



Provided Via Email

19000 W. Highway 72, Suite 100
Arvada, CO 80007
Tuesday, January 24, 2006

Ron Jones
Ascent Energy Inc.
1700 Redbud Blvd., Suite 450
McKinney, TX 75069

Re: Data Revision for the Woodford/Caney Shale six well (OGS Sample Library) Final Report

Dear Mr. Jones:

TICORA Geosciences, Inc. was contacted by Tim Ruble from Humble Geochemical Services on January 23, 2006 and informed us of some data discrepancies that came to light recently for the project and report we completed for you in January of 2005. The discrepancies involve the calculated %Ro, measured %Ro and Tmax values for TICORA sample # ISO052-2 from the Holt 1-19 well at a depth of 3701.8 feet.

It appears that the sample's thermal maturity was underestimated due to a large population of granular bitumen that was distinct from the true population of vitrinite. This error lead Humble to question the maturity assessment of all the other samples associated with this project, therefore they reevaluated the entire suite and found there were no other discrepancies beyond ISO052-2.

The relevant data that needs revision can be found in Appendix II of the report (pp. 55 of the pdf version).

I have attached the letter from Humble that was submitted to Mike Watt, our lab manager, along with the rerun Rock-Eval and TOC data. I have also attached a copy of the original report for your convenience.

Sincerely,
TICORA Geosciences, Inc.

A handwritten signature in black ink, appearing to read "Chad Hartman", written over a white background.

Chad Hartman
Manager of Isotherm Laboratory



Humble Geochemical Services

Division of Humble Instruments & Services, Inc.

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January 16, 2006

Michael Watt
TICORA Geosciences, Inc.
19000 West Hwy. 72
Suite 100
Arvada, CO 80007

Re. Project #04-2593 data revision

Dear Mike:

We have been informed of a possible discrepancy in reported maturity data for a sample from Humble Project #04-2593 that was sent to you back on October 25, 2004. The sample in question is HGS #04-2593-089835, also identified with a TICORA sample number ISO052-2. We are sending this letter to notify you and your clients that subsequent analyses have revealed an apparent error in the reported maturity values for Tmax, calculated %Ro and measured %Ro.

Brian Cardott from the Oklahoma Geological Survey sent an inquiry to HGS on 9/22/05 regarding maturity data from the sample obtained from the OGS and reported by Ascent Energy. There was a significant discrepancy between his measured mean vitrinite reflectance value of 1.23% on a sample from the same core and the HGS reported value of 0.77%. During his petrographic analysis, Brian noted a population of granular bitumen with a measured reflectance value of 0.50–0.93% BRo that was distinct from the true population of vitrinite (rare and often pitted) having a 1.23% Ro.

Upon being informed of this apparent discrepancy in measured vitrinite reflectance, we undertook a re-evaluation of both petrographic analyses and Rock-Eval data. The original Tmax value of this sample (438°C) and calculated %Ro (0.72%) closely matched the measured vitrinite reflectance value of 0.77%. While this gave confidence in the integrity of the original reported data, the presence of bitumen (or pyrobitumen) in the sample could have significantly affected both the Rock-Eval and petrographic data. In addition, the relatively high PI of 0.22 for this sample also suggested a possibly higher level of thermal maturity than indicated.

To address these concerns, the sample in question was solvent extracted to potentially remove the bitumen and then re-analyzed by Rock-Eval. The results clearly indicate that a bitumen component was contributing to the original S2 peak and thereby affecting the Tmax value. Rock-Eval S2 yields dropped by almost half in going from 10.34 mg/g rock in the original sample to 5.63 mg/g rock in the extracted sample (consequently HI also

dropped from 146 mg/g TOC to 85 mg/g TOC). The revised Tmax from the extracted sample is 456°C, giving a calculated %Ro of 1.05%. Although still below the measured %Ro value of 1.23% of Cardott, this revised data from the extracted rock indicates a significantly higher level of thermal maturity and supports Cardott's petrographic interpretation. Thus, we now believe that the HGS reported measured vitrinite reflectance value is incorrect and has been measured on granular bitumen as opposed to the true vitrinite population in this sample.

Our concerns for this apparent error in maturity assessment led us to also investigate the other sample in this project for which Rock-Eval and measured vitrinite reflectance were determined (HGS #04-2593-089840). Extraction of this sample resulted in essentially no discernable difference in Rock-Eval S2 yields or in the Tmax value. In this instance, the original and extracted calculated %Ro values were also in close agreement with measured %Ro values and were corroborated by relatively low PI values. Thus, the previous error does not appear to be a consequence of any analytical errors in Rock-Eval or petrographic measurements, but is likely related directly to the presence of bitumen within the sample in question.

We at HGS apologize for our inability to identify at the outset and correct geochemical results affected by the bitumen component in the sample in question. While we always strive to provide the most accurate data to our clients, occasionally peculiarities and heterogeneity in natural samples can thwart such goals. Our desire at this point is to correct the erroneous data by providing you with a complete discussion of the causes and outcome of our subsequent analyses. We are providing you with this information so that you can forward it on to all parties concerned, including your direct clients and those, such as the OGS, who received the erroneous data.

If you have any additional questions or requests regarding this please feel free to contact me and we will do what we can to address your concerns.

Best Regards,

Tim Ruble, Ph. D.
Geochemist

TOC and ROCK-EVAL DATA REPORT

Ticora Geosciences

HGS No.	Sample Id.	Sample Type	TOC	S1	S2	S3	Tmax (°C)	Cal. %Ro	Meas. %Ro	HI	OI	S2/S3	S1/TOC	PI	Notes	
															Checks	Pyrogram
04-2593-089834	ISO052-1	ground rock	7.86	2.85	9.70	0.42	454	1.01		123	5	23	36	0.23	c	n
04-2593-089835	ISO052-2	extracted	6.58	1.67	5.63	0.14	456	1.05	0.77	86	2	40	25	0.23		n
04-2593-089836	ISO052-3	ground rock	8.09	2.90	9.59	0.29	443	0.81		119	4	33	36	0.23		n
04-2593-089837	ISO052-4	ground rock	11.28	4.98	64.49	0.69	428	0.54		572	6	93	44	0.07		n
04-2593-089838	ISO052-5	ground rock	11.15	4.88	54.27	0.55	424	0.47		487	5	99	44	0.08		n
04-2593-089839	ISO052-6	ground rock	14.34	7.12	75.88	1.16	422	0.44		529	8	65	50	0.09		n
04-2593-089840	ISO052-7	ground rock	12.07	4.82	59.47	0.81	427	0.53	0.62	493	7	73	40	0.07		n
04-2593-089841	ISO052-8	ground rock	9.48	4.24	45.96	0.69	428	0.54		485	7	67	45	0.08		n
04-2593-089842	ISO052-9	ground rock	9.34	4.66	51.47	0.49	428	0.54		551	5	105	50	0.08	c	n

Note: "-1" indicates not measured or meaningless ratio

* Tmax data not reliable due to poor S2 peak

TOC = weight percent organic carbon in rock
S1, S2 = mg hydrocarbons per gram of rock
S3 = mg carbon dioxide per gram of rock
Tmax = °C

HI = hydrogen index = $S2 \times 100 / TOC$
OI = oxygen index = $S3 \times 100 / TOC$
S1/TOC = normalized oil content = $S1 \times 100 / TOC$
PI = production index = $S1 / (S1 + S2)$
Cal. %Ro = calculated vitrinite reflectance based on Tmax
Measured %Ro = measured vitrinite reflectance

Notes:

c = analysis checked and confirmed

Pyrogram:
n=normal
ltS2sh = low temperature S2 shoulder
ltS2p = low temperature S2 peak
htS2p = high temperature S2 peak
f = flat S2 peak



Final Report Reservoir Property Analysis

WOODFORD/CANEY SHALE

Six Wells Wells – OGS Sample Library

Holt 1-19 : 10N 12E-19 NW NW – Core Samples
MFU 5-17 : 2N 7E-29 SW NE NW NW – Core Samples
EFU 9-41 : 2N 7E-27 NW NE NE NW – Core Samples
Kirby Gilberth 1-20 : 9N 2E-20 NW SW SE NW – Core Samples
Jonas #3 : 5N 8E-17 – Cuttings Samples
Chandler #3 : 5N 7E-35 – Cuttings Samples
Oklahoma

Submitted To:

Ascent Energy Inc.

1700 Redbud Blvd., Suite 450
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Attention: Mr. John Pinkerton.

Submitted By:

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January 11, 2005

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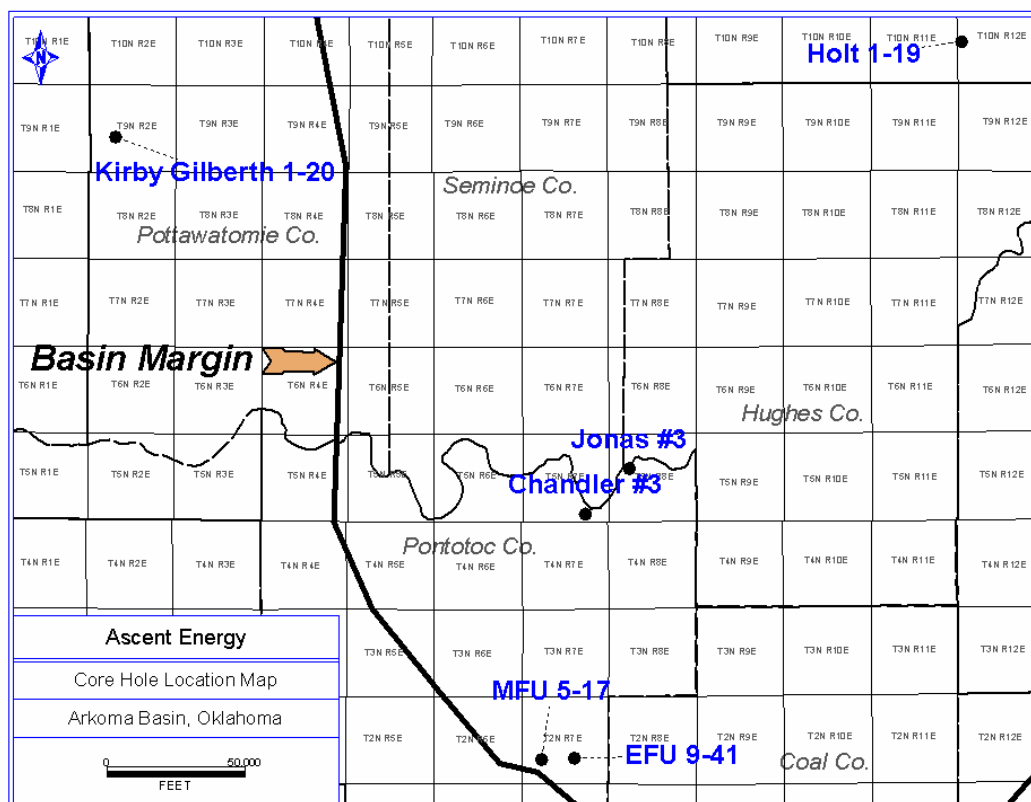
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Appendix V	Core Lithology and Photography
Appendix VI.....	Adsorption Isotherm

1.0 INTRODUCTION

This report summarizes the procedures and results of reservoir property analysis of core and cuttings samples from the Woodford and Caney Shale Zones from the five core holes listed in Table 1-1. The samples were obtained from the Oklahoma Geological Survey Core and Sample Library (OGS-C&SL). The core hole locations are also listed by Section, Township and Range in Table 1-1.

Figure 1-1 Core Hole Location Map



At the request of Mr. John Pinkerton (Ascent Energy), TICORA Geosciences, Inc. (TICORA) conducted analyses on core and cuttings samples collected from the Woodford and Caney Shale Zones. Five of the samples were cutting samples while the remaining samples were from core samples. Table 1-1 differentiates the sample type and depth for each core hole. The cutting sample volumes were very small (<50 grams)

Table 1-1 Well Details and Location

Well Name	Location	County	TICORA #	Depth	Sample Type
Jonas #3	Section 17-T5N-R8E	Pontotoc Cty, OK	362-1	3,600' - 3,610'	Woodford Shale Cuttings
			362-2	3,650' - 3,660'	Woodford Shale Cuttings
			362-3	3,670' - 3,680'	Woodford Shale Cuttings
Chandler #3	Section 35-T5N-R7E	Pontotoc Cty, OK	362-4	3,800' - 3,820'	Woodford Shale Cuttings
			362-5	3,900' - 3,920'	Woodford Shale Cuttings
Holt 1-19	NW1/4, NW1/4, Section 19-T10N-R12E	Hughes Cty, OK	ISO052-1	3,699.6	Woodford Shale Core
			ISO052-2	3,701.8	Woodford Shale Core
			ISO052-3	3,707.8	Woodford Shale Core
MFU 5-17	SW1/4, NE1/4, NW1/4 Section 29-T2N-R7E	Pontotoc Cty, OK	ISO052-4	3,379.6	Woodford Shale Core
			ISO052-5	3,385.0	Woodford Shale Core
			ISO052-6	3,391.1	Woodford Shale Core
EFU 9-41	NW1/4, NE1/4, NE1/4 Section 27-T2N-R7E	Pontotoc Cty, OK	ISO052-7	3,421.0	Woodford Shale Core
Kirby Gilberth 1-20	NW1/4, SW1/4, SE1/4 Section 20-T9N-R2E	Pottawatomie Cty, OK	ISO052-8	5,373.0	Caney Shale Core
			ISO052-9	5,376.8	Caney Shale Core

Table 1-2 represents the detailed analysis program conducted by TICORA indicating the samples analyzed by each analysis method.

Shale gas reservoirs behave as triple porosity systems that have different gas storage and flow characteristics, partially dependent on varying geological parameters. Gas storage occurs by sorption, compression, and solution. Mass transfer should be by diffusion (driven by concentration gradients) and Darcy flow (driven by pressure gradients).

Gas is stored by sorption within the first pore system consisting of micropores (with diameters less than 2 nm) and mesopores (with diameters between 2 and 50 nm). These pore sizes are found within clays and solid organic material. Mass transfer is dominated by diffusion. Although dry clays have the potential for sorption, generally the contribution to gas-in-place volumes from gas sorption within clay is insignificant since the clay was water filled at the time of gas generation. Laboratory measurements of gas storage capacity as a function of organic content are used to quantify gas storage by sorption.

The second pore system consists of macropores with sizes greater than 50 nm. Gas is expected to be stored by compression and in solution within liquid hydrocarbons (if any are present) and water. Mass transfer is by a combination of diffusion and Darcy flow in this system. The void volume of this porosity system can be quantified with core porosity measurements and log interpretation. Log interpretation techniques must take in to account the presence of low-density organic material and gas saturations to obtain accurate void volume estimates.

The third porosity system consists of natural fractures. Gas is expected to be stored by compression and in solution within liquid hydrocarbons (if any are present) and water. Mass transfer will be due to Darcy flow. Commercial gas production requires that the natural fracture system be present and interconnected.

The majority of gas-in-place is contained within the first two porosity systems. It is important to quantify the storage volumes within the first two porosity systems and the natural fracture permeability of the third porosity system. This project obtained estimates of void volumes and matrix permeability as discussed in this report. Well testing or production analysis would be required to determine natural fracture permeability.

Table 1-2 Detailed Analysis Program

Core Hole Name	TIC No.	Sample Depth (feet)	Shale Zone	Sample Type	Sample Handling	Total Organic Carbon (TOC)	Rock Eval Pyrolysis	Vitrinite Reflectance	Tight Rock Analysis	Helium Grain Density	Isotherm Analysis	Premium Sample Preservation
Jonas #3	362-1	3,600-3,610	Woodford	Cuttings	✓	✓	✓					
	362-2	3,650-3,660	Woodford	Cuttings	✓	✓	✓					
	362-3	3,670-3,680	Woodford	Cuttings	✓	✓	✓	✓				
Chandler #3	362-4	3,800-3,820	Woodford	Cuttings	✓	✓	✓					
	362-5	3,900-3,920	Woodford	Cuttings	✓	✓	✓	✓				
Holt 1-19	ISO052-1	3,699.6	Woodford	Core	✓	✓	✓		✓	✓		
	ISO052-2	3,701.8	Woodford	Core	✓	✓	✓	✓	✓	✓	✓	✓
	ISO052-3	3,707.8	Woodford	Core	✓	✓	✓		✓	✓		
MFU 5-17	ISO052-4	3,379.6	Woodford	Core	✓	✓	✓		✓	✓		
	ISO052-5	3,385.0	Woodford	Core	✓	✓	✓		✓	✓		
	ISO052-6	3,391.1	Woodford	Core	✓	✓	✓		✓	✓		
EFU 9-41	ISO052-7	3,421.0	Woodford	Core	✓	✓	✓	✓	✓	✓	✓	✓
Kirby Gilbreth 1-20	ISO052-8	5,373.0	Caney	Core	✓	✓	✓		✓	✓		
	ISO052-9	5,376.8	Caney	Core	✓	✓	✓		✓	✓		

2.0 LABORATORY ACTIVITIES

Drill cuttings (<50 grams) from the Jonas #3 and Chandler #3 wells and core samples from the Holt 1-19, MFU 5-17, EFU 9-41, and Kirby Gilbreth 1-20 well were sent to TICORA Geosciences, Inc. in September 2004. There was only sufficient drill cuttings sample to conduct TOC and rock eval pyrolysis. For the slabbed core samples (ISO052) Ascent specified core plug sampling. These plugs were analyzed for TOC, grain density, rock eval, and tight rock analysis. Subsequently the remaining core samples were cut around where plugs samples ISO052-2 and ISO052-7 were processed. These samples were used for methane adsorption isotherm analysis. In addition, four samples were submitted to Humble Geochemical for vitrinite reflectance analysis.

