability sub-sample was placed into a sealed sample chamber and approximately 30 cc of helium gas at ~200 psig was injected into the sample chamber system. Pressure decay was recorded in 0.25 sec increments to a maximum time of 2000 sec. Pressure vs. time data were used to calculate matrix permeability.

Fluid Saturations – Dean Stark Technique:

Reagent grade toluene was conditioned to remove excess water and used for the extraction. The Dean Stark sub-samples were placed in glass thimbles to eliminate grain loss and weighed to ± 0.001 g. The samples were loaded into the Dean-Stark apparatus under an argon bath and refluxed for 7 days. Water volumes were recorded twice daily to ensure complete water extraction. The extraction solvent discoloration was noted to validate removal of trace quantities of mobile hydrocarbon.

Sample Drying:

Samples were dried in a vacuum oven at 110°C until weight equilibrium was achieved (± 0.001 g). The minimum drying time was 1 week. After weight stabilization, samples were stored in a desiccator while awaiting further measurement.

Porosity and Grain Density:

Porosity was determined by measuring grain volume at ambient conditions using the Boyle's Law double-cell technique with helium as the expansion gas (API RP-40, Sec 5.3.2.1). Sample bulk volume is calculated using the weight of the sample before extraction and the bulk density of the original core piece. Grain density values were calculated by direct measurement of grain volume and weight on dried crushed samples.



TRIAxIAL COMPRESSIVE TEST RESULTS

Company	Endeavour Operating Corp	Date	Oct. 2013
Well Name	Federal 5-24-8-101	Job No.	HOU-131074
Field Name		Saturation Fluid	As Received
Location	Mesa County, Colorado	Rock Type	Shale

Table 1 Triaxial Static Young's Modulus, Poisson's Ratio and Compressive Strength

Sample Number	Depth (ft)	Confining Pressure (psi)	Bulk Density (gm/cm ³)	Compressive Strength (psi)	Young's Modulus (10 ⁶ psi)	Poisson's Ratio
1FD	5927.50	2140	2.572	14108	2.60	0.20
2FD	5948.50	2140	2.563	17103	2.86	0.20
3FD	6309.50	2140	2.471	9079	2.11	0.21
22V	6320.50	2140	2.395	8481	2.55	0.19



ACOUSTIC VELOCITIES AND DYNAMIC ELASTIC PARAMETERS

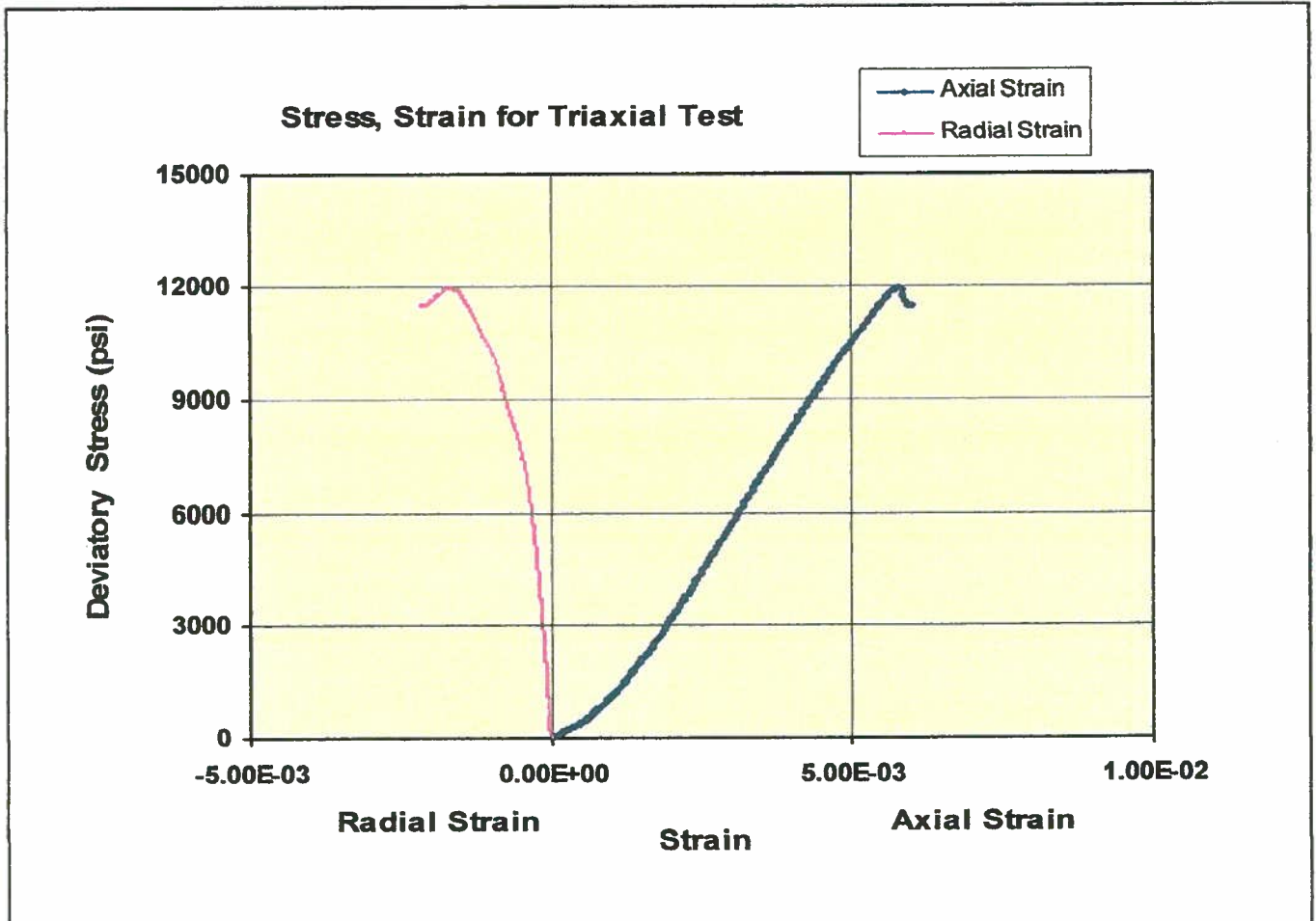
Company	Endeavour Operating Corp	Date	Oct. 2013
Well Name	Federal 5-24-8-101	Job No.	HOU-131074
Field Name		Saturation Fluid	As Received
Location	Mesa County, Colorado	Rock Type	Shale

Table 2 Acoustic Velocities and Dynamic Moduli at Triaxial Stress Conditions

Dynamic Elastic Parameters												
Sample No.	Depth (ft)	Confining Pressure (psi)	Axial Pressure (psi)	Bulk Density (g/cc)	Acoustic Velocity				Bulk Modulus (x10 ⁶ psi)	Young's Modulus (x10 ⁶ psi)	Shear Modulus (x10 ⁶ psi)	Poisson's Ratio
					Compressional		Shear					
					ft/sec	μs/ft	ft/sec	μs/ft				
1FD	5927.5	2140	2140	2.572	13384	74.72	8058	124.10	3.21	5.47	2.25	0.22
		2140	7000	2.572	13563	73.73	8110	123.31	3.34	5.57	2.28	0.22
2FD	5948.5	2140	2140	2.563	13910	71.89	8555	116.89	3.31	6.05	2.53	0.20
		2140	8000	2.563	14215	70.35	8640	115.74	3.54	6.23	2.58	0.21
3FD	6309.5	2140	2140	2.471	12106	82.61	7377	135.55	2.46	4.37	1.81	0.20
		2140	5000	2.471	12166	82.19	7406	135.03	2.49	4.40	1.83	0.21
22V	6320.5	2140	2140	2.395	13492	74.12	8177	122.29	3.00	5.22	2.16	0.21
		2140	5000	2.395	13757	72.69	8322	120.16	3.13	5.42	2.24	0.21