Samples were processed using systematic procedures that minimize sample aerial oxidation and aerial desiccation (moisture loss). TICORA uses an in-house improved procedure to air-dry processed samples that differs from the air-drying procedure described in the ASTM Method D3302. The reader should therefore be aware of this when evaluating analysis data reported on an air-dried basis. TICORA's air-drying procedure attempts not to over-dry samples by only removing surface moisture. These sample methodologies rigorously follow accurate analysis protocols developed by ASTM, the Gas Technology Institute (GTI), and TICORA.^{1,2,3}

2.1 Helium Density

Helium density represents the true powder or grain density of the organic and inorganic matter in a crushed sample. It differs from bulk density in that it does not include the effect of the primary or secondary (i.e. natural fractures) porosity systems. Helium density requires the measurement of sample volume and mass. Sample volume was measured at room temperature conditions on triplicate air-dried samples (representative of each desorption sample) of approximately 100-grams using a helium multi-pycnometer. Sample volume can be calculated from helium expansion pressure measured by the multi-pycnometer. Helium is used for volume determination since it enters the coal or shale micropores without adsorption and it does not add moisture to the sample. Sample weight was determined to the nearest 0.001-gram using an electronic balance. Sample density was calculated for all desorption and composite samples by dividing the measured sample weight by calculated sample volume. TICORA conducted all helium density and residual moisture described in this section.

2.2 TOC and Rock Eval Testing

The samples were initially dried and crushed. Subsequent treatment with hydrochloric acid effectively removed the carbonate portion of the material. The organic carbon component was measured through combustion (1,300°C) in a furnace while measuring the amount of evolved carbon dioxide using an IR detector.

TOC analysis is a comparatively quick and inexpensive procedure that is typically used to effectively screen potential source rock samples. TOC is a measure of the richness of a rock with respect to weight percent organic carbon. True shales can be extremely rich in organic carbon (~10%), but a minimum value for which rocks can be officially deemed source rocks is not always definable, as thermal history, specific variety of organic material, and efficiency of hydrocarbon migration all play a significant role in source rock potential. In general, shales containing less than 0.50 weight percent TOC and carbonates possessing less than 0.20 percent are not regarded as particularly good source rocks. However, when sufficient thickness and natural fracture permeability are present, low organic content shales can serve as productive shale gas reservoirs.

Rock Eval pyrolysis is a more advanced geochemical characterization than the TOC procedure. The measurements are based upon heating small samples over the temperature range of 300 to 550 °C. Four specific parameters are obtained from the analysis as follows:

1. S1 represents free hydrocarbons in the source rock, volatilized at 300 °C.
2. S2 is an estimate of the hydrocarbons generated in the subsurface under native-state conditions and is influenced by the amount of hydrocarbons produced by the thermal cracking of kerogen types.
3. S3 represents the amount of carbon dioxide produced from organic sources. The carbon dioxide is collected over a specific temperature range (300 to 390°C) such that contributions from inorganic carbonates are avoided. Inorganic sources of carbon dioxide are commonly generated at higher temperatures.
4. Tmax represents the temperature at which hydrocarbon generation occurs at its maximum rate during pyrolysis. Thermocouples are used to monitor this important event.

Third-party commercial laboratory *Humble Geochemical Services* conducted the TOC and Rock Eval testing.

2.3 Adsorption Gas Storage Capacity Analysis

The adsorption isotherm measures the gas storage capacity of organic material (kerogen) as a function of increasing pressure, as described by the Langmuir equation⁹. The measurement is performed on crushed analysis samples equilibrated to the air-dry, moisture content at the reservoir midpoint temperature and over a series of increasing pressure steps that range from 25-50 pounds per square inch absolute (psia) to an endpoint pressure that exceeds the initial reservoir pressure. Gas storage capacity is highly dependent upon pressure, temperature, moisture content, organic composition and thermal maturity. The proper measurement and interpretation of gas content and gas storage capacity data enables valid and very accurate assessments of the initial gas saturation level, the critical desorption pressure, the gas volume abandoned in-place, and the ultimate recovery factor. The gas saturation level is the ratio between the initial gas content and the initial gas storage capacity. The critical desorption pressure is used to determine the amount of draw down, if any, that is required before gas can be produced from the reservoir. If the operator anticipates an average abandonment reservoir pressure, it is possible to estimate the ultimate reserves and the volume of gas that will be abandoned in-place. The recovery factor is the ratio between the initial gas content minus the abandoned gas content and the initial gas content.

2.4 Vitrinite Reflectance Analysis

Third-party commercial laboratory, *Humble Geochemical Services* conducted the vitrinite reflectance analysis and is provided in the Appendices.

3.0 FINDINGS

This section provides summaries and discussions of the analysis results. Laboratory reports (raw data) are provided in the Appendices.

3.1 Total Organic Carbon (TOC) and Grain Density

Humble Geochemical Services (Humble) performed total organic carbon (TOC) analysis of all samples using the Leco method. The Humble report is included as Appendix IV.

The density of shale varies as a function of its bulk composition^{1, 4}. Since the mineral matter component of the shale has a significantly higher density than the organic matter component, the bulk density of shale varies directly as a function of its mineral matter content. Therefore a good relationship can be established between grain densities versus dry total organic carbon. For the ISO052 samples Figure 3-1 illustrates this well. Table 3-1 summarizes all grain density and TOC Results. Grain density results are summarized in Appendix I and TOC results are summarized in Appendix II.

Figure 3-1 Reciprocal Helium Density versus TOC Content

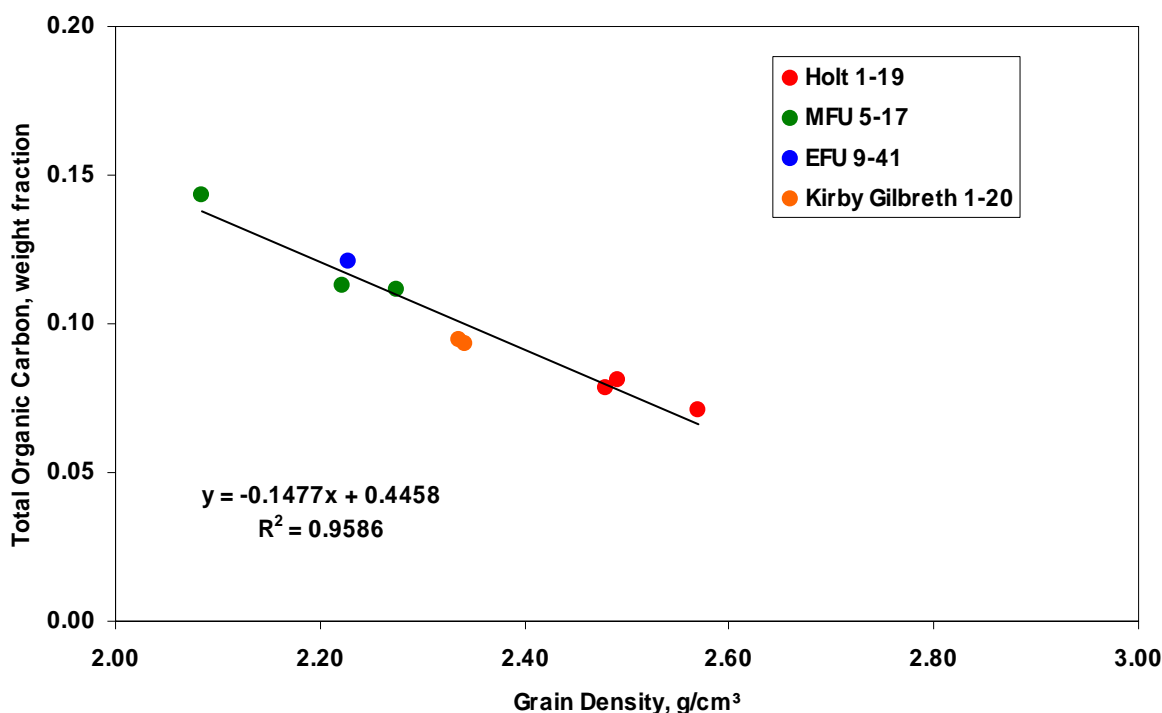


Table 3-1 Grain Density and TOC Results

Core Hole Name	TIC No.	Sample Depth (feet)	Shale Zone	Grain Density (g/cm ³)	Total Organic Carbon Weight %
Jonas #3	362-1	3,600-3,610	Woodford	N/D	2.55
	362-2	3,650-3,660	Woodford	N/D	3.66
	362-3	3,670-3,680	Woodford	N/D	4.19
Chandler #3	362-4	3,800-3,820	Woodford	N/D	5.91
	362-5	3,900-3,920	Woodford	N/D	5.70
Holt 1-19	ISO052-1	3,699.6	Woodford	2.480	7.86
	ISO052-2	3,701.8	Woodford	2.569	7.09
	ISO052-3	3,707.8	Woodford	2.491	8.09
MFU 5-17	ISO052-4	3,379.6	Woodford	2.222	11.28
	ISO052-5	3,385.0	Woodford	2.275	11.15
	ISO052-6	3,391.1	Woodford	2.084	14.34
EFU 9-41	ISO052-7	3,421.0	Woodford	2.228	12.07
Kirby Gilbreth 1-20	ISO052-8	5,373.0	Caney	2.337	9.48
	ISO052-9	5,376.8	Caney	2.341	9.34

N/D – Not Determined. Insufficient sample volume.

3.2 Rock Eval

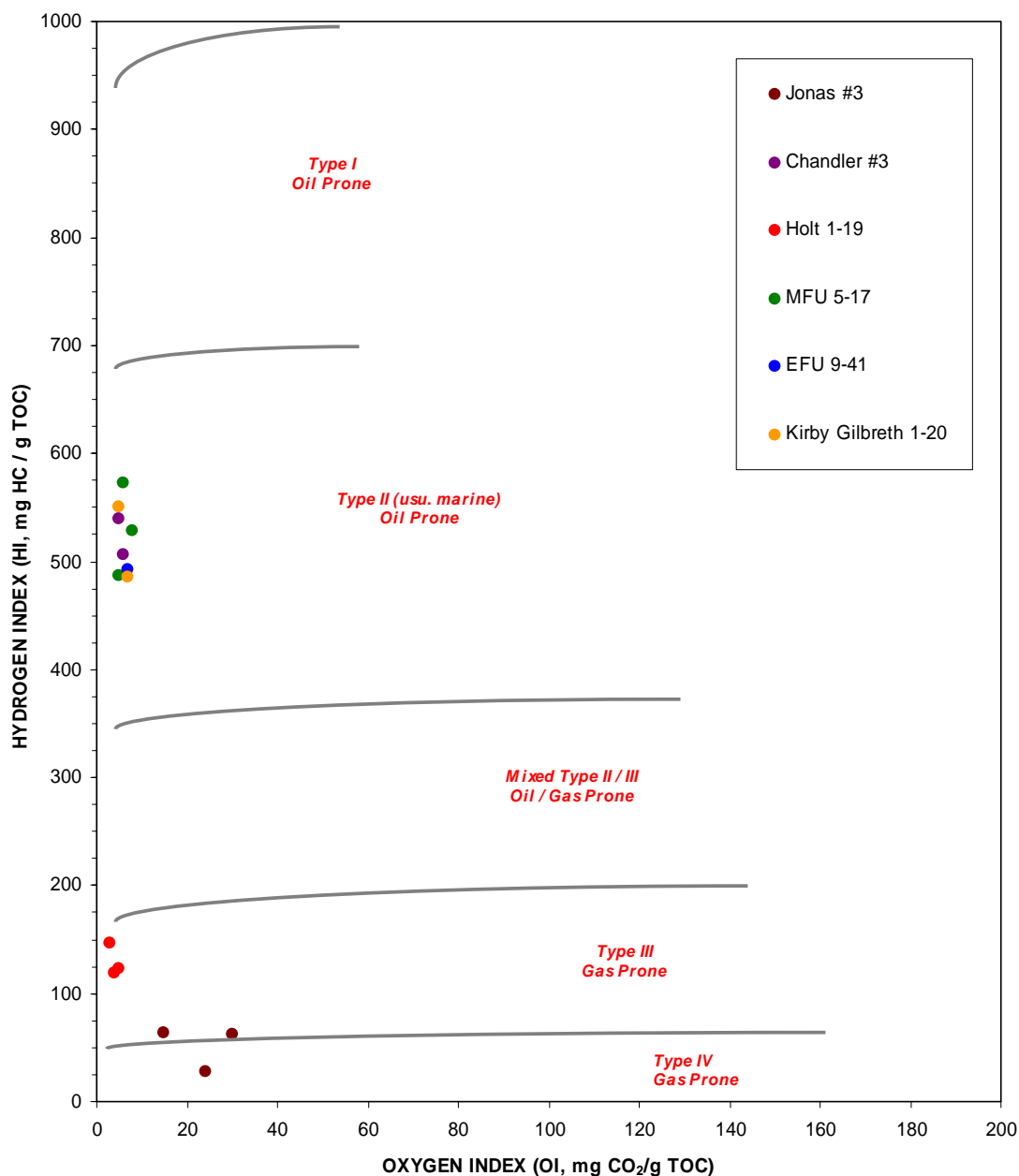
Rock Eval pyrolysis is a more advanced geochemical characterization than the TOC procedure. The measurements are based upon heating small samples over the temperature range of 300 to 550 °C. Four specific parameters are obtained from the analysis as follows:

1. S1 represents free hydrocarbons in the source rock, volatilized at 300 °C.
2. S2 is an estimate of the hydrocarbons generated in the subsurface under native-state conditions and is influenced by the amount of hydrocarbons produced by the thermal cracking of kerogen types.
3. S3 represents the amount of carbon dioxide produced from organic sources. The carbon dioxide is collected over a specific temperature range (300 to 390°C) such that contributions from inorganic carbonates are avoided. Inorganic sources of carbon dioxide are commonly generated at higher temperatures.
4. Tmax represents the temperature at which hydrocarbon generation occurs at its maximum rate during pyrolysis. Thermocouples are used to monitor this important event.

Third-party commercial laboratory Humble Geochemical Services performed Rock Eval pyrolysis on all samples. The Humble report is included as Appendix II. Kerogen (organic matter) type can be characterized by two indices: (1) the hydrogen index ($S2 \times 100/TOC$) and (2) the oxygen index ($S3 \times 100/TOC$). When plotted against one another, a plot similar to the Van Krevelen diagram for elemental kerogen analysis (modified by Waples for this purpose) is obtained as illustrated in Figure 3-2. Samples

that follow the line indicated for Type I kerogen are mainly aliphatic in nature, are derived from algal lipids, and can have very high oil or gas generating potential. Type II kerogen is predominately of a naphthenic nature and is usually formed from marine organic matter (plankton) in a reducing environment. The oil generating potential of type II kerogen is high although lower than for Type I. Type III kerogen is mainly aromatic in nature and is formed from terrestrial higher plants. This type of kerogen is similar to humic coals. The oil generating potential is low and dry gas is generated primarily from Type III kerogen. Based on Figure 3-2 the Jonas #3 well is in between a Types III and IV kerogen (gas prone), the Holt 1-19 well is a Type III kerogen (gas prone), and the Chandler #3, MFU 5-17, EFU 9-41, and Kirby Gilbreth 1-20 are Type II Kerogen (oil prone).

Figure 3-2 Kerogen Type



Adding the S1 and S2 parameters (S1+S2) and expressing this value in terms of kg/ton of rock can also yield a useful parameter for the evaluation of source rock potential. The evaluation guidelines are as follows:

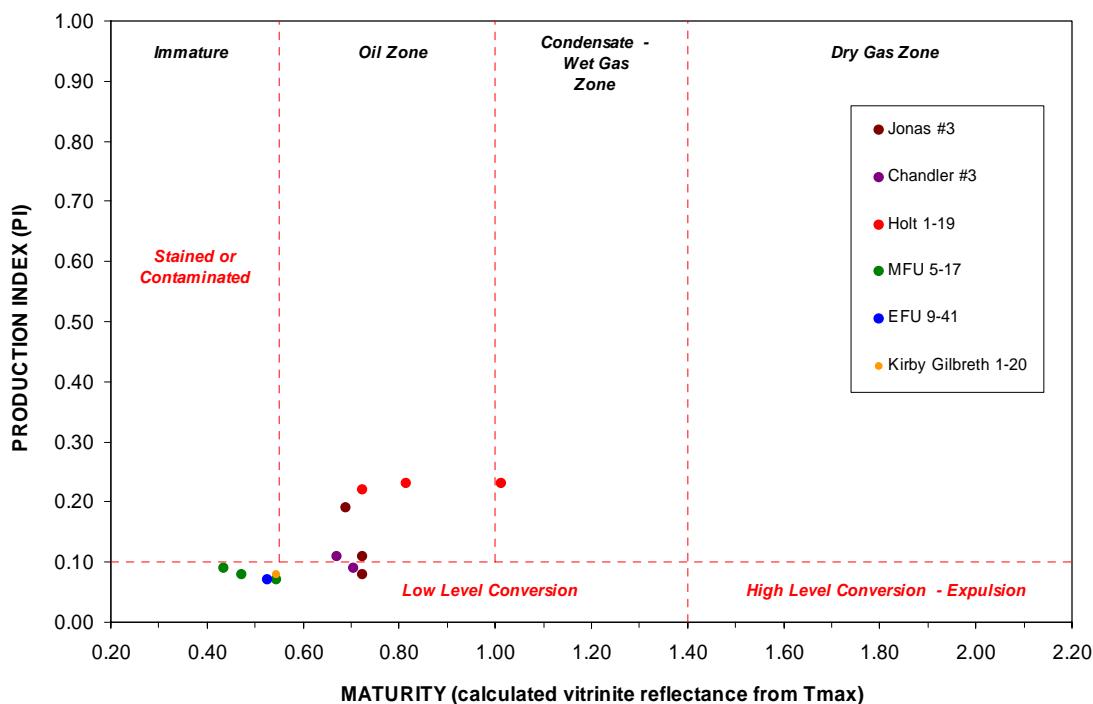
- Higher than 6 kg/ton: good source rock for oil;
- Between 2 and 6 kg/ton; moderate source potential for oil;
- Less than 2 kg/ton; and poor for oil, some potential for gas.