Results of Triaxial Test

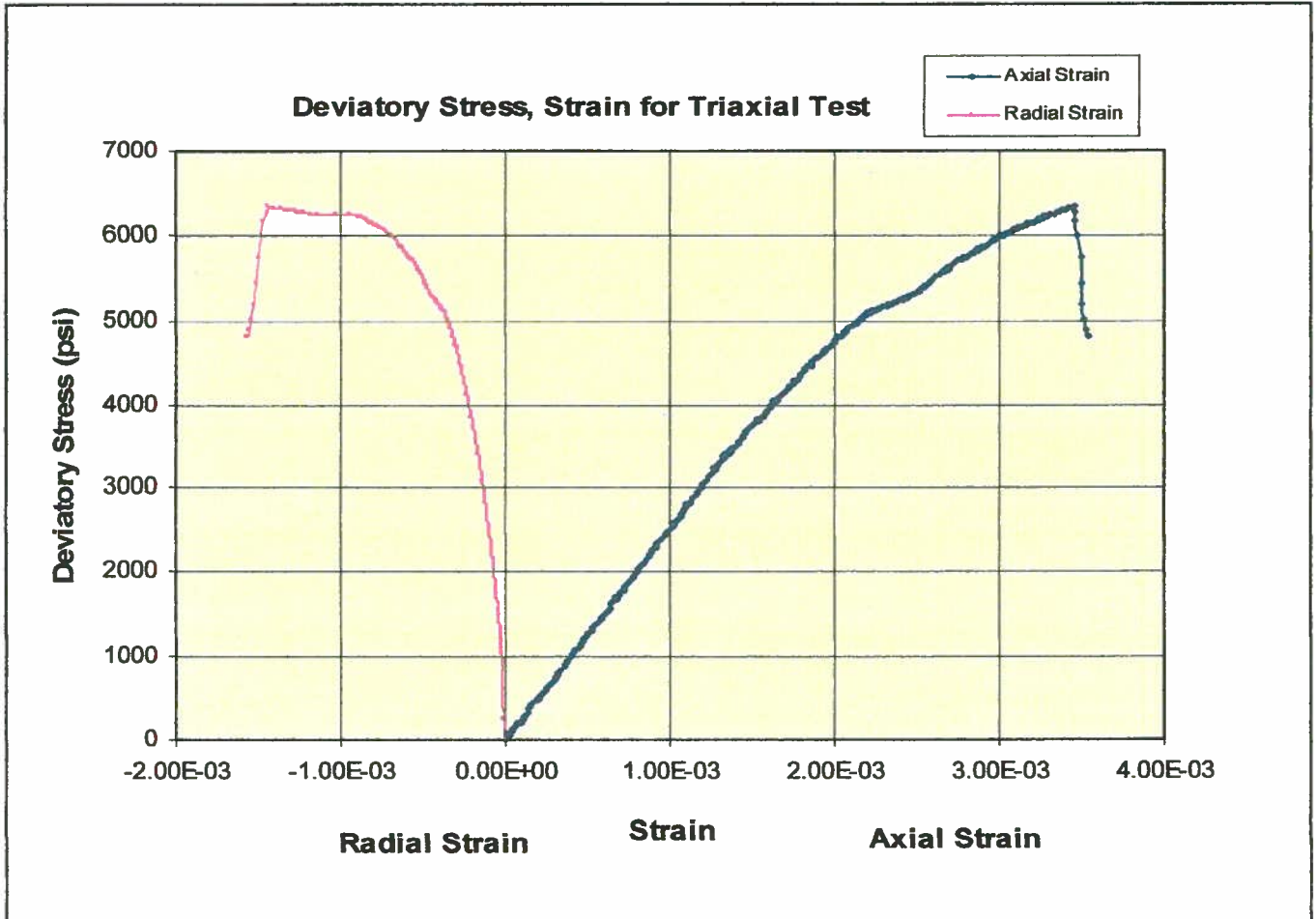
Company	Endeavour Operating Corp	Date	Oct. 2013
Well Name	Federal 5-24-8-101	Job No.	HOU-131074
Field Name		Saturation Fluid	As Received
Location	Mesa County, Colorado	Rock Type	Shale



Sample	1FD
Depth (ft)	5927.5
Diameter (in)	3.4568
Length (in)	2.4348
Mass (g)	963.1
Saturation Fluid	As Received
Bulk Density (g/cc)	2.57
Confining Pressure (psi)	2140
Pore Pressure (psi)	0
Static Young's Modulus ($\times 10^6$ psi)	2.60
Static Poisson's Ratio	0.20
Compressive Strength (psi)	14108

Results of Triaxial Test

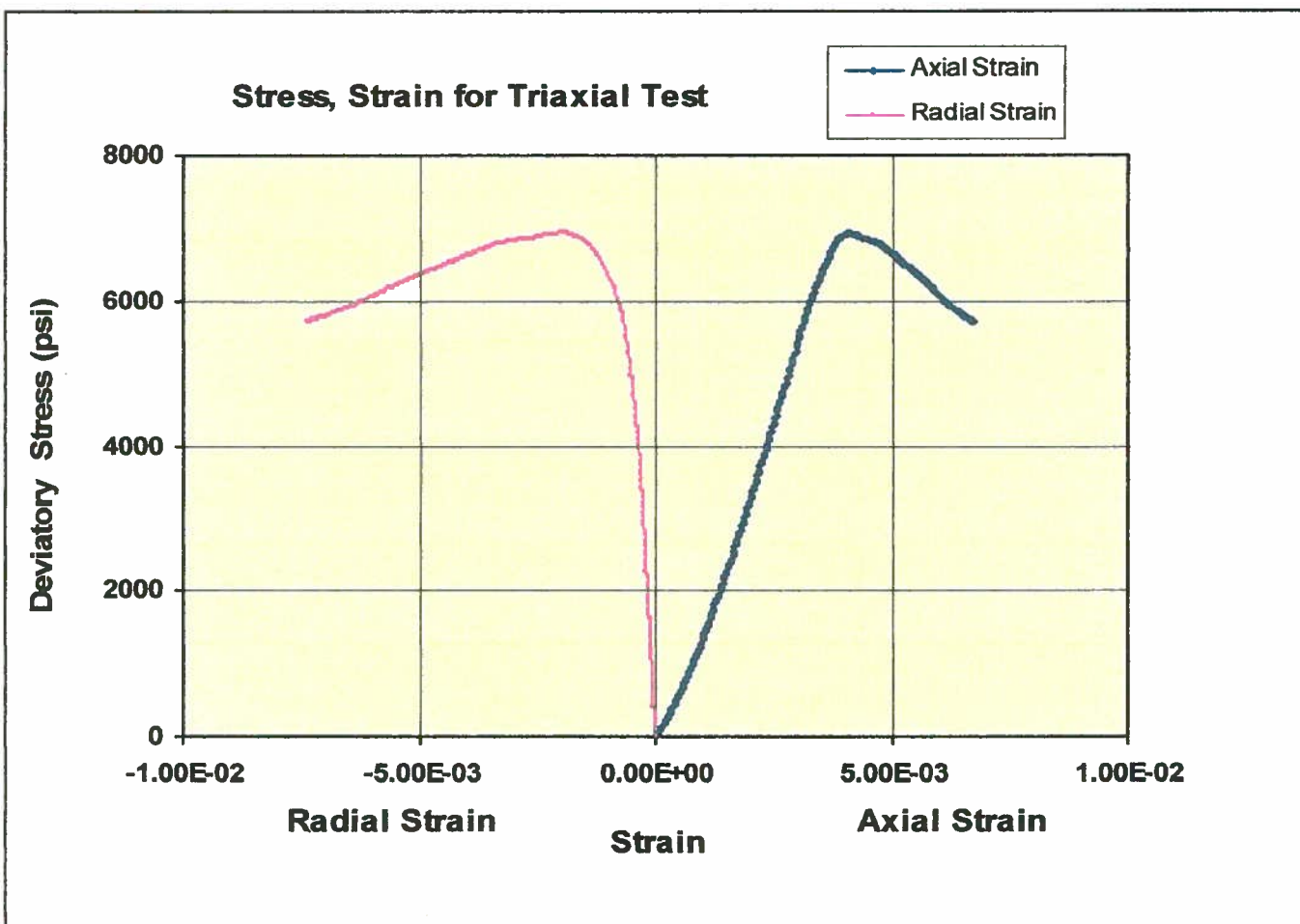
Company	Endeavour Operating Corp	Date	Oct. 2013
Well Name	Federal 5-24-8-101	Job No.	HOU-131074
Field Name		Saturation Fluid	As Received
Location	Mesa County, Colorado	Rock Type	Shale



Sample	22V
Depth (ft)	6320.5
Diameter (in)	0.9971
Length (in)	0.8419
Mass (g)	25.8
Saturation Fluid	As Received
Bulk Density (g/cc)	2.39
Confining Pressure (psi)	2140
Pore Pressure (psi)	0
Static Young's Modulus ($\times 10^6$ psi)	2.55
Static Poisson's Ratio	0.19
Compressive Strength (psi)	8481

Results of Triaxial Test

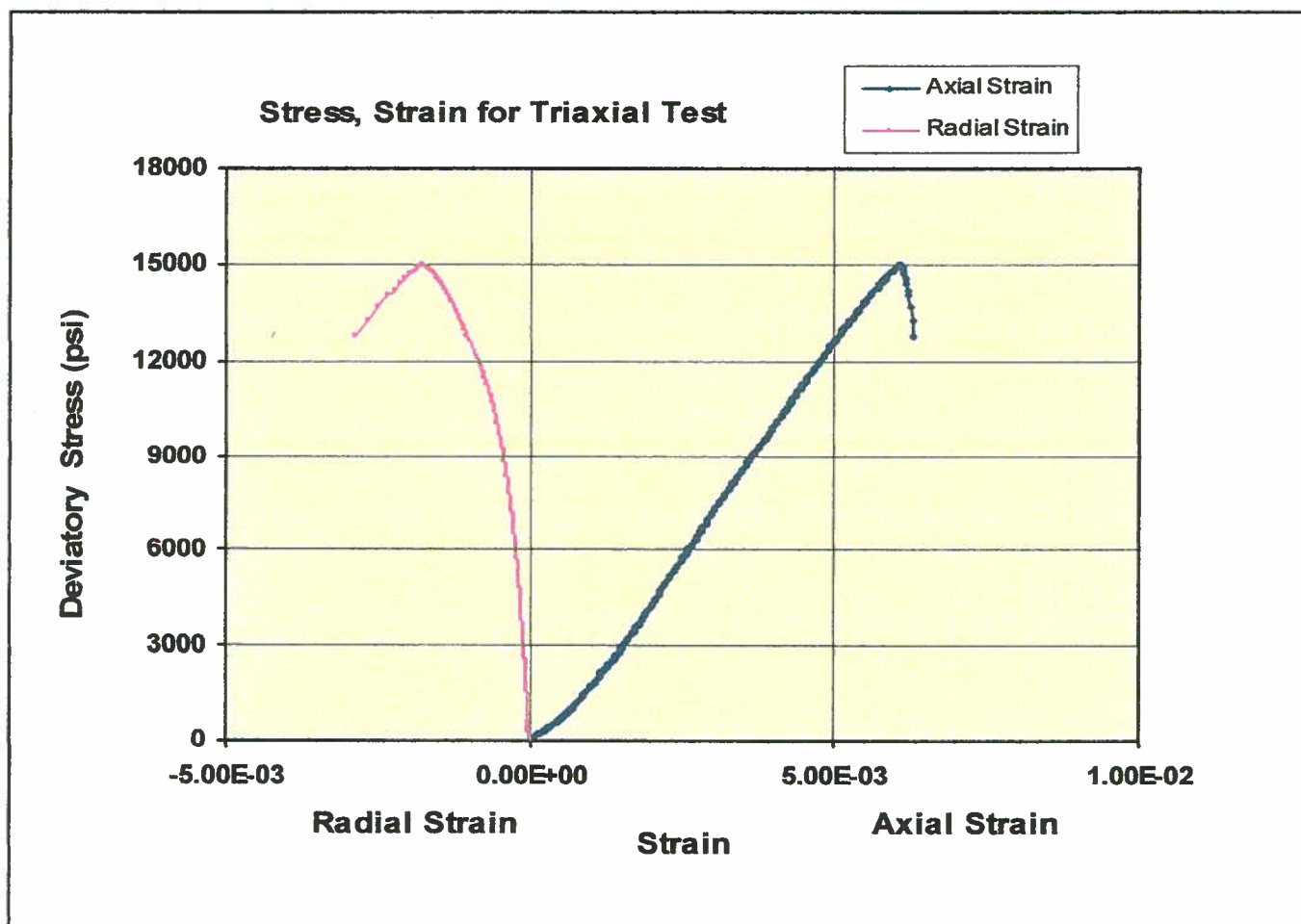
Company	Endeavour Operating Corp	Date	Oct. 2013
Well Name	Federal 5-24-8-101	Job No.	HOU-131074
Field Name		Saturation Fluid	As Received
Location	Mesa County, Colorado	Rock Type	Shale



Sample	3FD
Depth (ft)	6309.5
Diameter (in)	3.3719
Length (in)	2.3301
Mass (g)	842.4
Saturation Fluid	As Received
Bulk Density (g/cc)	2.47
Confining Pressure (psi)	2140
Pore Pressure (psi)	0
Static Young's Modulus ($\times 10^6$ psi)	2.11
Static Poisson's Ratio	0.21
Compressive Strength (psi)	9079

Results of Triaxial Test

Company	Endeavour Operating Corp	Date	Oct. 2013
Well Name	Federal 5-24-8-101	Job No.	HOU-131074
Field Name		Saturation Fluid	As Received
Location	Mesa County, Colorado	Rock Type	Shale



Sample	2FD
Depth (ft)	5948.5
Diameter (in)	3.4207
Length (in)	2.4905
Mass (g)	961.3
Saturation Fluid	As Received
Bulk Density (g/cc)	2.56
Confining Pressure (psi)	2140
Pore Pressure (psi)	0
Static Young's Modulus ($\times 10^6$ psi)	2.86
Static Poisson's Ratio	0.20
Compressive Strength (psi)	17103