Thermal maturation can be examined using Tmax, which typically increases with depth. Although values commonly vary from laboratory to laboratory, the following subdivision is normally followed: temperatures between 400 and 430°C correspond to the immature zone; temperatures between 430 and 470°C define the major interval of oil production; and temperatures above 470 °C represents the interval where gas rather than oil is generated. The Tmax values for samples for the MFU 5-17, EFU 9-41, and Kirby Gilbreth 1-20 wells correspond to immature shales where as on the other hand the Jonas #3, Chandler #3, and Holt 1-19 well correspond to the major interval of oil production.

The Production Index (PI) $S1/(S1+S2)$ can also to evaluate source rock potential. Figure 3-3 illustrates this well. PI is indicative of the conversion of kerogen into free hydrocarbons. The evaluation guidelines are as follows:

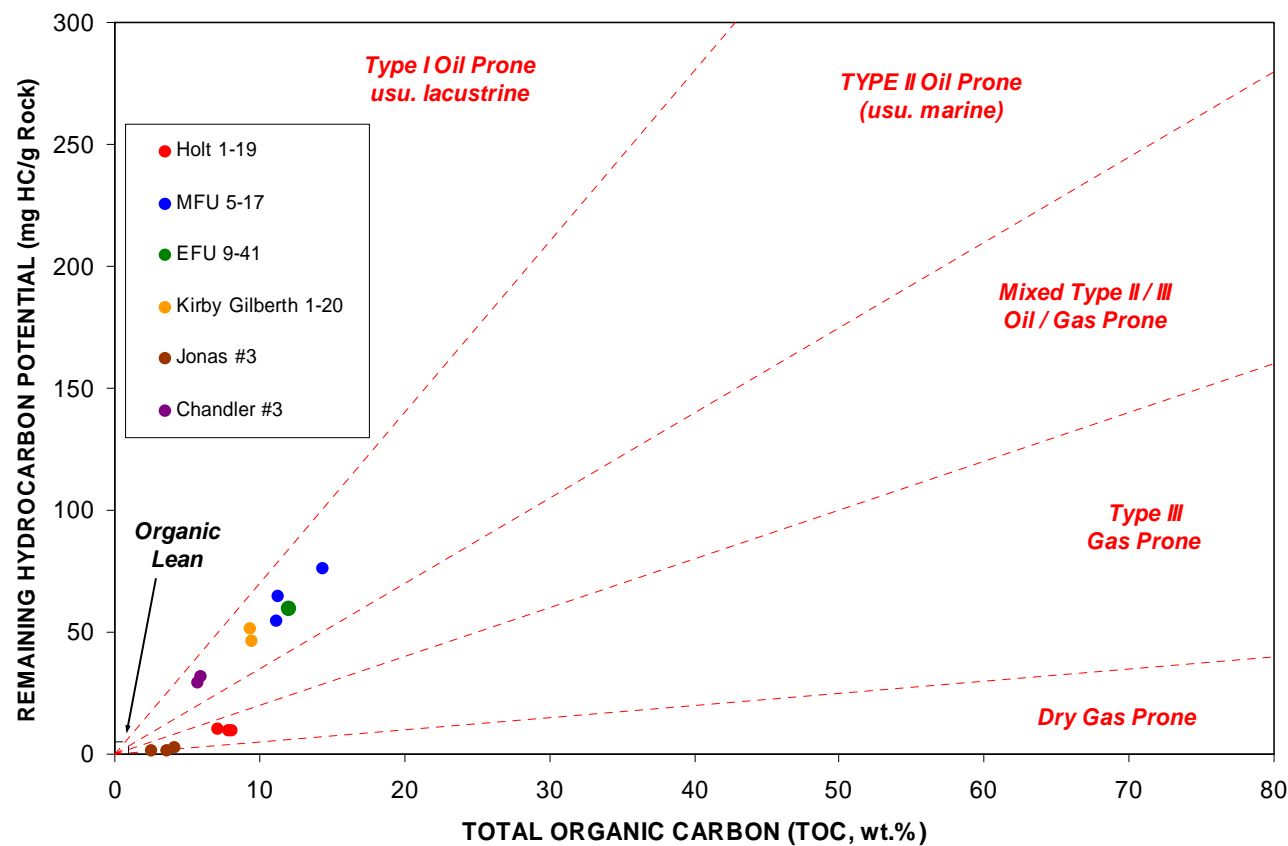
- 0.00 to 0.08: immature;
- 0.08 to 0.50: Oil Window;
- > 0.50: Gas Window.

Figure 3-3 Kerogen Conversion and Maturity



TOC values, determined by the Leco method, these core samples ranged from 2.55 to 14.34 weight percent. Another relationship exists that is useful in the evaluation of the hydrocarbon generation potential of shales. The relationship of TOC plotted against the value for Remaining Hydrocarbon Potential indicates the propensity for generation of oil in a given sample. In this instance, the plot indicates the presence of Type II kerogens appear in the MFU 5-17, EFU 9-41, Kirby Gilberth 1-20, and Chandler #3 wells, and that Type III kerogens appear in the Holt 1-19 and Jonas #3 wells. Figure 3-4 illustrates these results.

Figure 3-4 TOC versus Remaining Hydrocarbon Potential Diagram



3.3 Vitrinite Reflectance

This analysis was conducted to quantify thermal maturity for samples 362-3, 362-5, ISO052-2, and ISO052-7.

Vitrinite reflectance values are generally divided into the following categories of thermal maturity:

- Immature: up to 0.50%
- Early oil window maturity: 0.50% to 0.70%
- Peak oil window maturity: 0.7% to 1.1%

The results from the Humble Geochemical Services are included in Appendix III. Samples ISO052-2 (Holt 1-19) and 362-3 (Jonas #3) appear to be of high thermal maturity and fall within the peak oil maturity, whereas on the other hand samples ISO052-7 (EFU 9-41) and 362-5 (Chandler #3) are in the early oil maturity window.

3.4 Tight Rock Core (Shale) Analysis

CoreLab performed unconventional core (shale) analyses including: pulse-decay permeability and retort saturation analyses on core samples ISO052-2 through ISO052-9 to determine effect of fluid saturation and matrix permeability, effective porosity, and gas-filled porosity. The Core Lab report is included in Appendix IV. Table 3-2 summarizes the measured data.

Retort saturation measurements were performed on samples taken adjacent to the pulse-decay permeability plug locations. The total weight and bulk volume were determined before crushing to determine bulk density. The porosity, grain density, and fluid saturation were calculated from a representative portion after crushing. The samples were crushed and sieved until a significant portion passed a -12 mesh (1.70 mm) sieve and was retained on a -25 mesh (0.71 mm) sieve. A split of this sample was weighed and placed in a retort vessel and heated to 220°F to collect interstitial water. Once fluid production had ceased, the temperature was increased to 1,200°F to remove any remaining fluids including: bound water, interstitial oil, and cracked kerogen hydrocarbons. A fresh sieved sample was then weighed and the partial grain volume (grain volume plus interstitial fluid volume) of each sample was determined by Boyle's Law technique in order to measure the gas-filled pore space (bulk volume minus the partial grain volume). The porosity, bulk density, grain density, and fluid saturation were then calculated. The definition of each of these terms follows:

- Effective porosity is the interconnected pore volume in the rock expressed as a percentage of the bulk volume.
- Gas-filled porosity is the pore space that is gas filled expressed as a percentage of the bulk volume. This is equal to the effective porosity multiplied by the gas saturation divided by 100. The gas saturation in this case is 100 minus the water and hydrocarbon saturations (expressed as percentages).
- Interstitial water saturation is the percentage of the effective porosity occupied by water.
- Bound water is water bound between clay layers (not occupying effective pore space) as a percentage of the bulk volume.
- Bound hydrocarbons are oil bound in organic material (not occupying effective pore space) as a percentage of the bulk volume.
- Condensation/Oil saturation is the percentage of the effective porosity occupied by oil or condensate.

These results will be used in a later section of this report to estimate potential gas storage capacity in both free and sorbed states.

Table 3-2 Tight Rock Analysis Results

Parameter	Units	ISO052-2	ISO052-3	ISO052-4	ISO052-5	ISO052-6	ISO052-7	ISO052-8	ISO052-9
Effective porosity	vol. fraction	0.0585	0.0371	0.0310	0.0529	0.0672	0.0953	0.0619	0.0722
Water saturation	vol. fraction	0.4345	0.6117	0.8096	0.7478	0.5478	0.3434	0.5685	0.3735
Bulk density	g/cm ³	2.473	2.396	2.191	2.213	2.019	2.123	2.245	2.282
Grain Density	g/cm ³	2.569	2.491	2.222	2.275	2.084	2.228	2.337	2.341
Mobil Oil Saturation	% of PV	0.00	0.00	8.10	2.80	2.74	1.79	3.39	3.26
Gas filled porosity	% of BV	3.31	1.44	0.34	1.19	2.85	6.08	2.46	4.29
Bound Hydrocarbon Saturation	% of BV	0.48	0.53	12.75	7.22	11.71	7.33	6.46	7.01
Bound Clay Water	% of BV	5.38	5.93	6.04	7.22	7.32	6.84	6.22	6.35

3.5 Total Gas Storage Capacity

The majority of the gas storage capacity in shale gas reservoirs is a combination of multi-component gas mixtures adsorbed within organic material and the gas storage capacity of the macro-porosity (free gas). Adsorption, free gas and dissolved gas storage capacity are discussed in this section.

3.5.1 Methane Adsorption Gas Storage Capacity

Individual methane adsorption isotherms were measured by TICORA on samples ISO052-2 (Holt 1-19) and ISO052-7 (EFU 9-41). Sample properties and Langmuir coefficients are summarized in Table 3-3.

The isotherm analysis determines the volume of methane that is adsorbed upon the organic content within the shale matrix at a given experimental pressure and temperature.

The mass balance with an absorbing gas is given by Equation 4.1.

$$V_r \frac{p_{r1} \hat{M}}{z_{r1} RT_{r1}} + V_v \frac{p_{s1} \hat{M}}{z_{s1} RT_{s1}} = V_r \frac{p_{r2} \hat{M}}{z_{r2} RT_{r2}} + V_v \frac{p_{s2} \hat{M}}{z_{s2} RT_{s2}} + (n_2 - n_1) \hat{M} \quad [4.1]$$

where:

n_1	number of sorbed molecules at the start of the pressure step, lbmoles
n_2	number of sorbed molecules at the end of the pressure step, lbmoles
p_{r1}	initial reference cell pressure
p_{r2}	final reference cell pressure
p_{s1}	initial sample cell pressure
p_{s2}	final sample cell pressure
V_r	reference cell volume
V_v	void volume within the sample cell (includes macroporosity)
\hat{M}	molecular weight
T_{r1}	initial reference cell temperature
T_{r2}	final reference cell temperature
T_{s1}	initial sample cell temperature
T_{s2}	final sample cell temperature
z_{r1}	initial compressibility factor in the reference cell
z_{r2}	final compressibility factor in the reference cell
z_{s1}	initial compressibility factor in the sample cell
z_{s2}	final compressibility factor in the sample cell

Solving for the change in the number of molecules in the sorbed state and eliminating the common molecular weight results in Equation 4.2.

$$n_2 - n_1 = V_r \left(\frac{p_{r1}}{z_{r1} RT_{r1}} - \frac{p_{r2}}{z_{r2} RT_{r2}} \right) + V_v \left(\frac{p_{s1}}{z_{s1} RT_{s1}} - \frac{p_{s2}}{z_{s2} RT_{s2}} \right) \quad [4.2]$$

The void volume is reduced by the volume of the sorbed phase. Therefore, the number of sorbed molecules determined by Equation 10 must be corrected as discussed below.

The number of molecules can be converted to the volume of gas at standard temperature and pressure (STP) with Equation 4.3.

$$V_s = \frac{nz_{sc}RT_{sc}}{p_{sc}} \quad [4.3]$$

where:

V_s sorbed gas volume at STP, ft^3
 z_{sc} real gas deviation factor at STP, dimensionless
 T_{sc} temperature at standard conditions, degrees Rankine
 p_{sc} pressure at standard conditions, psia

For example, 1 lbmole of methane at 14.73 and 60 °F, occupies a volume of 377.8504 scf as z_{sc} is generally 0.998 for methane at these conditions. The gas storage capacity at the stabilized sample cell pressure and temperature is then computed with Equation 4.4 by dividing by the sample mass that was measured before placing the sample in the sample cell.

$$G'_s = \frac{2000V_s}{m_m} \quad [4.4]$$

where:

G'_s Gibbs isotherm gas storage capacity, scf/ton
 m_m material mass, lbm

Note that the material mass is often reported in grams. Grams are converted to lbm by multiplying grams by 2.204622622(10^{-3}). Gas storage capacity in cm^3/g is equal to the gas storage capacity in units of scf/ton divided by 32.036929.

The isotherm determined in this manner is referred to as a Gibbs isotherm due to the simplification assumed by Gibbs during his study of sorption thermodynamics. The resulting Gibbs isotherm can be corrected to the true adsorption isotherm through the use of Equation 4.5. The free gas density is computed in the normal fashion at the stabilized sample cell end point pressure and temperature conditions. The sorbed phase density is assumed to be equal to the liquid density of the molecules of interest at the atmospheric pressure boiling point.

$$G_s = \frac{G'_s}{1 - \frac{\rho_f}{\rho_s}} \quad [4.5]$$

where:

G'_s Gibb's isotherm storage capacity, scf/ton
 G_s total isotherm storage capacity, scf/ton
 ρ_f free gas density, lbm/ft^3
 ρ_s sorbed gas density, lbm/ft^3

Adsorption isotherm data are critical because isotherm behavior indicates the ultimate gas recovery that can be obtained at a specific reservoir pressure. The gas storage capacity of coal typically increases non-linearly as pressure increases and decreases as temperature, moisture, and ash content increase. Gas storage capacity also varies as a function of the type of gas species, shale kerogen composition, and organic material thermal maturity.

The Langmuir equation (Equation 4.6) was used to model the variation of gas storage capacity as a function of pressure.²

$$G_s = G_{sL} \frac{P}{p + p_L} \quad [4.6]$$

where:

G_s gas storage capacity, scf/ton
 p_L Langmuir pressure, psia
 G_{sL} Langmuir storage capacity, scf/ton
 p_R Mid-point reservoir pressure, psia

As shown in Equation 4.6 the Langmuir storage capacity and Langmuir pressure are required to calculate the gas storage capacity using the Langmuir equation. The Langmuir storage capacity is the gas storage capacity of the sample at infinite pressure and the Langmuir pressure is the pressure at which the gas storage capacity of the sample equals one-half the Langmuir storage capacity value.