Methane Adsorption Isotherm Summary

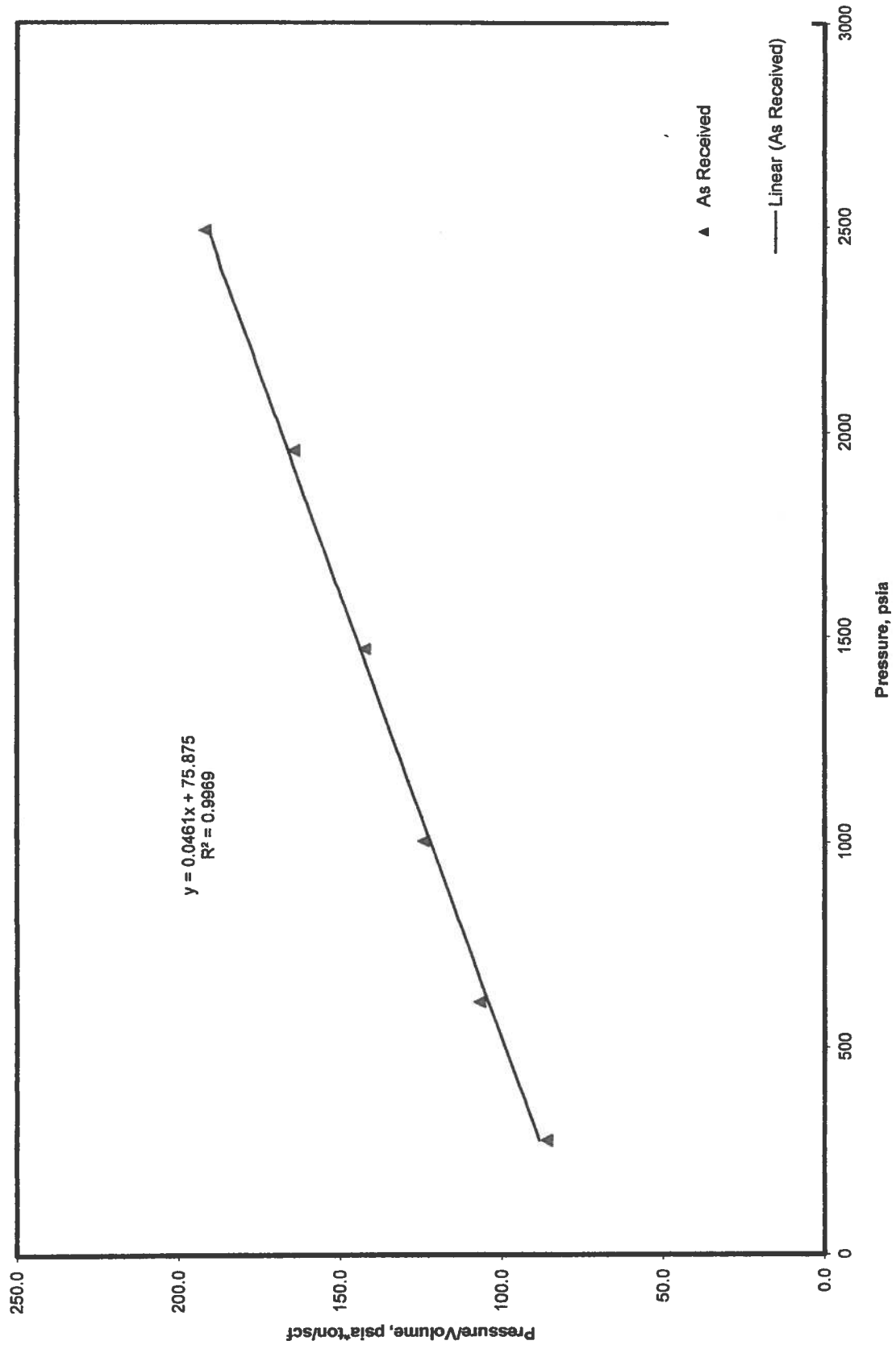
Well: Federal 5-24-8-101
Reservoir:
Sample Number:
Sample Type: Shale
Drill Depth, Feet: 5,919.00
Temperature, °F: 170.00
Average Particle Size, mesh: -60.00

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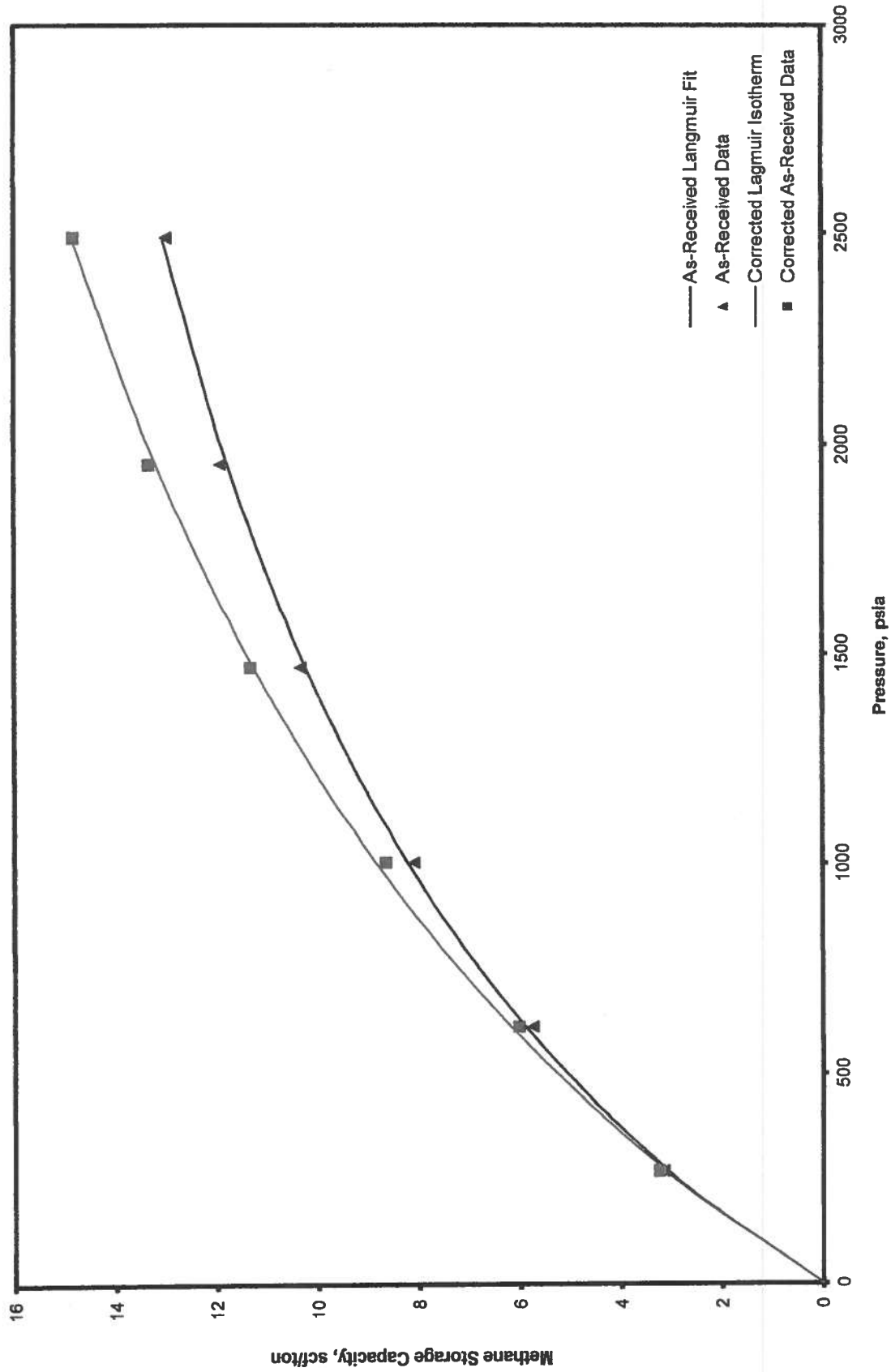
Pressure	Methane Storage Capacity, scf/ton
psia	As-Received
0.0	Measured 0.00 Calculated 0.00
271.3	3.16 3.07
613.1	5.74 5.89
1,003.7	8.09 8.22
1,469.0	10.33 10.23
1,954.1	11.91 11.77
2,489.9	12.98 13.06
Parameters	Methane Langmuir Parameters (U.S. Units)
Slope, ton/scf:	As-Received 0.0461
Intercept, psia*ton/scf:	75.8752
Regression Coefficient (squared):	0.9973
Intercept Variation, psia*ton/scf:	7.0516
Slope Variation, ton/scf:	0.0043
GsL Variation, scf/ton:	2.0314
PL Variation, psia:	0.1200
Langmuir Storage Capacity, scf/ton:	21.69
Langmuir Pressure, psia:	1,645.48
Langmuir Equation:	Gs = (GsL*p)/(PL+p)
Reservoir Pressure (Midpoint), psia:	2,270.00
Storage Capacity, scf/ton:	12.57
Absolute/Corrected Isotherm	
Corrected Langmuir Storage Capacity, scf/ton:	27.44
Corrected Langmuir Pressure, psia:	2,110.99
Langmuir Equation:	Gs = (GsL*p)/(PL+p)
Reservoir Pressure (Midpoint), psia:	2,270.00
Adsorbed Phase Methane Density, gm/cc	0.372
Storage Capacity, scf/ton:	14.22