3.5.1.1 Holt 1-19 (Sample ISO052-2)

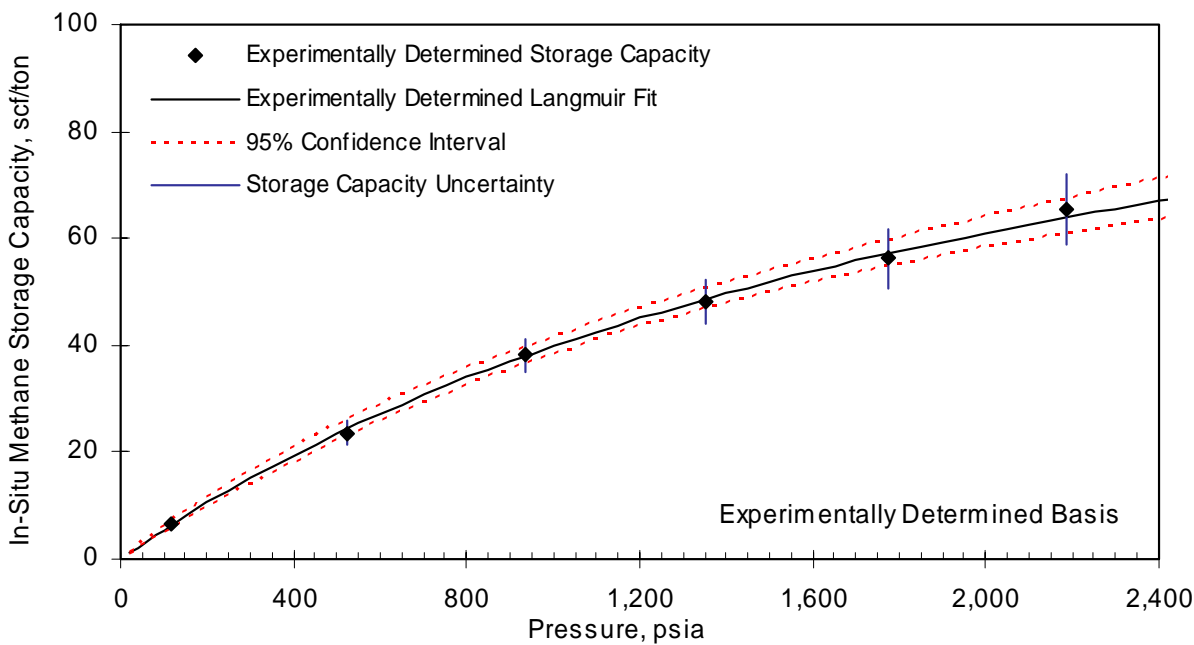
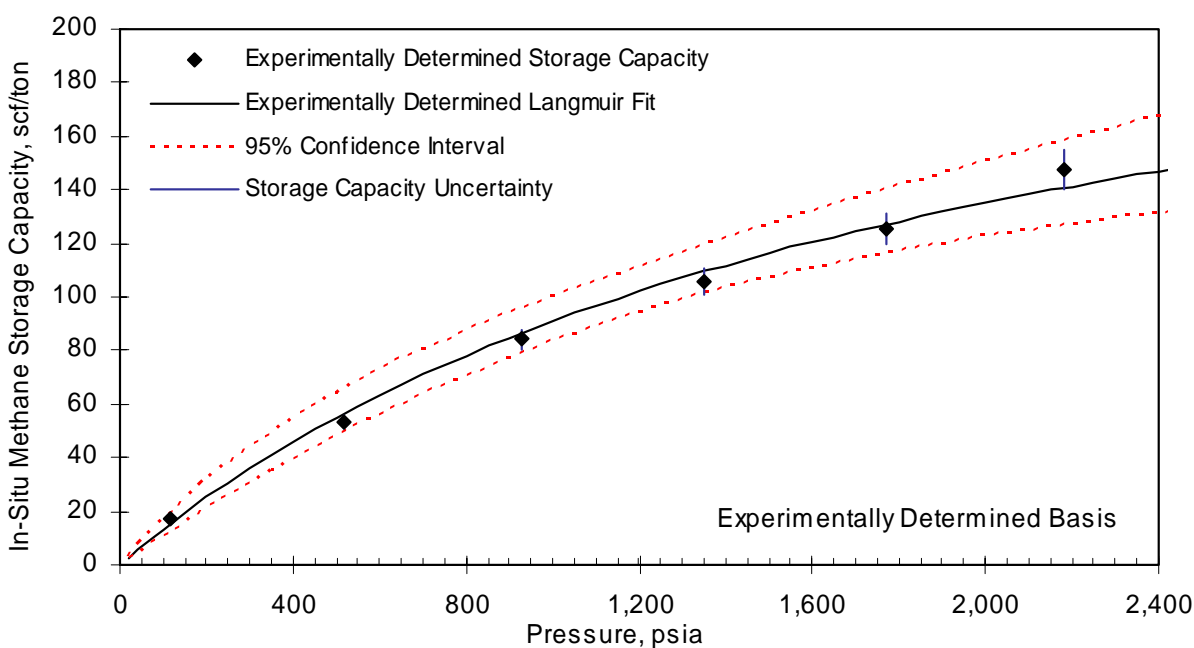
Adsorption isotherm data were used to estimate methane storage capacity (i.e. assuming sorbed gas is 100% methane) for core sample ISO052-2, the Langmuir model predicts an air-dry based methane storage capacity of 53.94 scf/ton at an initial reservoir pressure of 1,602.75 psia (based on a 0.433 psi/ft pressure gradient). Langmuir and gas storage parameters have been summarized in Table 3-3. Gas storage capacity data for sample ISO052-2 are illustrated in Figure 3-5.

3.5.1.2 EFU 9-41 (Sample ISO052-7)

Adsorption isotherm data were used to estimate methane storage capacity (i.e. assuming sorbed gas is 100% methane) for core sample ISO052-7, the Langmuir model predicts an air-dry based methane storage capacity of 115.53 scf/ton at an initial reservoir pressure of 1,481.51 psia (based on a 0.433 psi/ft pressure gradient). Langmuir and gas storage parameters have been summarized in Table 3-3. Gas storage capacity data for sample ISO052-7 are illustrated in Figure 3-6.

Table 3-3 Sorption Isotherm Test Parameters and Results

Sample Information			
Well		Holt 1-19	EFU 9-41
Reservoir		Woodford	Woodford
Sample No.		ISO052-2	ISO052-7
Sample Type		Core	Core
Depth (drill depth)	feet	~3,701.8	~3,421.0
Gas Storage Capacity Parameters			
Reservoir Pressure based on 0.433 psi/ft	psia	1,602.75	1,481.51
Measurement Temperature	°F	130.0	130.0
Total Organic Carbon	wt. %	7.09	12.07
Helium Density, (air-dry basis)	g/cm³	2.569	2.337
Adsorbate		Methane	
Langmuir Parameters			
Methane Langmuir Pressure	psia	2,276.15	1,885.97
Methane Langmuir Storage Capacity (100% Kerogen basis)	scf/ton	1,841.28	2,175.66
Methane Langmuir Storage Capacity (air-dry basis)	scf/ton	130.55	262.60
Adsorbed Gas Storage Capacity Results			
Kerogen Adsorbed Storage Capacity at Reservoir Pressure	scf/ton	760.81	957.17
In-Situ Gas Storage Capacity at Reservoir Pressure	scf/ton	53.94	115.53

Figure 3-5 Adsorbed Gas Storage Capacity for ISO052-2**Figure 3-6 Adsorbed Gas Storage Capacity for ISO052-7**

3.5.2 Total Gas Storage Capacity

The total gas storage capacity is the sum of the adsorbed gas storage capacity, the free gas storage capacity of the macro-porosity containing both free and dissolved gas components, and the free gas storage capacity within natural fractures. Equation 4.7 lists this relationship. This section discusses the range in these possible volumes ignoring the negligible contribution from the natural fracture system.

$$G_{st} = G_s + G_{sf} + G_{sd} \quad [4.7]$$

where:

G_{st} total gas storage capacity, scf/ton
 G_s sorbed gas storage capacity, scf/ton
 G_{sf} free gas storage capacity, scf/ton
 G_{sd} dissolved gas storage capacity, scf/ton

The special core analysis data are useful for estimating the proportion of the total gas content that is the result of free gas within the macropore system. Equation 4.8 can be used for this purpose.⁴

$$G_{cf} = \frac{32.0368\phi(1 - S_w)}{\bar{\rho}B_g} \quad [4.8]$$

where:

G_{cf} gas content of the free gas phase, scf/ton
 ϕ macroporosity, fraction of bulk volume
 S_w water saturation within macroporosity, fraction of macroporosity
 $\bar{\rho}$ average bulk density, g/cm³
 B_g gas formation volume factor, reservoir volume / surface volume

The gas formation volume factor is defined in the usual manner by Equation 4.9.⁵

$$B_g = \frac{zT}{p} \frac{p_{sc}}{z_{sc}T_{sc}} \quad [4.9]$$

where:

p pressure of interest, psia
 T temperature of interest, °R (°R = °F + 459.67)
 z real gas deviation factor at p and T , dimensionless
 p_{sc} pressure at standard conditions, psia
 T_{sc} temperature at standard conditions, °R
 z_{sc} z factor at standard conditions, dimensionless

In this report, standard conditions are 60°F, and 14.696 psia. The z factor at standard conditions for hydrocarbon gases is usually 0.998.

The free gas was calculated using equation 4.7 for each equilibrium pressure of the methane adsorption isotherm and reflects the volume of methane that can be compressed within the available macropore system (macro-porosity volume minus the volume saturated with reservoir water) of the shale for a given pressure and temperature.

The dissolved gas was computed similarly using equation 4.10 for each equilibrium pressure of the methane adsorption isotherm analysis and represents the volume of methane that can be stored within the reservoir water at a given salinity, pressure and temperature.

Gas is also dissolved in the water contained within the secondary porosity system. Equation 4.10 presents a relationship for this volume⁵.

$$G_{cD} = \frac{5.706\phi S_w R_{sw}}{\bar{\rho} B_w} \quad [4.10]$$

where:

G_{cD}	dissolved gas content, scf/ton
R_{sw}	solution gas-water ratio, scf/STB
B_w	water formation volume factor, reservoir volume / surface volume
ϕ	macroporosity, fraction of bulk volume
S_w	water saturation within macroporosity, fraction of macroporosity
$\bar{\rho}$	average bulk density, g/cm ³

The possible contribution to the total gas storage capacity for adsorbed, free, and dissolved gas components at reservoir conditions is summarized in Table 3-6 (based on 0.433 psi/ft pressure gradient). Since the sorption data may include gas dissolution in hydrocarbons, solution in hydrocarbons is not explicitly included in the calculations. The free gas contribution is highly dependent upon the effective porosity and the water saturation within the effective porosity.

Table 3-4 Total Gas Storage Capacity Estimates

Parameter	Units	ISO052-1	ISO052-2	ISO052-3	ISO052-4	ISO052-5	ISO052-6	ISO052-7	ISO052-8	ISO052-9
Effective porosity	vol. fraction	N/A	0.0585	0.0371	0.031	0.0529	0.0672	0.0953	0.0619	0.0722
Water saturation	vol. fraction	N/A	0.4345	0.6117	0.8096	0.7478	0.5478	0.3434	0.5685	0.3735
Bulk density	g/cm ³	2.754	2.473	2.396	2.191	2.213	2.019	2.123	2.245	2.282
Reservoir pressure	psia	1601.9	1602.9	1605.5	1463.4	1465.7	1468.3	1481.3	2326.5	2328.2
Reservoir temperature	°F	130	130	130	130	130	130	130	130	130
Z _{sc}	dimensionless	0.9980	0.9980	0.9980	0.9980	0.9980	0.9980	0.9980	0.9980	0.9980
Z	dimensionless	0.8969	0.8968	0.8967	0.9025	0.9024	0.9022	0.9017	0.8817	0.8817
Salinity	weight %	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Solution gas-water ratio	scf/STB	9.35	9.35	9.36	8.78	8.79	8.80	8.85	12.01	12.02
Water formation volume factor	res.vol/surf.vol	1.0121	1.0121	1.0121	1.0123	1.0123	1.0123	1.0123	1.0112	1.0112
Gas formation volume factor	res.vol/surf.vol	0.0094	0.0093	0.0093	0.0103	0.0103	0.0103	0.0102	0.0063	0.0063
Adsorbed gas storage capacity	scf/ton	N/D	53.94	N/D	N/D	N/D	N/D	115.53	N/D	N/D
Free gas storage capacity	scf/ton	N/A	45.84	20.64	8.38	18.78	46.96	92.84	60.19	100.35
Dissolved gas capacity	scf/ton	N/A	0.54	0.50	0.57	0.89	0.90	0.77	1.06	0.80
Total gas storage capacity	scf/ton	N/A	100.32	21.14¹	8.94¹	19.66¹	47.87¹	209.14	61.25¹	101.16¹

1. Total gas storage capacity does not include adsorbed gas storage capacity.

4.0 REFERENCES

1. McLennan, J.D., Schafer, P.S., and Pratt, T.J.: *A Guide to Determining Coalbed Gas Content*, Gas Research Institute Report GRI-94/0393, Chicago, IL (1995), 182p.
2. Mavor, M.J. and Nelson, C.R.: *Coalbed Reservoir Gas-In-Place Analysis*, Gas Research Institute Report GRI-97/0263, Chicago, IL (1997), 144 p.
3. *2001 Annual Book of ASTM Standards, Volume 05.05 Gaseous Fuels; Coal and Coke*, American Society for Testing and Materials, Philadelphia, PA (2001).
4. Mavor, M.J., Bereskihn, S.R., Robinson, J.R., and Pratt, T.J.: *Lewis Shale Gas Resource and Production Potential*, Gas Research Institute, Report No. GRI-03/0037, Chicago, IL (March 2003) pp. 4-47
5. Whitson, C.H. and Brule, M.R.: *Phase Behavior*, Monograph Volume 20, Henry L. Doherty Series, Society of Petroleum Engineers, Richardson, TX (2000) p. 20.

Appendix I

Ascent Energy, Inc
Holt 1-19, MFY 5-17, EFU 9-41,
& Kirby Gilbreth 1-20

Grain Density

TICORA Geosciences, Inc



Multipycnometer Helium Density Summary
True Powder Density

TICORA No.: 362

Client: Ascent Energy

Well Name: Shale Assessment wells

Dates Performed: 12/10/04-14/10/04

Sample No.	Depth feet	Density, g/cm ³			Standard Deviation	Mean Density g/cm ³
		A	B	C		
52-1	3,699.60	2.472	2.481	2.486	0.007	2.480
52-2	3,701.80	2.564	2.572	2.571	0.004	2.569
52-3	3,707.80	2.488	2.491	2.494	0.003	2.491
52-4	3,379.60	2.220	2.226	2.221	0.003	2.222
052-5	3,385.00	2.276	2.274	2.274	0.001	2.275
052-6	3,391.10	2.083	2.085	2.083	0.001	2.084
052-7	3,421.00	2.221	2.231	2.231	0.006	2.228
052-8	5,373.00	2.335	2.336	2.339	0.002	2.337
052-9	5,376.80	2.339	2.342	2.342	0.002	2.341



Multipycnometer Helium Density Work Sheet True Powder Density

<p>Ticora No.: <u>ISO052</u></p> <p>Client: <u>#N/A</u></p> <p>Well Name: <u>#N/A</u></p> <p>Sample No.: <u>52-1-A</u></p> <p>Depth Interval (feet): <u>0.00</u></p> <p>Sample Description: <u>Crushed</u></p> <p>Outgassing Conditions: <u>Purged for 2-minutes at 1.5 psi</u></p>	<p>Operator: <u>MAW</u></p> <p>Pycnometer: <u>2</u></p> <p>Date: <u>10/12/04</u></p> <p>Time Start: <u>14:00</u></p> <p>Time Finish: <u>14:20</u></p> <p>Ambient Temperature (°F): <u>69.0</u></p>
---	--

<p>Cell Size: <u>Large (covered)</u></p> <p>Cell Weight, grams: <u>25.201</u></p> <p>Sample + Cell, grams: <u>124.516</u></p> <p>Sample Weight, grams: <u>99.315</u></p>	<p>Reference Volume (V_R), cm^3: <u>79.661</u></p> <p>Cell Volume (V_c), cm^3: <u>147.134</u></p>
--	---

DATA	
P_1	<u>17.033</u>
P_2	<u>7.271</u>
V_s	<u>40.182</u>
Sample Density (D_s), g/cm^3	<u>2.472</u>

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm^3/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm^3)

V_c = Volume of Sample Cell (cm^3)

V_R = Reference Volume (cm^3)

P_1 = Pressure of Reference Volume

P_2 = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/12/04
Sample No.:	52-1-B	Time Start:	14:00
Depth Interval (feet):	0.00	Time Finish:	14:20
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V_R), cm^3 :	79.661
Cell Weight, grams:	25.201	Cell Volume (V_c), cm^3 :	147.134
Sample + Cell, grams:	124.516		
Sample Weight, grams:	99.315		

DATA	
P_1	17.052
P_2	7.273
V_s	40.025
Sample Density (D_s), g/cm^3	2.481

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm^3/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm^3)

V_c = Volume of Sample Cell (cm^3)

V_R = Reference Volume (cm^3)

P_1 = Pressure of Reference Volume

P_2 = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/12/04
Sample No.:	52-1-C	Time Start:	14:00
Depth Interval (feet):	0.00	Time Finish:	14:20
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.661
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.134
Sample + Cell, grams:	124.516		
Sample Weight, grams:	99.315		

DATA	
P ₁	17.063
P ₂	7.275
V _s	39.956
Sample Density (D _s), g/cm ³	2.486

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D _s = Sample Density (cm ³ /g)	V _R = Reference Volume (cm ³)
M _s = Sample Weight (g)	P ₁ = Pressure of Reference Volume
V _s = Sample Volume (cm ³)	P ₂ = Pressure of System
V _c = Volume of Sample Cell (cm ³)	



Multipycnometer Helium Density Work Sheet True Powder Density

<p>Ticora No.: <u>ISO052</u></p> <p>Client: <u>#N/A</u></p> <p>Well Name: <u>#N/A</u></p> <p>Sample No.: <u>52-2-A</u></p> <p>Depth Interval (feet): <u>0.00</u></p> <p>Sample Description: <u>Crushed</u></p> <p>Outgassing Conditions: <u>Purged for 2-minutes at 1.5 psi</u></p>	<p>Operator: <u>MAW</u></p> <p>Pycnometer: <u>2</u></p> <p>Date: <u>10/12/04</u></p> <p>Time Start: <u>15:30</u></p> <p>Time Finish: <u>15:50</u></p> <p>Ambient Temperature (°F): <u>70.0</u></p>
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<p>Cell Size: <u>Large (covered)</u></p> <p>Cell Weight, grams: <u>25.204</u></p> <p>Sample + Cell, grams: <u>124.421</u></p> <p>Sample Weight, grams: <u>99.217</u></p>	<p>Reference Volume (V_R), cm^3: <u>79.661</u></p> <p>Cell Volume (V_c), cm^3: <u>147.135</u></p>
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DATA	
P_1	<u>17.058</u>
P_2	<u>7.224</u>
V_s	<u>38.693</u>
Sample Density (D_s), g/cm^3	<u>2.564</u>

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s / V_s$$

D_s = Sample Density (cm^3/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm^3)

V_c = Volume of Sample Cell (cm^3)

V_R = Reference Volume (cm^3)

P_1 = Pressure of Reference Volume

P_2 = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/12/04
Sample No.:	52-2-B	Time Start:	15:30
Depth Interval (feet):	0.00	Time Finish:	15:50
Sample Description:	Crushed	Ambient Temperature (°F):	70.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.661
Cell Weight, grams:	25.204	Cell Volume (V _c), cm ³ :	147.135
Sample + Cell, grams:	124.421		
Sample Weight, grams:	99.217		

DATA	
P ₁	17.040
P ₂	7.212
V _s	38.579
Sample Density (D _s), g/cm ³	2.572

OPERATIONAL EQUATIONS

$$V_S = V_c - V_R((P_1/P_2) - 1)$$

$$D_S = M_S/V_S$$

D_S = Sample Density (cm³/g)

M_S = Sample Weight (g)

V_S = Sample Volume (cm³)

V_c = Volume of Sample Cell (cm³)

V_R = Reference Volume (cm³)

P₁ = Pressure of Reference Volume

P₂ = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/12/04
Sample No.:	52-2-C	Time Start:	15:30
Depth Interval (feet):	0.00	Time Finish:	15:50
Sample Description:	Crushed	Ambient Temperature (°F):	70.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.661
Cell Weight, grams:	25.204	Cell Volume (V _c), cm ³ :	147.135
Sample + Cell, grams:	124.421		
Sample Weight, grams:	99.217		

DATA	
P ₁	17.238
P ₂	7.296
V _s	38.584
Sample Density (D _s), g/cm ³	2.571

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm³/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm³)

V_c = Volume of Sample Cell (cm³)

V_R = Reference Volume (cm³)

P₁ = Pressure of Reference Volume

P₂ = Pressure of System



Multipycnometer Helium Density Work Sheet True Powder Density

<p>Ticora No.: <u>ISO052</u></p> <p>Client: <u>#N/A</u></p> <p>Well Name: <u>#N/A</u></p> <p>Sample No.: <u>52-3-A</u></p> <p>Depth Interval (feet): <u>0.00</u></p> <p>Sample Description: <u>Crushed</u></p> <p>Outgassing Conditions: <u>Purged for 2-minutes at 1.5 psi</u></p>	<p>Operator: <u>MAW</u></p> <p>Pycnometer: <u>2</u></p> <p>Date: <u>10/12/04</u></p> <p>Time Start: <u>16:00</u></p> <p>Time Finish: <u>16:20</u></p> <p>Ambient Temperature (°F): <u>70.0</u></p>
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<p>Cell Size: <u>Large (covered)</u></p> <p>Cell Weight, grams: <u>25.204</u></p> <p>Sample + Cell, grams: <u>124.713</u></p> <p>Sample Weight, grams: <u>99.509</u></p>	<p>Reference Volume (V_R), cm^3: <u>79.661</u></p> <p>Cell Volume (V_c), cm^3: <u>147.135</u></p>
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DATA	
P_1	<u>17.076</u>
P_2	<u>7.282</u>
V_s	<u>39.994</u>
Sample Density (D_s), g/cm^3	<u>2.488</u>

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm^3/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm^3)

V_c = Volume of Sample Cell (cm^3)

V_R = Reference Volume (cm^3)

P_1 = Pressure of Reference Volume

P_2 = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/12/04
Sample No.:	52-3-B	Time Start:	16:00
Depth Interval (feet):	0.00	Time Finish:	16:20
Sample Description:	Crushed	Ambient Temperature (°F):	70.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.661
Cell Weight, grams:	25.204	Cell Volume (V _c), cm ³ :	147.135
Sample + Cell, grams:	124.713		
Sample Weight, grams:	99.509		

DATA	
P ₁	17.061
P ₂	7.274
V _s	39.953
Sample Density (D _s), g/cm ³	2.491

OPERATIONAL EQUATIONS

$$V_S = V_c - V_R((P_1/P_2) - 1)$$

$$D_S = M_S/V_S$$

D_S = Sample Density (cm³/g)

M_S = Sample Weight (g)

V_S = Sample Volume (cm³)

V_c = Volume of Sample Cell (cm³)

V_R = Reference Volume (cm³)

P₁ = Pressure of Reference Volume

P₂ = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/12/04
Sample No.:	52-3-C	Time Start:	16:00
Depth Interval (feet):	0.00	Time Finish:	16:20
Sample Description:	Crushed	Ambient Temperature (°F):	70.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V_R), cm^3 :	79.661
Cell Weight, grams:	25.204	Cell Volume (V_c), cm^3 :	147.135
Sample + Cell, grams:	124.713		
Sample Weight, grams:	99.509		

DATA	
P_1	17.127
P_2	7.300
V_s	39.898
Sample Density (D_s), g/cm^3	2.494

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm^3/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm^3)

V_c = Volume of Sample Cell (cm^3)

V_R = Reference Volume (cm^3)

P_1 = Pressure of Reference Volume

P_2 = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/12/04
Sample No.:	52-4-A	Time Start:	16:25
Depth Interval (feet):	0.00	Time Finish:	16:47
Sample Description:	Crushed	Ambient Temperature (°F):	70.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.661
Cell Weight, grams:	25.204	Cell Volume (V _c), cm ³ :	147.135
Sample + Cell, grams:	122.412		
Sample Weight, grams:	97.208		

DATA	
P ₁	17.288
P ₂	7.525
V _s	43.782
Sample Density (D _s), g/cm ³	2.220

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm³/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm³)

V_c = Volume of Sample Cell (cm³)

V_R = Reference Volume (cm³)

P₁ = Pressure of Reference Volume

P₂ = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/12/04
Sample No.:	52-4-B	Time Start:	16:25
Depth Interval (feet):	0.00	Time Finish:	16:47
Sample Description:	Crushed	Ambient Temperature (°F):	70.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.661
Cell Weight, grams:	25.204	Cell Volume (V _c), cm ³ :	147.135
Sample + Cell, grams:	122.412		
Sample Weight, grams:	97.208		

DATA	
P ₁	17.206
P ₂	7.485
V _s	43.677
Sample Density (D _s), g/cm ³	2.226

OPERATIONAL EQUATIONS

$$V_S = V_c - V_R((P_1/P_2) - 1)$$

$$D_S = M_S/V_S$$

D _S = Sample Density (cm ³ /g)	V _R = Reference Volume (cm ³)
M _S = Sample Weight (g)	P ₁ = Pressure of Reference Volume
V _S = Sample Volume (cm ³)	P ₂ = Pressure of System
V _c = Volume of Sample Cell (cm ³)	



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/12/04
Sample No.:	52-4-C	Time Start:	16:25
Depth Interval (feet):	0.00	Time Finish:	16:47
Sample Description:	Crushed	Ambient Temperature (°F):	70.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.661
Cell Weight, grams:	25.204	Cell Volume (V _c), cm ³ :	147.135
Sample + Cell, grams:	122.412		
Sample Weight, grams:	97.208		

DATA	
P ₁	17.228
P ₂	7.498
V _s	43.761
Sample Density (D _s), g/cm ³	2.221

OPERATIONAL EQUATIONS

$$V_S = V_c - V_R((P_1/P_2) - 1)$$

$$D_S = M_S/V_S$$

D _S = Sample Density (cm ³ /g)	V _R = Reference Volume (cm ³)
M _S = Sample Weight (g)	P ₁ = Pressure of Reference Volume
V _S = Sample Volume (cm ³)	P ₂ = Pressure of System
V _c = Volume of Sample Cell (cm ³)	



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/13/04
Sample No.:	052-5-A	Time Start:	10:40
Depth Interval (feet):	0.00	Time Finish:	11:00
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.661
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.054
Sample + Cell, grams:	124.277		
Sample Weight, grams:	99.076		

DATA	
P ₁	17.098
P ₂	7.435
V _s	43.521
Sample Density (D _s), g/cm ³	2.276

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm³/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm³)

V_c = Volume of Sample Cell (cm³)

V_R = Reference Volume (cm³)

P₁ = Pressure of Reference Volume

P₂ = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/13/04
Sample No.:	052-5-B	Time Start:	10:40
Depth Interval (feet):	0.00	Time Finish:	11:00
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.661
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.054
Sample + Cell, grams:	124.277		
Sample Weight, grams:	99.076		

DATA	
P ₁	17.022
P ₂	7.404
V _s	43.572
Sample Density (D _s), g/cm ³	2.274

OPERATIONAL EQUATIONS

$$V_S = V_c - V_R((P_1/P_2) - 1)$$

$$D_S = M_S/V_S$$

D _S = Sample Density (cm ³ /g)	V _R = Reference Volume (cm ³)
M _S = Sample Weight (g)	P ₁ = Pressure of Reference Volume
V _S = Sample Volume (cm ³)	P ₂ = Pressure of System
V _c = Volume of Sample Cell (cm ³)	



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/13/04
Sample No.:	052-5-C	Time Start:	10:40
Depth Interval (feet):	0.00	Time Finish:	11:00
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V_R), cm^3 :	79.661
Cell Weight, grams:	25.201	Cell Volume (V_c), cm^3 :	147.054
Sample + Cell, grams:	124.277		
Sample Weight, grams:	99.076		

DATA	
P_1	17.009
P_2	7.398
V_s	43.564
Sample Density (D_s), g/cm^3	2.274

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm^3/g)	V_R = Reference Volume (cm^3)
M_s = Sample Weight (g)	P_1 = Pressure of Reference Volume
V_s = Sample Volume (cm^3)	P_2 = Pressure of System
V_c = Volume of Sample Cell (cm^3)	



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-6-A	Time Start:	14:25
Depth Interval (feet):	0.00	Time Finish:	14:55
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.773
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.181
Sample + Cell, grams:	124.264		
Sample Weight, grams:	99.063		

DATA	
P ₁	17.094
P ₂	7.601
V _s	47.551
Sample Density (D _s), g/cm ³	2.083

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm³/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm³)

V_c = Volume of Sample Cell (cm³)

V_R = Reference Volume (cm³)

P₁ = Pressure of Reference Volume

P₂ = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-6-B	Time Start:	14:25
Depth Interval (feet):	0.00	Time Finish:	14:55
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V_R), cm^3 :	79.773
Cell Weight, grams:	25.201	Cell Volume (V_c), cm^3 :	147.181
Sample + Cell, grams:	124.264		
Sample Weight, grams:	99.063		

DATA	
P_1	17.112
P_2	7.607
V_s	47.504
Sample Density (D_s), g/cm^3	2.085

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm^3/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm^3)

V_c = Volume of Sample Cell (cm^3)

V_R = Reference Volume (cm^3)

P_1 = Pressure of Reference Volume

P_2 = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-6-C	Time Start:	14:25
Depth Interval (feet):	0.00	Time Finish:	14:55
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.773
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.181
Sample + Cell, grams:	124.264		
Sample Weight, grams:	99.063		

DATA	
P ₁	17.066
P ₂	7.589
V _s	47.562
Sample Density (D _s), g/cm ³	2.083

OPERATIONAL EQUATIONS

$$V_S = V_c - V_R((P_1/P_2) - 1)$$

$$D_S = M_S/V_S$$

D_S = Sample Density (cm³/g)

M_S = Sample Weight (g)

V_S = Sample Volume (cm³)

V_c = Volume of Sample Cell (cm³)

V_R = Reference Volume (cm³)

P₁ = Pressure of Reference Volume

P₂ = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-7-A	Time Start:	15:00
Depth Interval (feet):	0.00	Time Finish:	15:20
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.773
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.181
Sample + Cell, grams:	124.776		
Sample Weight, grams:	99.575		

DATA	
P ₁	17.107
P ₂	7.493
V _s	44.827
Sample Density (D _s), g/cm ³	2.221

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm³/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm³)

V_c = Volume of Sample Cell (cm³)

V_R = Reference Volume (cm³)

P₁ = Pressure of Reference Volume

P₂ = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-7-B	Time Start:	15:00
Depth Interval (feet):	0.00	Time Finish:	15:20
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.773
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.181
Sample + Cell, grams:	124.776		
Sample Weight, grams:	99.575		

DATA	
P ₁	17.132
P ₂	7.496
V _s	44.634
Sample Density (D _s), g/cm ³	2.231

OPERATIONAL EQUATIONS

$$V_S = V_c - V_R((P_1/P_2) - 1)$$

$$D_S = M_S/V_S$$

D _S = Sample Density (cm ³ /g)	V _R = Reference Volume (cm ³)
M _S = Sample Weight (g)	P ₁ = Pressure of Reference Volume
V _S = Sample Volume (cm ³)	P ₂ = Pressure of System
V _c = Volume of Sample Cell (cm ³)	



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-7-C	Time Start:	15:00
Depth Interval (feet):	0.00	Time Finish:	15:20
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.773
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.181
Sample + Cell, grams:	124.776		
Sample Weight, grams:	99.575		

DATA	
P ₁	17.032
P ₂	7.452
V _s	44.628
Sample Density (D _s), g/cm ³	2.231

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D _s = Sample Density (cm ³ /g)	V _R = Reference Volume (cm ³)
M _s = Sample Weight (g)	P ₁ = Pressure of Reference Volume
V _s = Sample Volume (cm ³)	P ₂ = Pressure of System
V _c = Volume of Sample Cell (cm ³)	



Multipycnometer Helium Density Work Sheet True Powder Density

<p>Ticora No.: <u>ISO052</u></p> <p>Client: <u>#N/A</u></p> <p>Well Name: <u>#N/A</u></p> <p>Sample No.: <u>052-8-A</u></p> <p>Depth Interval (feet): <u>0.00</u></p> <p>Sample Description: <u>Crushed</u></p> <p>Outgassing Conditions: <u>Purged for 2-minutes at 1.5 psi</u></p>	<p>Operator: <u>MAW</u></p> <p>Pycnometer: <u>2</u></p> <p>Date: <u>10/14/04</u></p> <p>Time Start: <u>15:22</u></p> <p>Time Finish: <u>15:46</u></p> <p>Ambient Temperature (°F): <u>69.0</u></p>
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<p>Cell Size: <u>Large (covered)</u></p> <p>Cell Weight, grams: <u>25.201</u></p> <p>Sample + Cell, grams: <u>124.187</u></p> <p>Sample Weight, grams: <u>98.986</u></p>	<p>Reference Volume (V_R), cm^3: <u>79.773</u></p> <p>Cell Volume (V_c), cm^3: <u>147.181</u></p>
--	---

DATA	
P_1	<u>17.136</u>
P_2	<u>7.407</u>
V_s	<u>42.400</u>
Sample Density (D_s), g/cm^3	<u>2.335</u>

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s / V_s$$

D_s = Sample Density (cm^3/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm^3)

V_c = Volume of Sample Cell (cm^3)

V_R = Reference Volume (cm^3)

P_1 = Pressure of Reference Volume

P_2 = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-8-B	Time Start:	15:22
Depth Interval (feet):	0.00	Time Finish:	15:46
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.773
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.181
Sample + Cell, grams:	124.187		
Sample Weight, grams:	98.986		

DATA	
P ₁	17.058
P ₂	7.372
V _s	42.368
Sample Density (D _s), g/cm ³	2.336

OPERATIONAL EQUATIONS

$$V_S = V_c - V_R((P_1/P_2) - 1)$$

$$D_S = M_S / V_S$$

D _S = Sample Density (cm ³ /g)	V _R = Reference Volume (cm ³)
M _S = Sample Weight (g)	P ₁ = Pressure of Reference Volume
V _S = Sample Volume (cm ³)	P ₂ = Pressure of System
V _c = Volume of Sample Cell (cm ³)	



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-8-C	Time Start:	15:22
Depth Interval (feet):	0.00	Time Finish:	15:46
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V_R), cm^3 :	79.773
Cell Weight, grams:	25.201	Cell Volume (V_c), cm^3 :	147.181
Sample + Cell, grams:	124.187		
Sample Weight, grams:	98.986		

DATA	
P_1	17.118
P_2	7.396
V_s	42.320
Sample Density (D_s), g/cm^3	2.339

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm^3/g)	V_R = Reference Volume (cm^3)
M_s = Sample Weight (g)	P_1 = Pressure of Reference Volume
V_s = Sample Volume (cm^3)	P_2 = Pressure of System
V_c = Volume of Sample Cell (cm^3)	



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-9-A	Time Start:	15:47
Depth Interval (feet):	0.00	Time Finish:	16:10
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.773
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.181
Sample + Cell, grams:	124.221		
Sample Weight, grams:	99.020		

DATA	
P ₁	17.160
P ₂	7.415
V _s	42.341
Sample Density (D _s), g/cm ³	2.339

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm³/g)

M_s = Sample Weight (g)

V_s = Sample Volume (cm³)