Gs Gas Storage Capacity
GsL Langmuir Gas Storage Capacity
PL Langmuir Pressure
p Relevant Pressure (Reservoir Pressure)

Langmuir Interpretation Graph



Langmuir Isotherm Graph



Methane Adsorption Isotherm Summary

Well: Federal 5-24-8-101

Reservoir: _____

Sample Number: _____

Sample Type: Shale

Drill Depth, Feet: 5,949.00

Temperature, °F: 170.00

Average Particle Size, mesh: -80.00

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Pressure	Methane Storage Capacity, scf/ton	
psia	As-Received	
	Measured	Calculated
0.0	0.00	0.00
252.4	3.05	3.06
591.0	6.26	6.18
988.3	8.78	8.90
1,437.1	11.11	11.19
1,865.2	13.06	12.88
2,423.3	14.48	14.54

Parameters	Methane Langmuir Parameters (U.S. Units)
	As-Received
Slope, ton/scf:	0.0387
Intercept, psia*ton/scf:	72.8149
Regression Coefficient (squared):	0.9968
Intercept Variation, psia*ton/scf:	6.4530
Slope Variation, ton/scf:	0.0040
GsL Variation, scf/ton:	2.7280
PL Variation, psia:	30.0771
Langmuir Storage Capacity, scf/ton:	25.84
Langmuir Pressure, psia:	1,881.27
Langmuir Equation:	Gs = (GsL*p)/(PL+p)
Reservoir Pressure (Midpoint), psia:	2,270.00
Storage Capacity, scf/ton:	14.13

Absolute/Corrected Isotherm	
Corrected Langmuir Storage Capacity, scf/ton:	33.29
Corrected Langmuir Pressure, psia:	2,450.36
Langmuir Equation:	Gs = (GsL*p)/(PL+p)
Reservoir Pressure (Midpoint), psia:	2,270.00
Adsorbed Phase Methane Density, gm/cc	0.372
Storage Capacity, scf/ton:	16.01