V_c = Volume of Sample Cell (cm³)

V_R = Reference Volume (cm³)

P₁ = Pressure of Reference Volume

P₂ = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-9-B	Time Start:	15:47
Depth Interval (feet):	0.00	Time Finish:	16:10
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V _R), cm ³ :	79.773
Cell Weight, grams:	25.201	Cell Volume (V _c), cm ³ :	147.181
Sample + Cell, grams:	124.221		
Sample Weight, grams:	99.020		

DATA	
P ₁	17.170
P ₂	7.417
V _s	42.283
Sample Density (D _s), g/cm ³	2.342

OPERATIONAL EQUATIONS

$$V_S = V_c - V_R((P_1/P_2) - 1)$$

$$D_S = M_S/V_S$$

D_S = Sample Density (cm³/g)

M_S = Sample Weight (g)

V_S = Sample Volume (cm³)

V_c = Volume of Sample Cell (cm³)

V_R = Reference Volume (cm³)

P₁ = Pressure of Reference Volume

P₂ = Pressure of System



Multipycnometer Helium Density Work Sheet **True Powder Density**

Ticora No.:	ISO052	Operator:	MAW
Client:	#N/A	Pycnometer:	2
Well Name:	#N/A	Date:	10/14/04
Sample No.:	052-9-C	Time Start:	15:47
Depth Interval (feet):	0.00	Time Finish:	16:10
Sample Description:	Crushed	Ambient Temperature (°F):	69.0
Outgassing Conditions:	Purged for 2-minutes at 1.5 psi		

Cell Size:	Large (covered)	Reference Volume (V_R), cm^3 :	79.773
Cell Weight, grams:	25.201	Cell Volume (V_c), cm^3 :	147.181
Sample + Cell, grams:	124.221		
Sample Weight, grams:	99.020		

DATA	
P_1	17.143
P_2	7.405
V_s	42.275
Sample Density (D_s), g/cm^3	2.342

OPERATIONAL EQUATIONS

$$V_s = V_c - V_R((P_1/P_2) - 1)$$

$$D_s = M_s/V_s$$

D_s = Sample Density (cm^3/g)	V_R = Reference Volume (cm^3)
M_s = Sample Weight (g)	P_1 = Pressure of Reference Volume
V_s = Sample Volume (cm^3)	P_2 = Pressure of System
V_c = Volume of Sample Cell (cm^3)	

Appendix II

Ascent Energy, Inc
Holt 1-19, MFY 5-17, EFU 9-41,
& Kirby Gilbreth 1-20

TOC and Rock Eval Results

Humble Geochemical Services

TOC and ROCK-EVAL DATA REPORT

Ticora Geosciences

HGS No.	Sample Id.	Sample Type	TOC	S1	S2	S3	Tmax (°C)	Cal. %Ro	Meas. %Ro	HI	OI	S2/S3	S1/TOC	PI	Notes	
															Checks	Pyrogram
04-2593-089834	ISO052-1	ground rock	7.86	2.85	9.70	0.42	454	1.01		123	5	23	36	0.23	c	n
04-2593-089835	ISO052-2	ground rock	7.09	2.87	10.34	0.23	438	0.72	0.77	146	3	45	40	0.22		n
04-2593-089836	ISO052-3	ground rock	8.09	2.90	9.59	0.29	443	0.81		119	4	33	36	0.23		n
04-2593-089837	ISO052-4	ground rock	11.28	4.98	64.49	0.69	428	0.54		572	6	93	44	0.07		n
04-2593-089838	ISO052-5	ground rock	11.15	4.88	54.27	0.55	424	0.47		487	5	99	44	0.08		n
04-2593-089839	ISO052-6	ground rock	14.34	7.12	75.88	1.16	422	0.44		529	8	65	50	0.09		n
04-2593-089840	ISO052-7	ground rock	12.07	4.82	59.47	0.81	427	0.53	0.62	493	7	73	40	0.07		n
04-2593-089841	ISO052-8	ground rock	9.48	4.24	45.96	0.69	428	0.54		485	7	67	45	0.08		n
04-2593-089842	ISO052-9	ground rock	9.34	4.66	51.47	0.49	428	0.54		551	5	105	50	0.08	c	n
	362-1	Drill Cuttings	2.55	0.13	1.58	0.76	438	0.72		62	30	2	5	0.08	c	n
	362-2	Drill Cuttings	3.66	0.24	1.04	0.86	436	0.69		28	24	1	7	0.19		n
	362-3	Drill Cuttings	4.19	0.35	2.70	0.61	438	0.72	0.85	64	15	4	8	0.11		n
	362-4	Drill Cuttings	5.91	3.27	31.93	0.27	437	0.71		540	5	118	55	0.09		n
	362-5	Drill Cuttings	5.70	3.40	28.85	0.32	435	0.67	0.67	506	6	90	60	0.11	c	n

Note: "-1" indicates not measured or meaningless ratio

* Tmax data not reliable due to poor S2 peak

TOC = weight percent organic carbon in rock
S1, S2 = mg hydrocarbons per gram of rock
S3 = mg carbon dioxide per gram of rock
Tmax = °C

HI = hydrogen index = $S2 \times 100 / TOC$
OI = oxygen index = $S3 \times 100 / TOC$
S1/TOC = normalized oil content = $S1 \times 100 / TOC$
PI = production index = $S1 / (S1+S2)$
Cal. %Ro = calculated vitrinite reflectance based on Tmax
Measured %Ro = measured vitrinite reflectance

Notes:

c = analysis checked and confirmed

Pyrogram:
n=normal
ltS2sh = low temperature S2 shoulder
ltS2p = low temperature S2 peak
htS2p = high temperature S2 peak
f = flat S2 peak

KEROGEN QUALITY
Ticora Geosciences

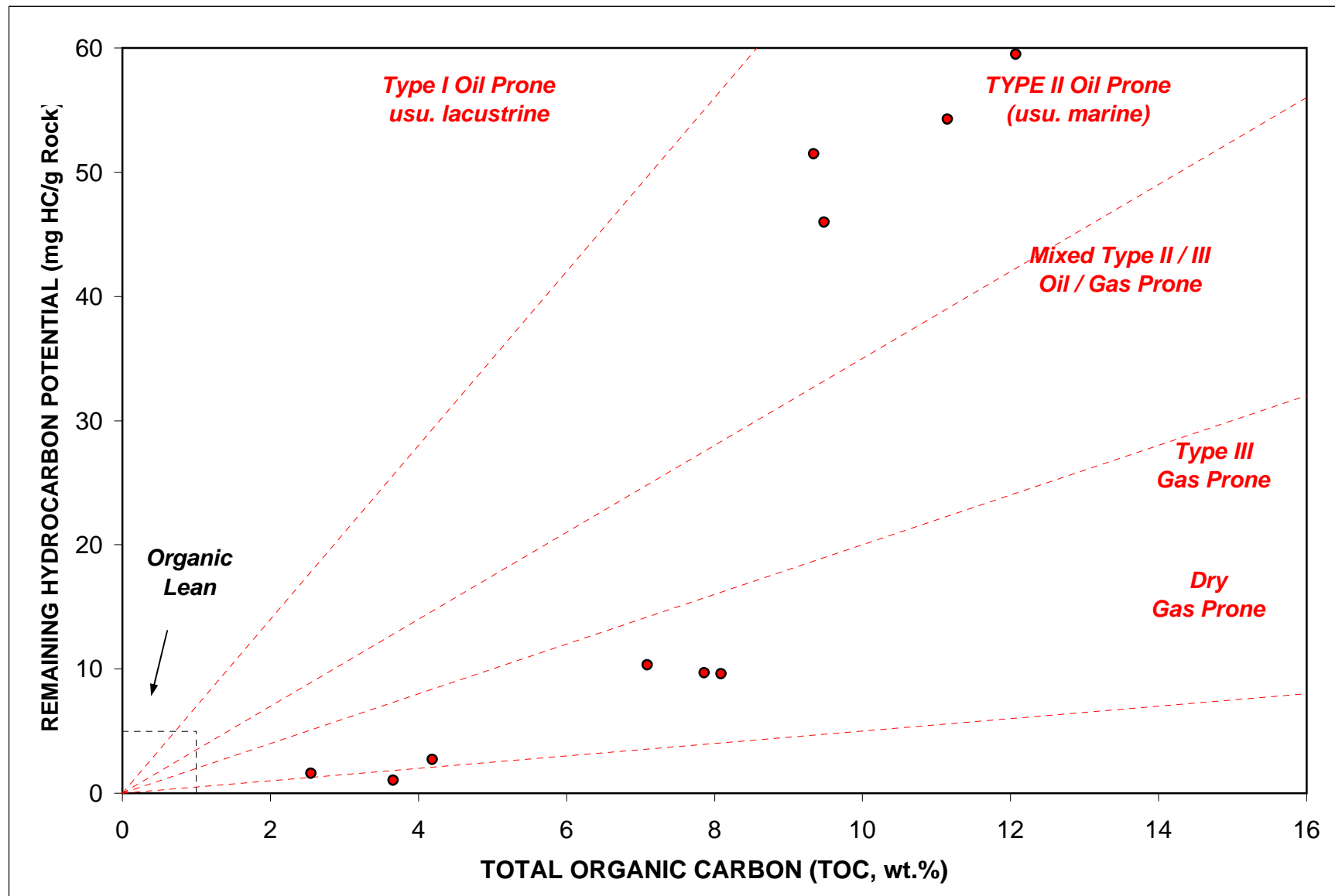


Figure 1. Kerogen Quality

KEROGEN TYPE
Ticora Geosciences

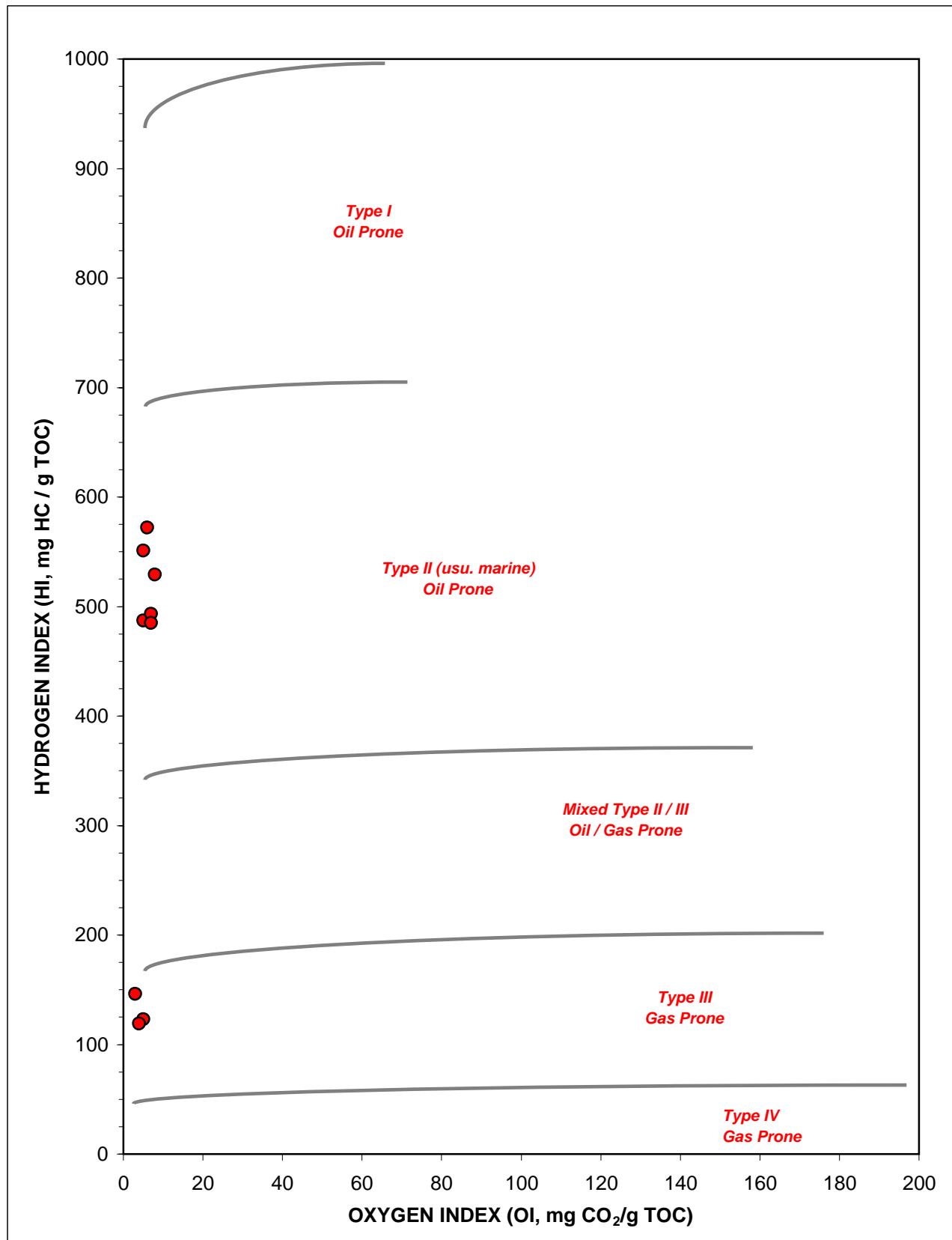


Figure 2. Kerogen type

KEROGEN TYPE and MATURITY

3

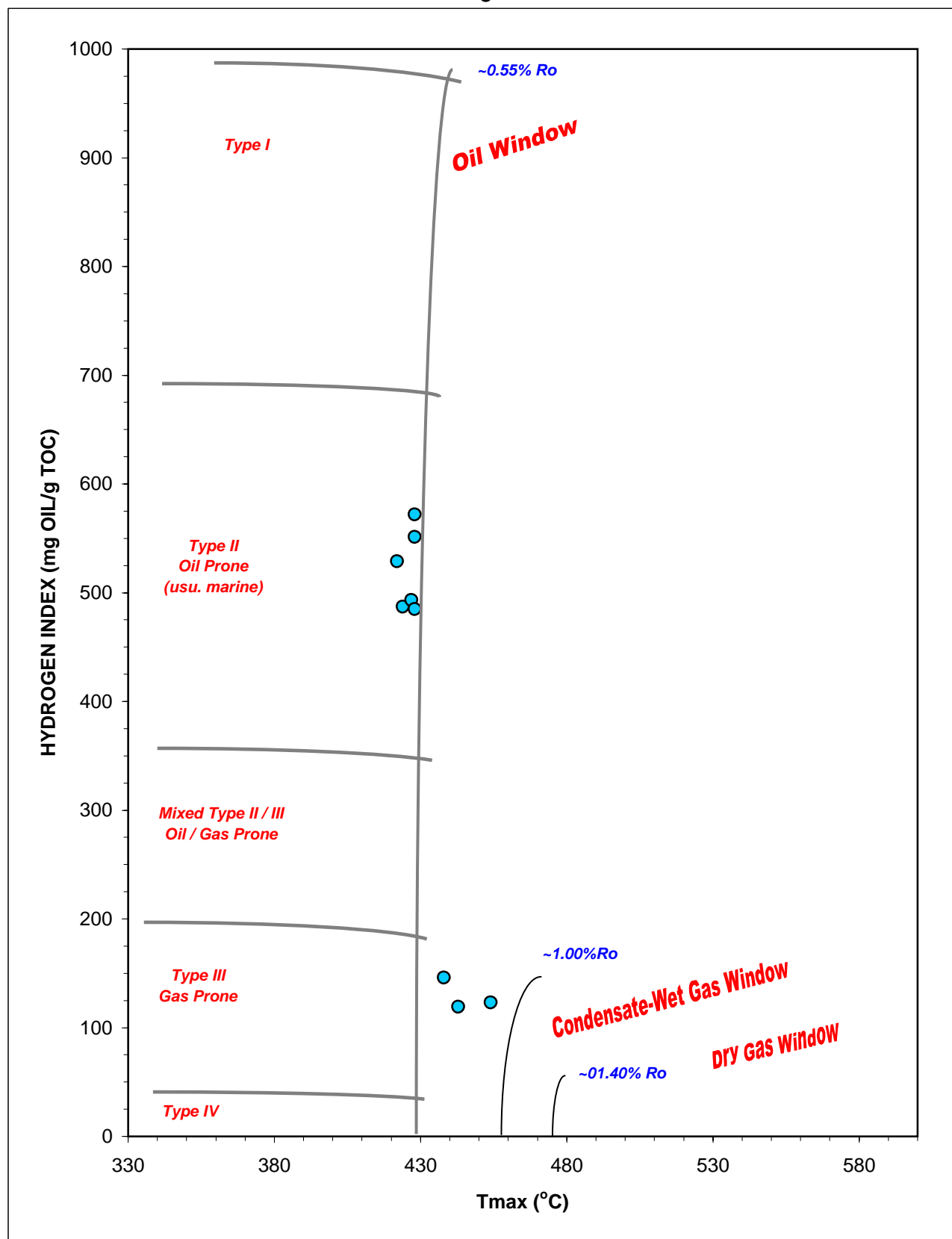


Figure 3a. Kerogen Type and Maturity (Tmax)