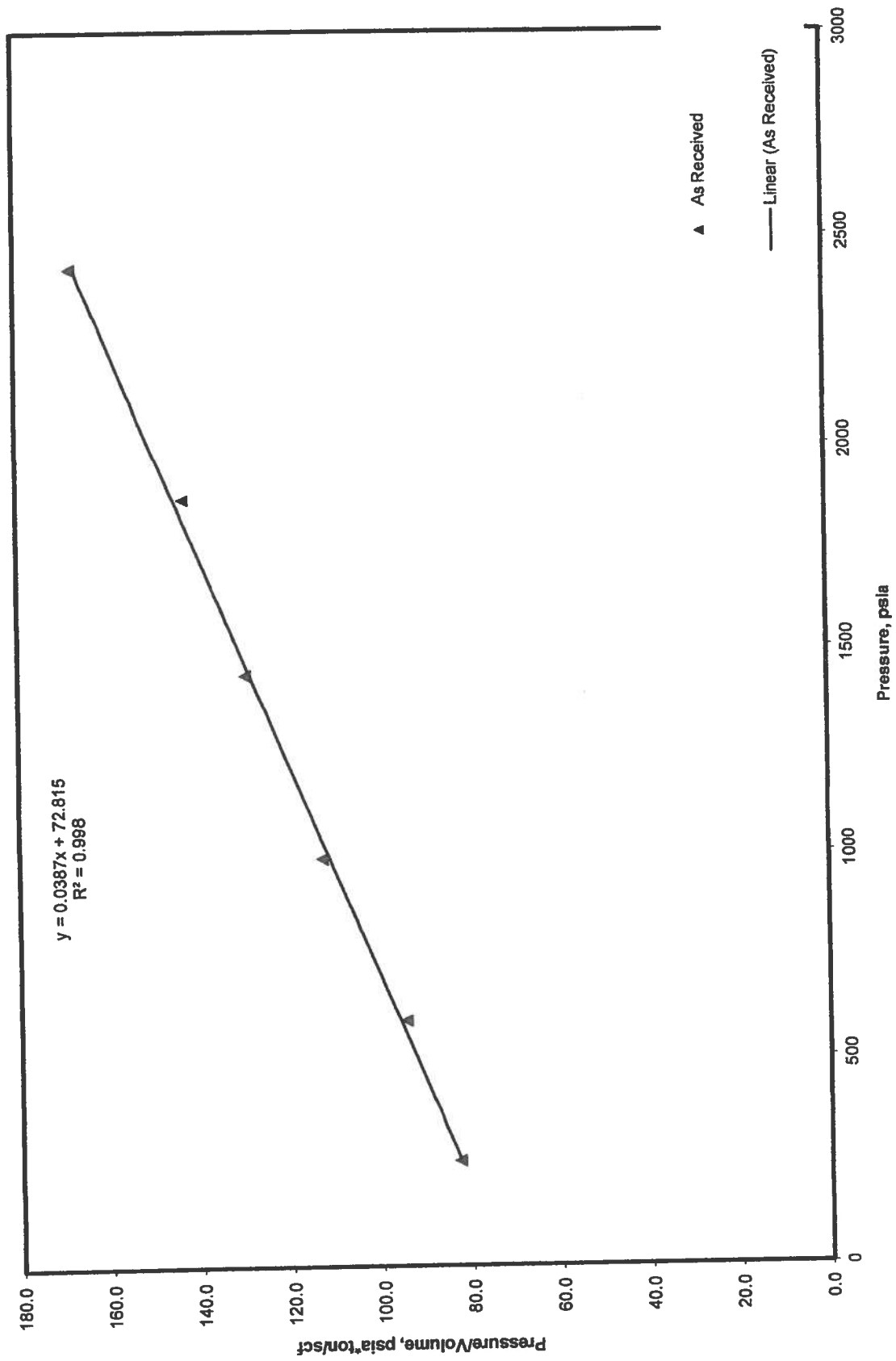
Gs Gas Storage Capacity

GsL Langmuir Gas Storage Capacity

PL Langmuir Pressure

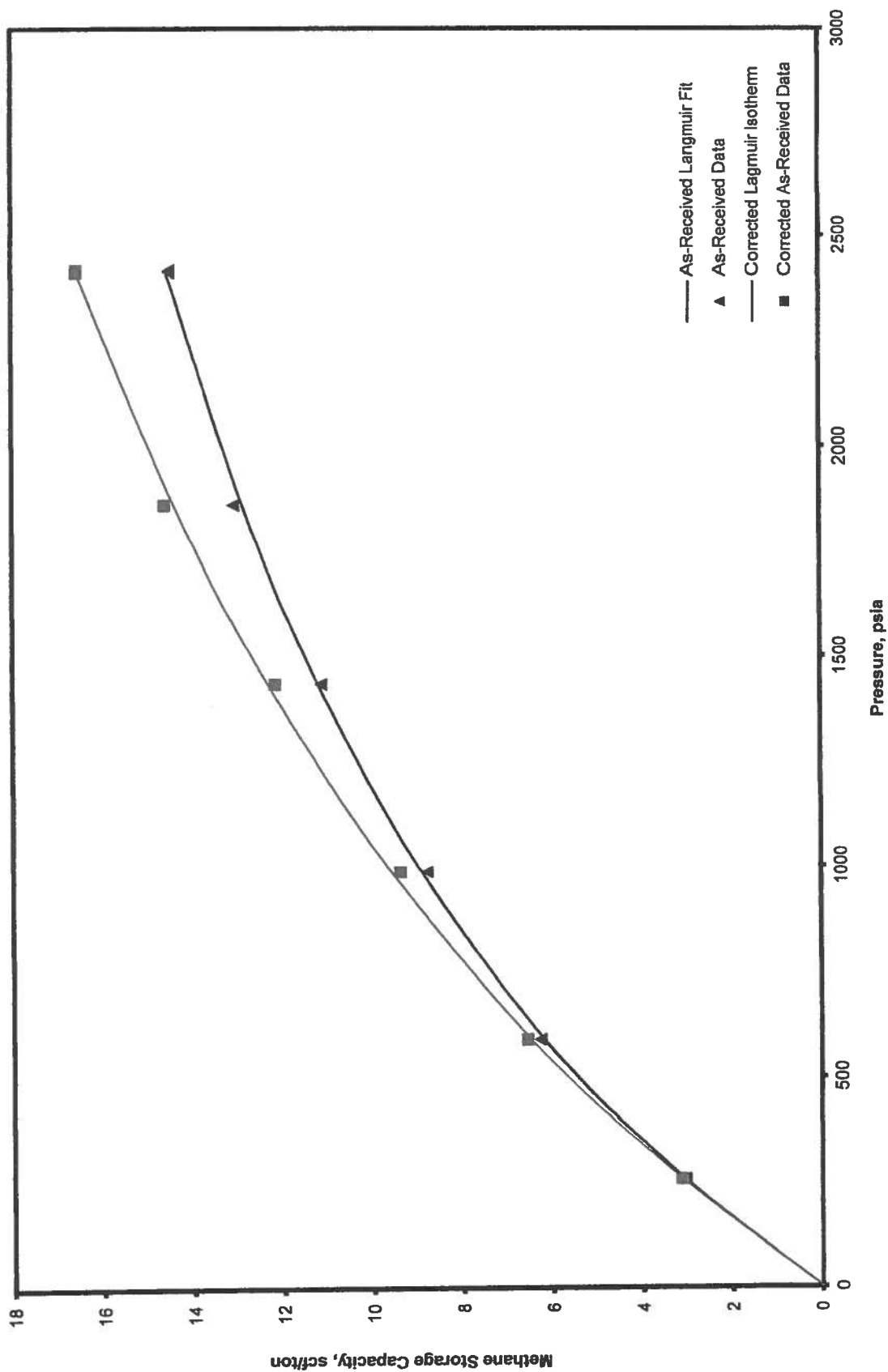
p Relevant Pressure (Reservoir Pressure)

Langmuir Interpretation Graph



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Langmuir Isotherm Graph



Methane Adsorption Isotherm Summary

Well: Federal 5-24-8-101

Reservoir:

Sample Number:

Sample Type: Shale

Drill Depth, Feet: 6,310.50

Temperature, °F: 176.90

Average Particle Size, mesh: -60.00

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Pressure	Methane Storage Capacity, scf/ton
psia	As-Received
0.0	Measured 0.00 Calculated 0.00
290.8	6.16 6.22
633.0	11.52 11.35
1,005.9	15.25 15.34
1,450.6	18.77 18.77
1,923.9	21.52 21.44
2,462.6	23.64 23.70
Parameters	Methane Langmuir Parameters (U.S. Units)
Slope, ton/scf:	As-Received 0.0263
Intercept, psia*ton/scf:	39.0784
Regression Coefficient (squared):	0.9995
Intercept Variation, psia*ton/scf:	1.8253
Slope Variation, ton/scf:	0.0011
GsL Variation, scf/ton:	1.6178
PL Variation, psia:	6.2170
Langmuir Storage Capacity, scf/ton:	37.97
Langmuir Pressure, psia:	1,483.95
Langmuir Equation:	$G_s = (G_{sL} * p) / (P_L + p)$
Reservoir Pressure (Midpoint), psia:	2,430.00
Storage Capacity, scf/ton:	23.58
Absolute/Corrected Isotherm	
Corrected Langmuir Storage Capacity, scf/ton:	47.03
Corrected Langmuir Pressure, psia:	1,865.62
Langmuir Equation:	$G_s = (G_{sL} * p) / (P_L + p)$
Reservoir Pressure (Midpoint), psia:	2,430.00
Adsorbed Phase Methane Density, gm/cc	0.372
Storage Capacity, scf/ton:	26.61

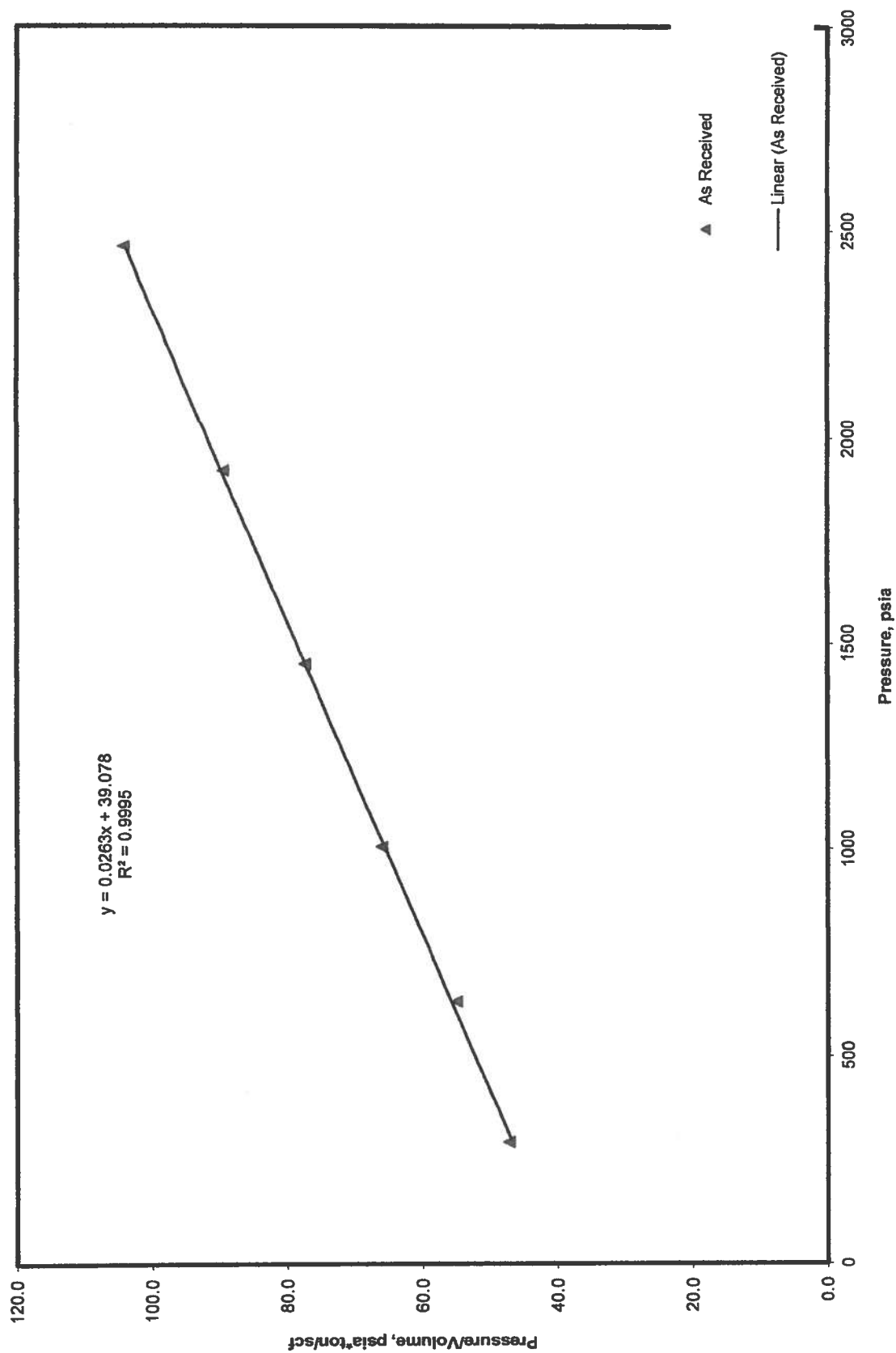
Gs Gas Storage Capacity

GsL Langmuir Gas Storage Capacity

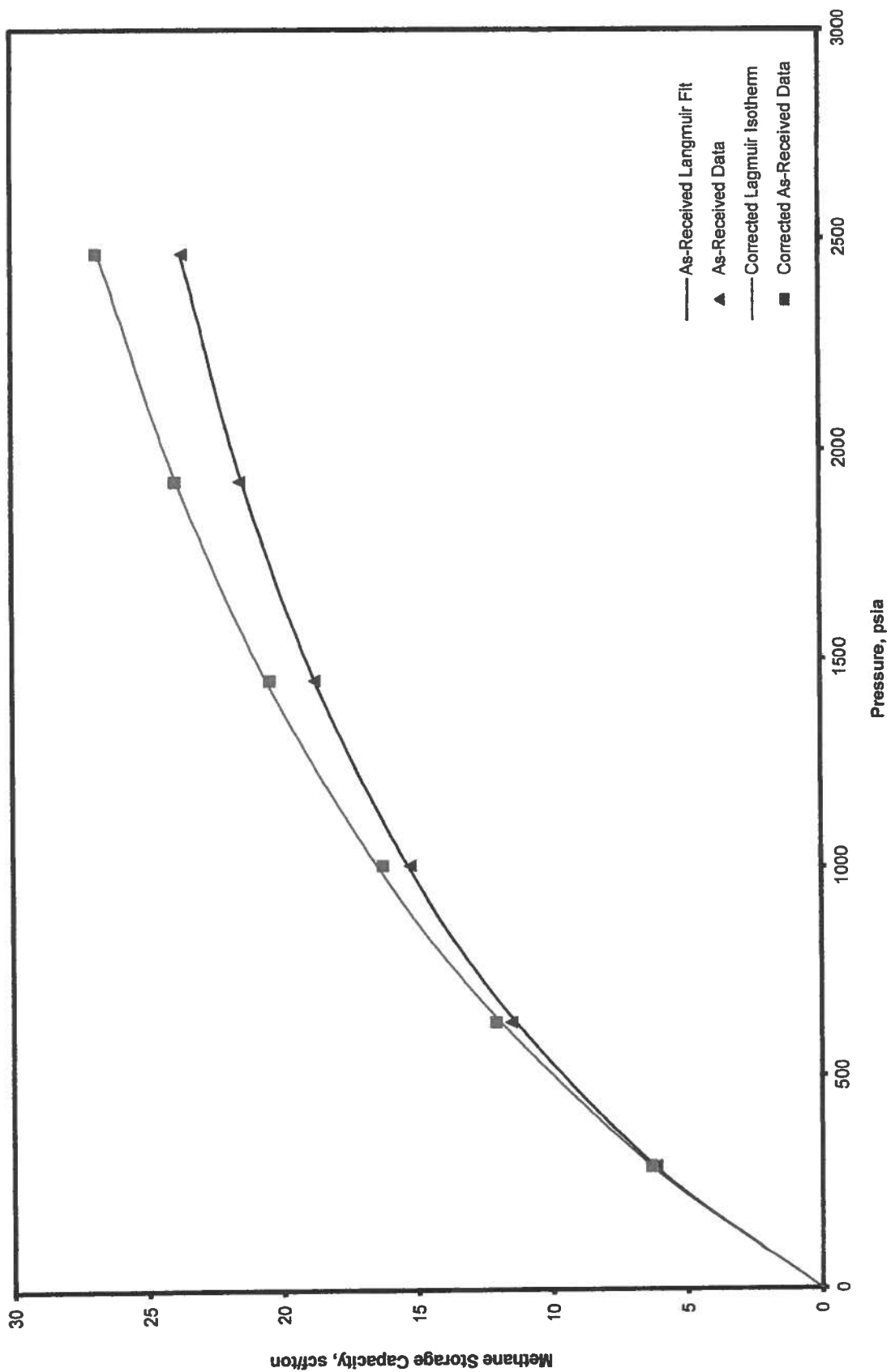
PL Langmuir Pressure

p Relevant Pressure (Reservoir Pressure)

Langmuir Interpretation Graph



Langmuir Isotherm Graph



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Methane Adsorption Isotherm Summary

Well: Federal 5-24-8-101

Reservoir:

Sample Number:

Sample Type: Shale

Drill Depth, Feet: 6,335.00

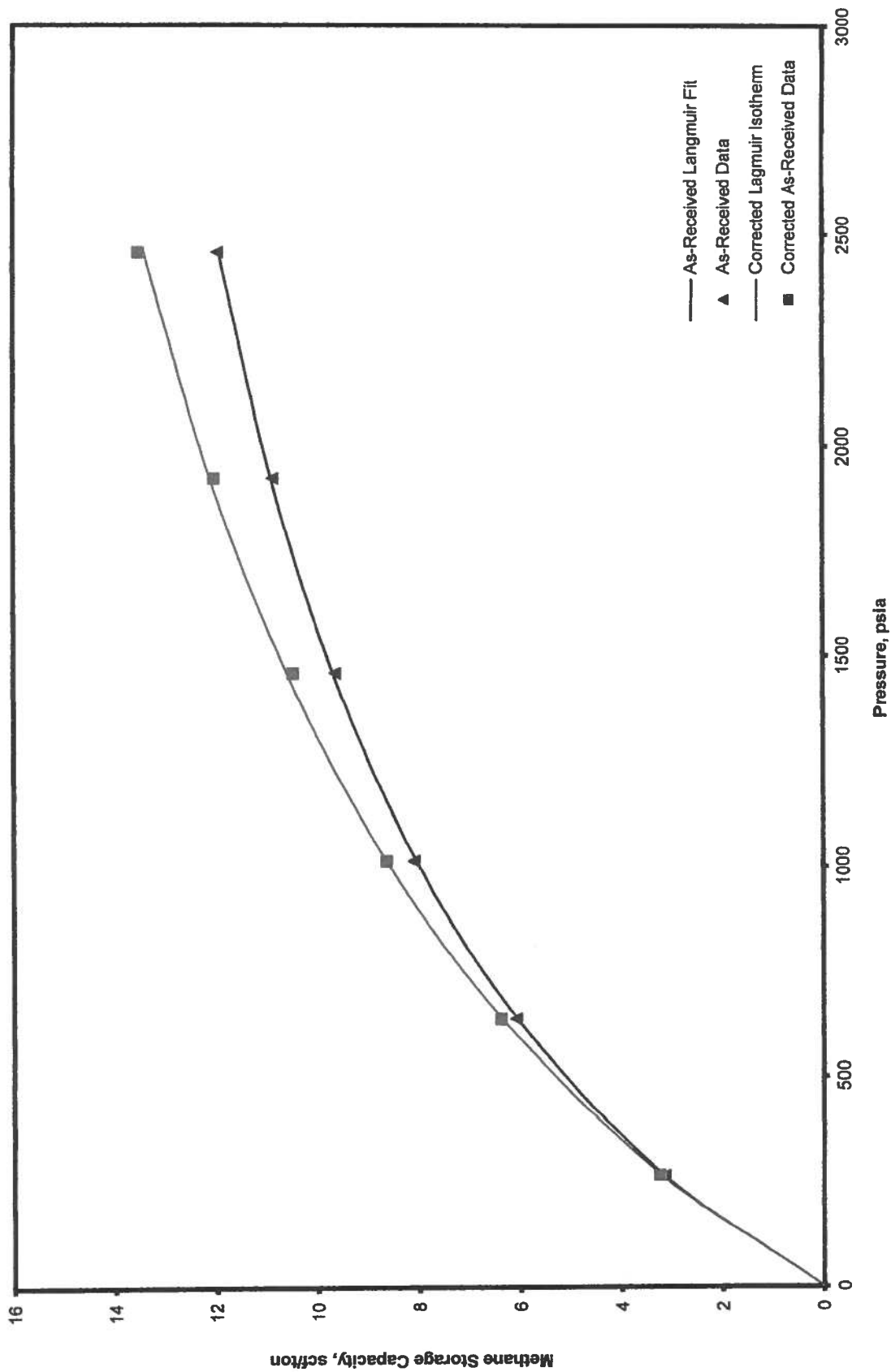
Temperature, °F: 176.90

Average Particle Size, mesh: -60.00

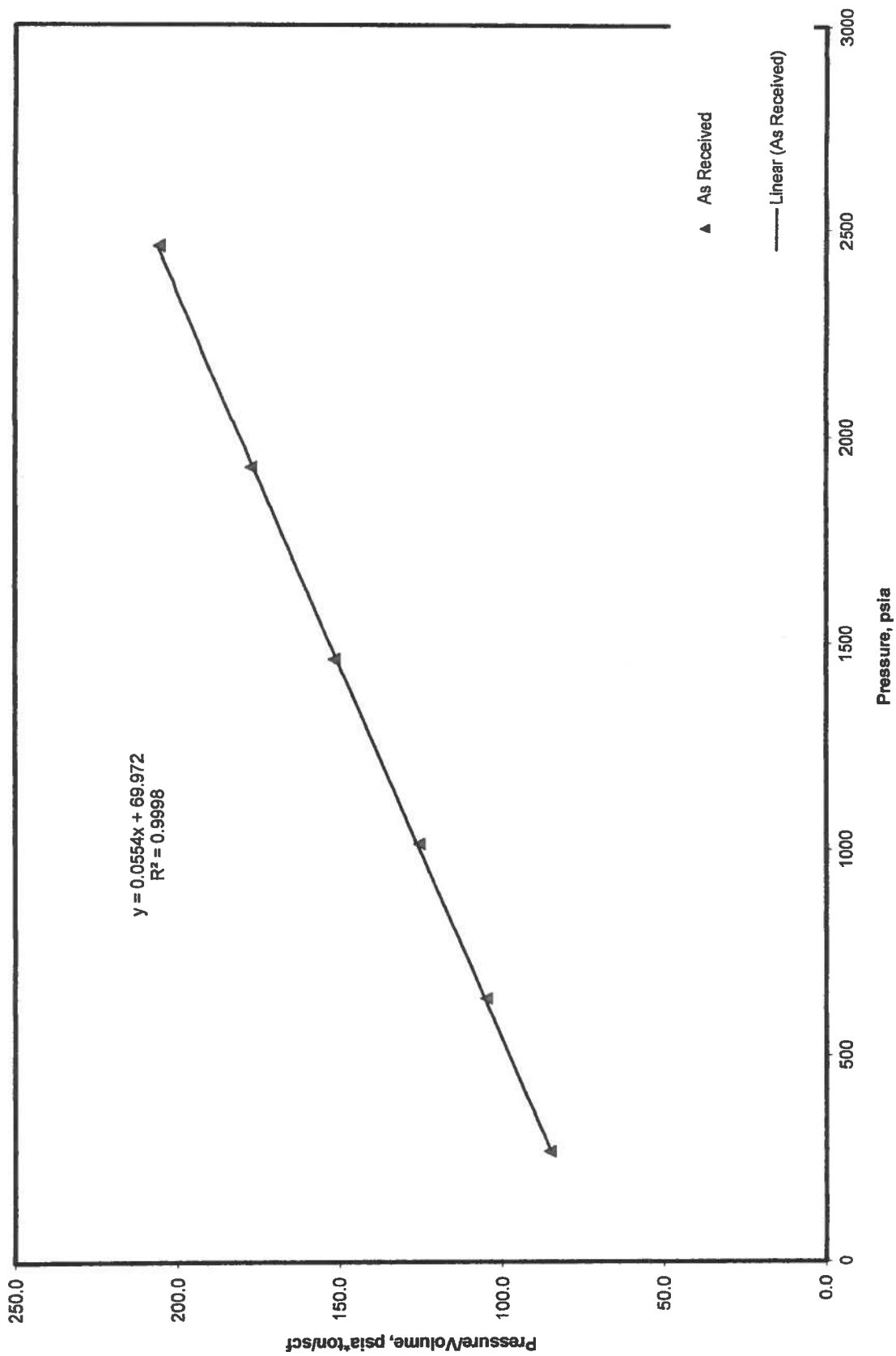
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Pressure	Methane Storage Capacity, scf/ton
psia	As-Received
0.0	Measured 0.00 Calculated 0.00
268.4	3.15
636.7	6.08
1,014.7	8.09
1,460.5	9.64
1,926.0	10.87
2,458.6	11.96
	11.93
Parameters	Methane Langmuir Parameters (U.S. Units)
	As-Received
Slope, ton/scf:	0.0554
Intercept, psia*ton/scf:	69.9717
Regression Coefficient (squared):	0.9997
Intercept Variation, psia*ton/scf:	2.7301
Slope Variation, ton/scf:	0.0017
GsL Variation, scf/ton:	0.5458
PL Variation, psia:	11.1502
Langmuir Storage Capacity, scf/ton:	18.06
Langmuir Pressure, psia:	1,263.43
Langmuir Equation:	Gs = (GsL*p)/(PL+p)
Reservoir Pressure (Midpoint), psia:	2,430.00
Storage Capacity, scf/ton:	11.88
Absolute/Corrected Isotherm	
Corrected Langmuir Storage Capacity, scf/ton:	21.92
Corrected Langmuir Pressure, psia:	1,562.41
Langmuir Equation:	Gs = (GsL*p)/(PL+p)
Reservoir Pressure (Midpoint), psia:	2,430.00
Adsorbed Phase Methane Density, gm/cc	0.372
Storage Capacity, scf/ton:	13.34
Gs Gas Storage Capacity	
GsL Langmuir Gas Storage Capacity	
PL Langmuir Pressure	
p Relevant Pressure (Reservoir Pressure)	

Langmuir Isotherm Graph



Langmuir Interpretation Graph



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