Humble Geochemical Services Division

KEROGEN TYPE and MATURITY

Ticora Geosciences

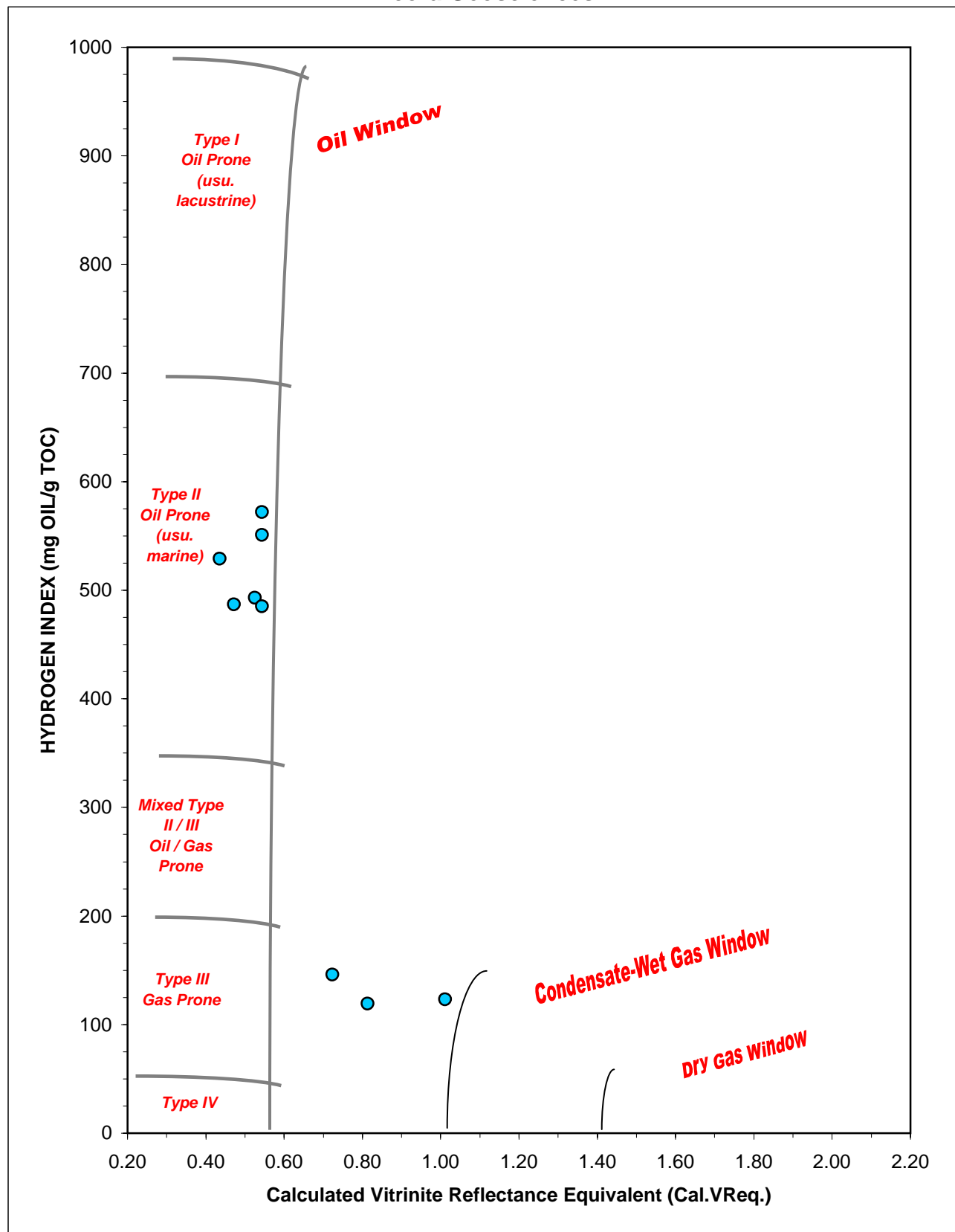


Figure 3b. Kerogen Type and Maturity (Tmax calculated %VRo)

Humble Geochemical Services Division

Ticora Geosciences

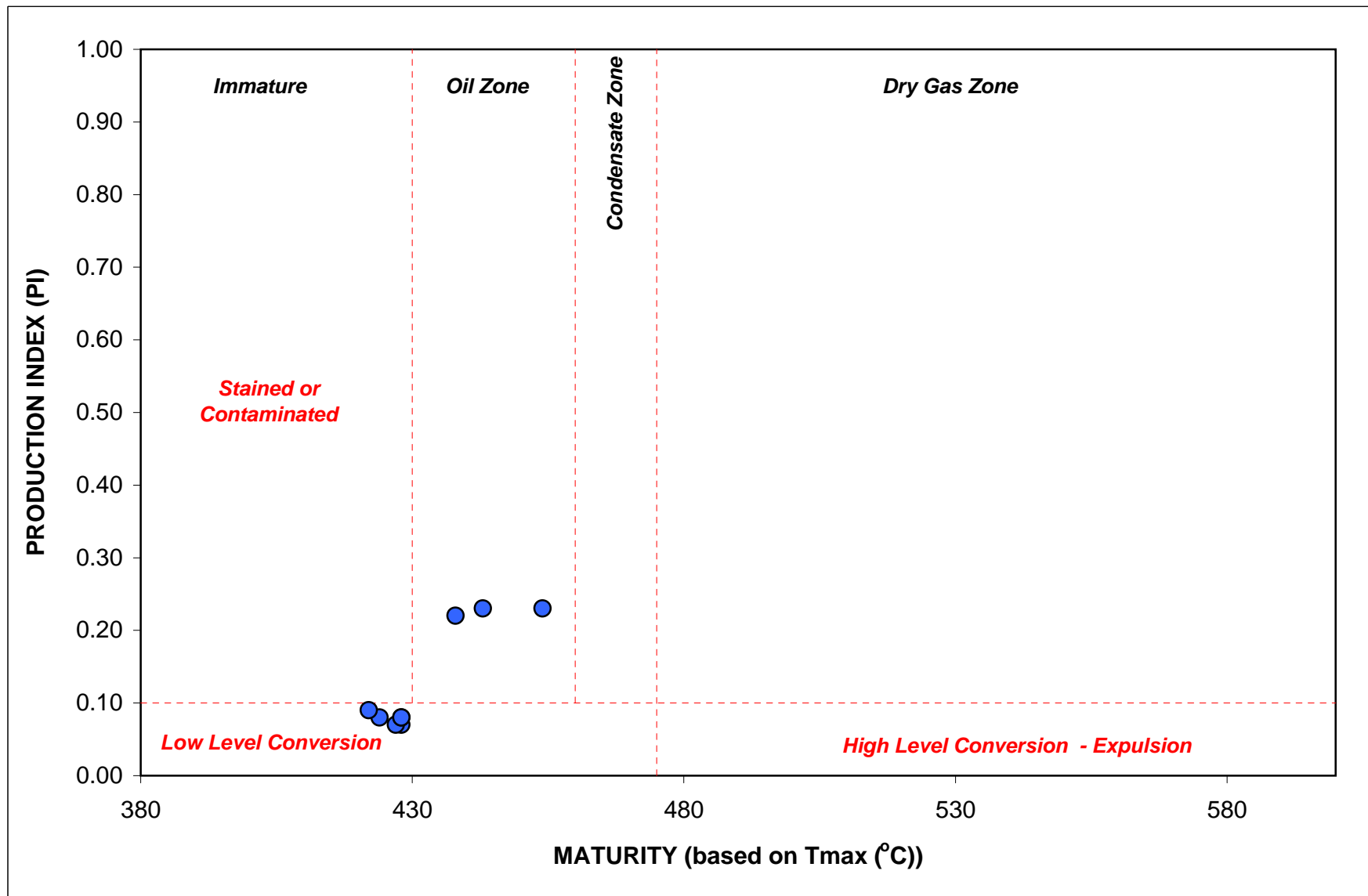


Figure 4a. Kerogen conversion and maturity (based on Tmax).

Ticora Geosciences

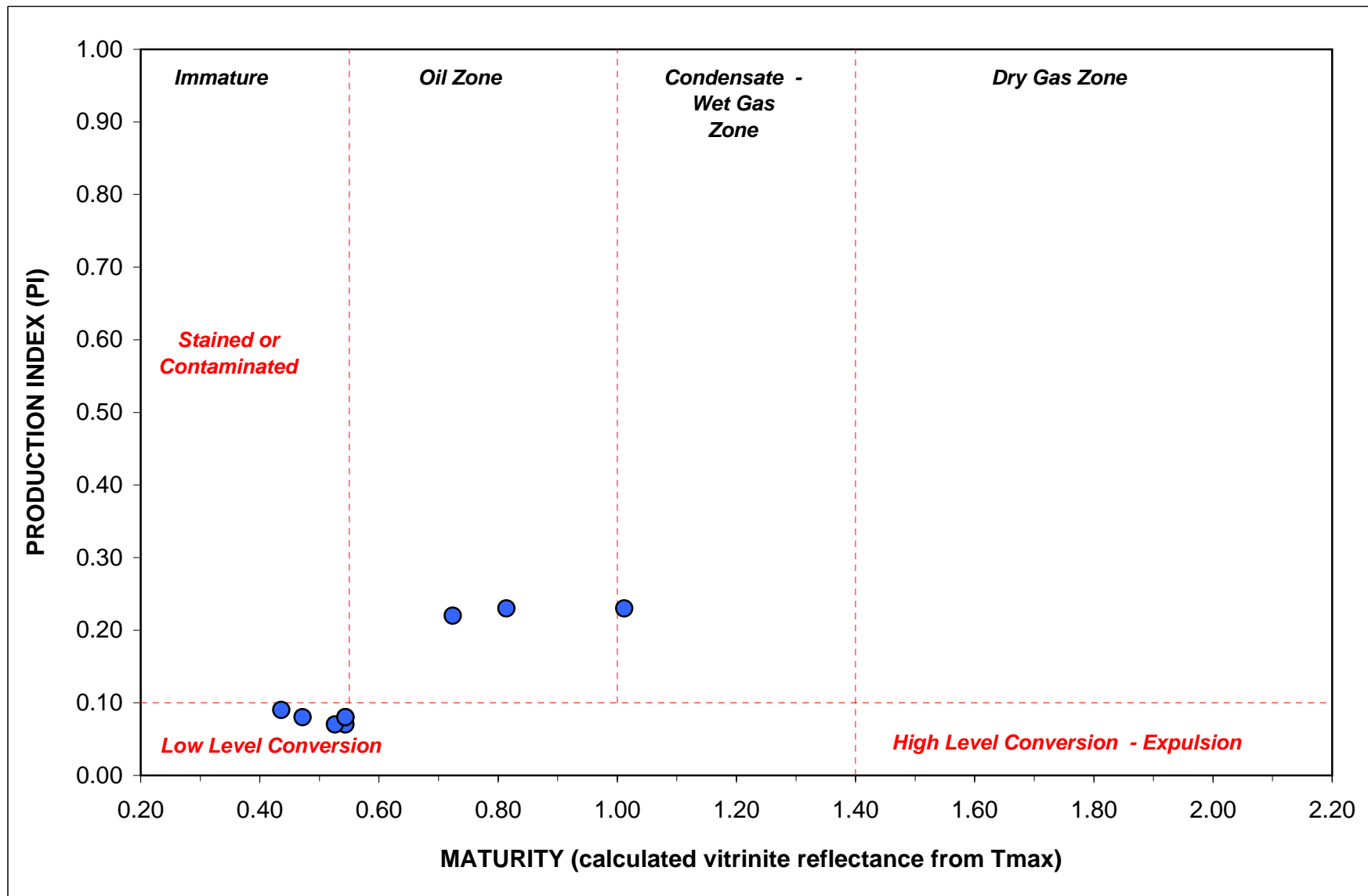


Figure 4b. Kerogen conversion and maturity (calculated %VRo from Tmax).

Appendix III

Ascent Energy, Inc
Holt 1-19, MFY 5-17, EFU 9-41,
& Kirby Gilbreth 1-20

Vitrinite Reflectance

Humble Geochemical Services

Table 1
Thermal Alteration, Kerogen Type, and Palynofacies

CLIENT: Ticora Geosciences
County/State: Pontotoc County, Oklahoma

HGS ID	Well Id.	Depth	Source Quality				Color	TAI	% Source Material							Preservation			Recovery		Palynofacies					Ro Data		Comments
			TOC	S2	Hydrogen Index (HI)	Tmax (°C)			Amorphous Debris	Finely Dissem. OM	Herb. Plant Debris	Woody Plant Debris	Coaly Fragments	Algal Debris	Palynomorphs	GOOD	FAIR	POOR	Very poor	Barren	MARINE	NEARSHORE	CONTINENTAL	LACUSTRINE	UNKNOWN	% OM Fluorescing	Measured Ro (%)	
H04-2576-88243	Jonas #3 (362-3)	3670-3680	4.19	2.70	64	438	YO	2.0	45		45		5	5					x						5	0.85	28	
H04-2576-88245	Chandler #3 (362-5)	3900-3920	5.70	28.85	506	435	YO	1.0	45		40		5	10						x					5	0.67	33	very sparse recovery of kerogen

Color Abbreviations:

GLY Green-Light Yellow
Y Yellow
YO Yellow-Orange
OB Orange-Brown
LB Light Brown

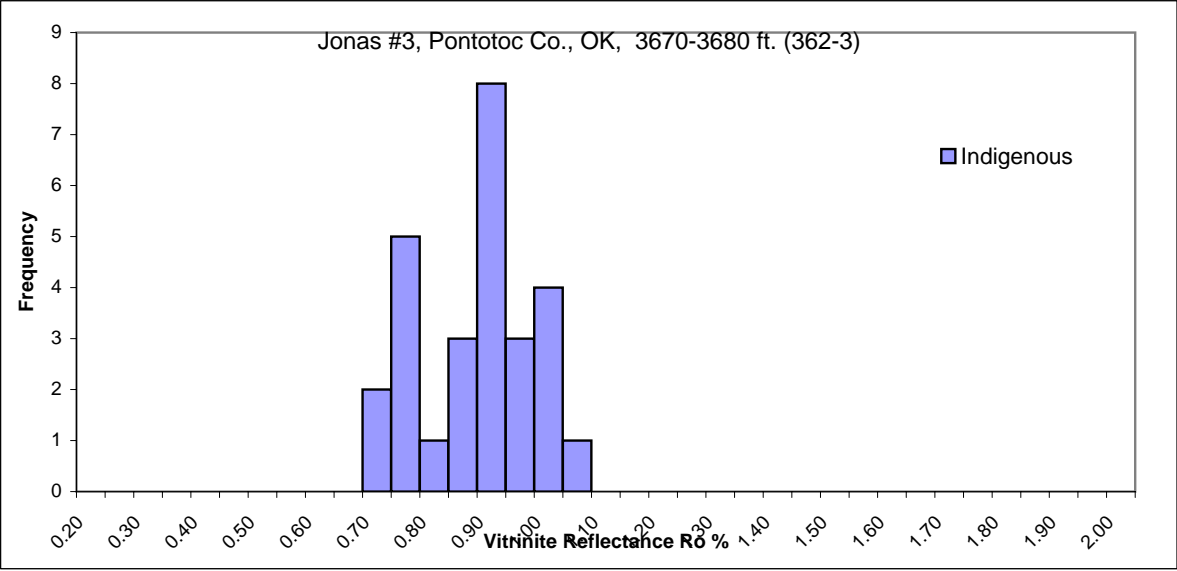
B Brown
DBDG Dark Brown-Dark Gray
DGBL Dark Gray-Black
BLK Black

TAI Scale:

1=Unaltered
1+ or 1.5
2=Slight alteration
2+ or 2.5
3=Moderate alteration
3+ or 3.5
4=Strong alteration
4+ or 4.5
5=Severe alteration

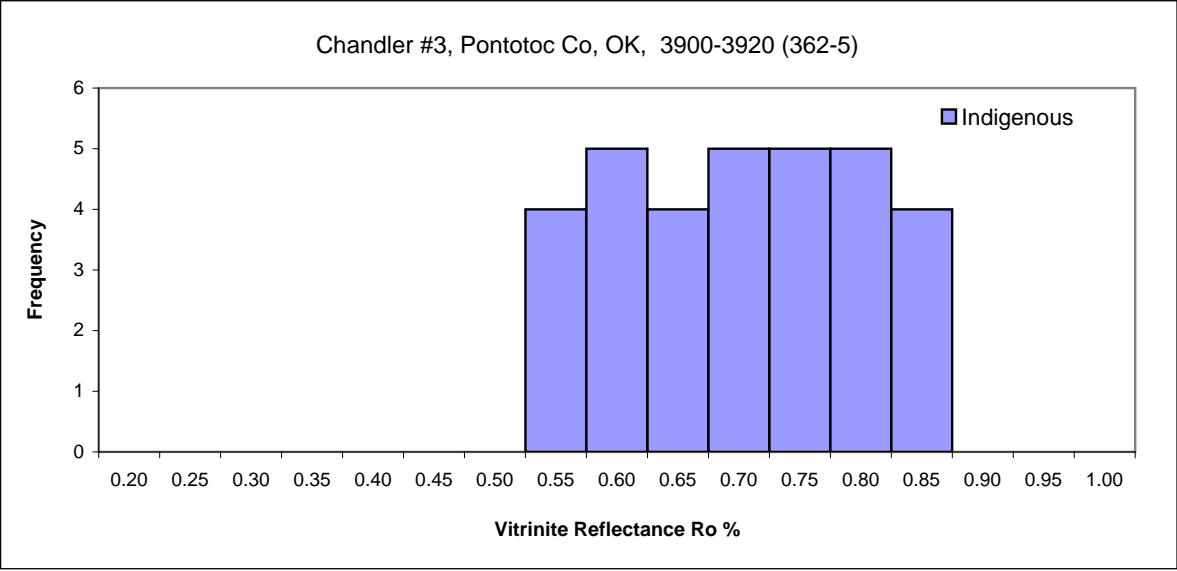
Palynomorph Key:

A = Abundant
C = Common
P = Present
R = Rare
N = None Seen



Indigenous Population Statistics
MEAN: 0.85 MIN: 0.68 MAX: 1.02 STD DEV: 0.10 COUNT: 28

Indigenous	
0.85	0.92
1.02	0.88
0.99	0.90
0.75	0.93
0.98	0.89
0.88	
0.83	
0.97	
0.82	
0.84	
0.76	
0.72	
0.73	
0.96	
0.68	
0.75	
0.72	
0.86	
0.90	
0.86	
0.94	
0.68	
0.90	



Indigenous Population Statistics

MEAN: 0.67 MIN: 0.52 MAX: 0.82 STD DEV: 0.10 COUNT: 33

Indigenous	
0.52	0.60
0.66	0.59
0.52	0.73
0.77	0.71
0.74	0.68
0.54	0.61
0.66	0.81
0.70	0.71
0.81	0.62
0.76	0.63
0.56	
0.62	
0.59	
0.82	
0.76	
0.70	
0.72	
0.80	
0.52	
0.82	
0.53	
0.76	
0.58	

Table 1
Dispersed Organic Matter Thermal Alteration, Kerogen Type and Total Compositional Analysis
TICORA GEOSCIENCES

HGS ID	SAMPLE ID.	Color	TAI	% Source Material							Preservation				Recovery			% Kerogen Comp.							Vitrinite				Comments
				Amorphous Debris	Finely Dissem. OM	Herb. Plant Debris (Vit.)	Woody Plant Debris	Coaly Fragments	Algal Debris	Palynomorphs	Good	Fair	Poor	Very poor	Good	Very Poor	Barren	Indigenous Vitrinite	Caved Vitrinite	Recycled/Oxidized Vitrinite	Inertinite	Solid Bitumen	Drilling Additive/Contamination	Amorphous Kerogen	# of Readings	Total Sample Ro (%)	# of Indigenous Readings	Indigenous Ro (%)	
04-2593-089835	ISO052-2	OB	2.7?	45	45	10				trace?	X	X			X			6	trace	1	3	trace		90	40	0.78	38	0.77	amorph. has oxidized appearance
04-2593-089840	ISO052-7	O	2.3	96	2	1				1	X				X			1	trace	trace	trace	trace		99	40	0.62	39	0.62	spherical palynomorphs=acritarchs?

Color Abbreviations:

GLY Green-Light Yellow
Y Yellow
YO Yellow-Orange
OB Orange-Brown
LB Light Brown

B Brown
DBDG Dark Brown-Dark Gray
DGBL Dark Gray-Black
BLK Black

TAI Scale: 1=Unaltered
1+ or 1.5
2=Slight alteration
2+ or 2.5
3=Moderate alteration

3+ or 3.5
4=Strong alteration
4+ or 4.5
5=Severe alteration

Table 2. Kerogen Fluorescence colors and brightness intensities (subjective determinations)

TICORA GEOSCIENCES

0 = No fluorescence noted

1 = very low intensity

2 = low intensity

3 = medium intensity

4 = high intensity

5 = very high intensity

G = Green

Y = Yellow

O = Orange

B = Brown

HGS ID	SAMPLE ID.	Pollen/Spores				Amorphous				Mounting Medium			
		G	Y	O	B	G	Y	O	B	G	Y	O	B
04-2593-089835	ISO052-2			1	1	0	0	0	0	1			
04-2593-089840	ISO052-7		5	3			3	2		1			

Table 3. Pyrite types and abundance in kerogen

TICORA GEOSCIENCES

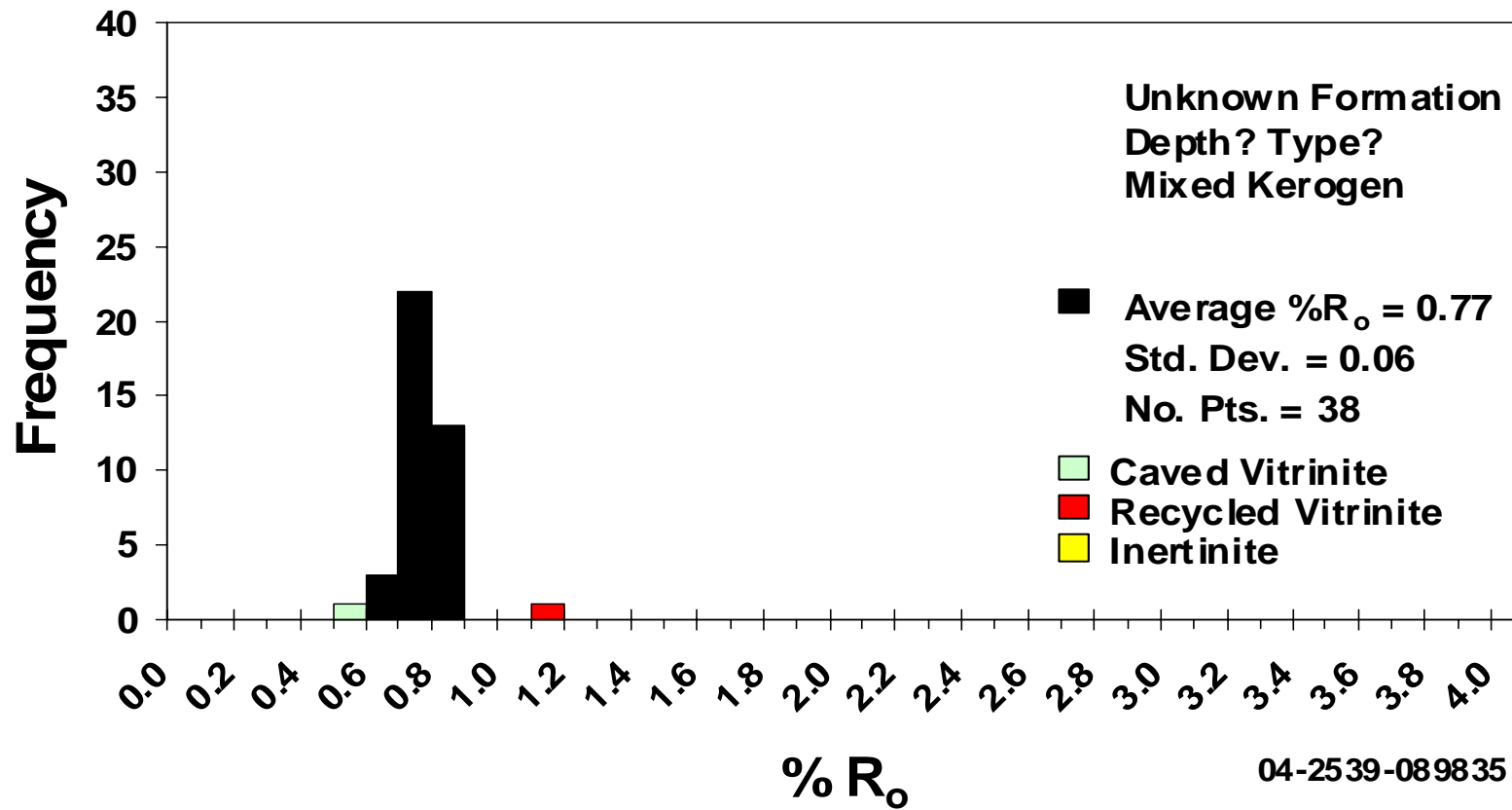
1 = very rare 2 = rare 3 = common 4 = abundant 5 = very abundant				
HGS ID	SAMPLE ID.	Pyrite types		
		Finely Disseminated	Euhedral	Framboidal
04-2593-089835	ISO052-2	3	1	1
04-2593-089840	ISO052-7	3	4	4

Table 4. Individual Reflectance Readings

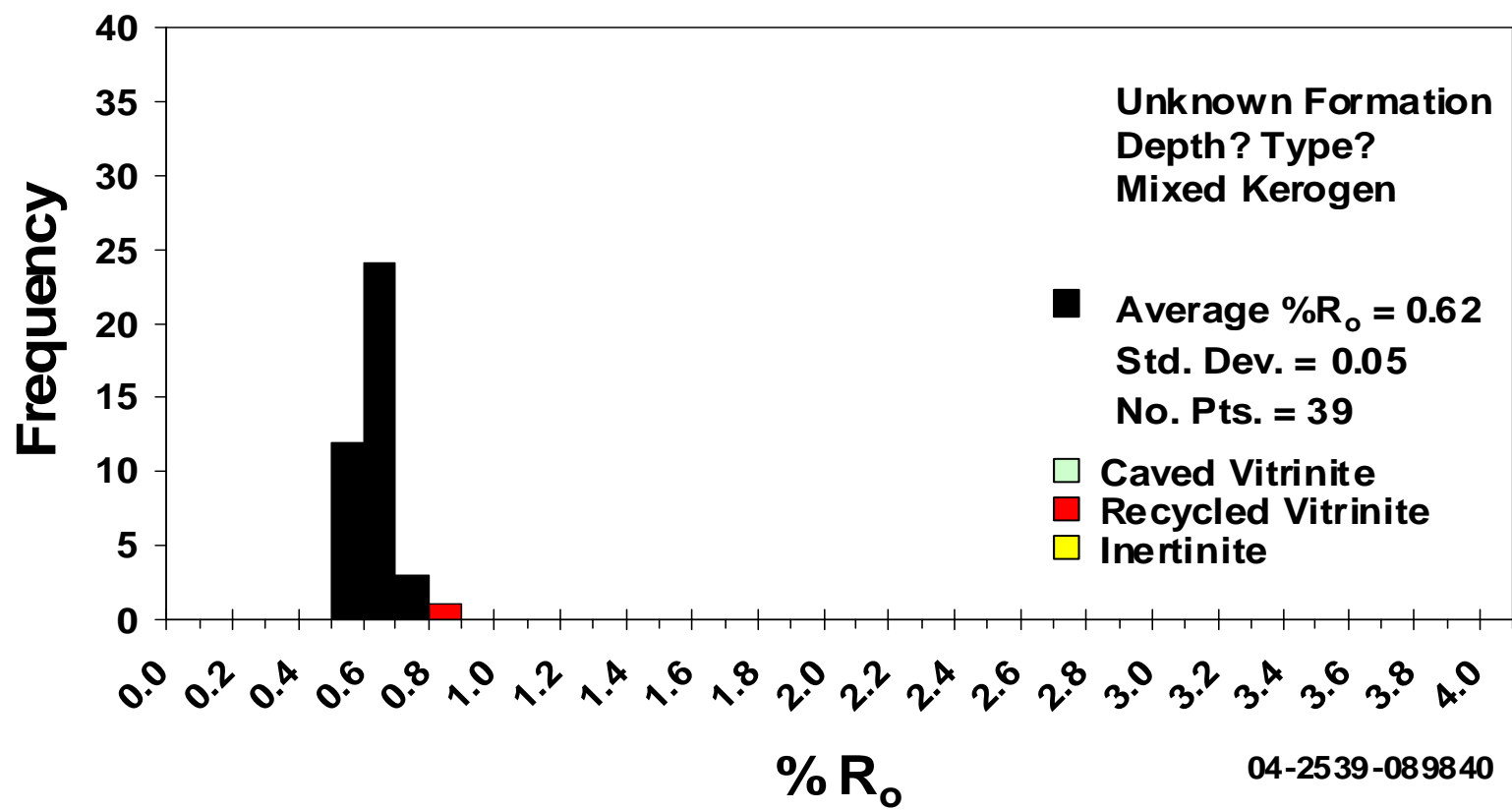
TICORA GEOSCIENCES

HGS ID	04-2593-089835		04-2593-089840	
SAMPLE ID.	ISO052-2		ISO052=7	
	All Data	Indigenou s Data	All Data	Indigenou s Data
	0.57	0.66	0.5	0.5
	0.66	0.67	0.5	0.5
	0.67	0.69	0.53	0.53
	0.69	0.7	0.56	0.56
	0.7	0.7	0.56	0.56
	0.7	0.7	0.56	0.56
	0.7	0.71	0.57	0.57
	0.71	0.72	0.58	0.58
	0.72	0.73	0.58	0.58
	0.73	0.73	0.58	0.58
	0.73	0.73	0.58	0.58
	0.73	0.74	0.59	0.59
	0.74	0.75	0.6	0.6
	0.75	0.76	0.6	0.6
	0.76	0.76	0.6	0.6
	0.76	0.77	0.6	0.6
	0.77	0.77	0.6	0.6
	0.77	0.77	0.6	0.6
	0.77	0.78	0.61	0.61
	0.78	0.78	0.61	0.61
	0.78	0.79	0.62	0.62
	0.79	0.79	0.62	0.62
	0.79	0.79	0.63	0.63
	0.79	0.79	0.63	0.63
	0.79	0.79	0.63	0.63
	0.79	0.8	0.64	0.64
	0.8	0.81	0.64	0.64
	0.81	0.81	0.65	0.65
	0.81	0.82	0.65	0.65
	0.82	0.82	0.65	0.65
	0.82	0.83	0.65	0.65
	0.83	0.83	0.66	0.66
	0.83	0.84	0.67	0.67
	0.84	0.84	0.68	0.68
	0.84	0.85	0.68	0.68
	0.85	0.86	0.68	0.68
	0.86	0.87	0.7	0.7
	0.87	0.88	0.7	0.7
	0.88		0.71	0.71
	1.11		0.81	
Average %R _o	0.78	0.77	0.62	0.62
Standard Dev.		0.06		0.05
# of Points	40	38	40	39

ISO052-2



ISO052-7



Appendix IV

Ascent Energy, Inc
Holt 1-19, MFY 5-17, EFU 9-41,
& Kirby Gilbreth 1-20

Tight Rock Analysis

Core Lab

CORE LABORATORIES
HOUSTON ADVANCED TECHNOLOGY CENTER

Ticora Geosciences, INC
Shale Samples Analysis
ISOΦ52 Project



CL File No.: HOU-040865
Date: October 29, 2004, 2004
Analyst(s): RL, JH

Sample	Depth	As received		Dry & Dean Stark Extracted Conditions						Retort Analysis	
		Bulk Density g/cc	Matrix Permeability ⁽¹⁾ mD	Grain Density g/cc	Φ ⁽²⁾ (%)	Sg (%)	Gas filled Φ (%)	Sw ⁽²⁾ (%)	Mobile Oil Saturation (So ⁽²⁾) (%)	Bound Hydrocarbon Saturation So(%BV) ⁽³⁾	Bound Clay Water Sw (%BV) ⁽³⁾
1	ISOΦ52-1	2.754	na	2.639	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	ISOΦ52-2	2.473	5.555E-05	2.602	5.85	56.6	3.31	43.45	0.00	0.48	5.38
3	ISOΦ52-3	2.396	4.748E-08	2.465	3.71	38.8	1.44	61.17	0.00	0.53	5.93
4	ISOΦ52-4	2.191	1.514E-07	2.233	3.10	10.9	0.34	80.96	8.10	12.75	6.04
5	ISOΦ52-5	2.213	1.348E-04	2.303	5.29	22.4	1.19	74.78	2.80	7.22	7.22
6	ISOΦ52-6	2.019	1.861E-04	2.135	6.72	42.5	2.85	54.78	2.74	11.71	7.32
7	ISOΦ52-7	2.123	3.065E-04	2.311	9.53	63.9	6.08	34.34	1.79	7.33	6.84
8	ISOΦ52-8	2.245	2.007E-04	2.360	6.19	39.8	2.46	56.85	3.39	6.46	6.22
9	ISOΦ52-9	2.282	1.615E-04	2.431	7.22	59.4	4.29	37.35	3.26	7.01	6.35

Footnotes:

(1) Matrix Permeability calculated from measured pressure decay data on a fresh, crushed, 20/35 mesh size sample.

(2) Dean Stark extracted sample dried @ 110 °C. Sample crushed 20/35 mesh size.

(3) Calculated from Retort Analysis.

Sample 1 ISOΦ52-1 : It is likely that the analytical procedure has altered the average mineralogy of this sample. This is evidenced by the clean Grain Density being lower than the uncleaned Bulk Density. We are confident in the accuracy of both measurements. Calculation of porosity, permeability and saturations resulted in anomalous values and have not been reported.

Appendix V

Ascent Energy, Inc
Holt 1-19, MFY 5-17, EFU 9-41,
& Kirby Gilbreth 1-20

Core Lithology and Photography

TICORA Geosciences, Inc

Core Lithology



Client Name: Ascent Energy, Inc

TICORA NO: ISO052

SAMPLE ID.	SAMPLE INTERVAL Depth Drilled (feet)	COAL						MUDSTONE				GRAINSTONE				OTHER	COLOR	DESCRIPTION																		Texture	Comments
		Non-Banded			Banded			Bony	Shale	Shale color			Siltstn	Sandstone				Integrity	Fluid Sensitivity			Carbonate Mineralization			Organic (Humic)			Exsudatinite (Resinite)									
		Luster												Grain Size																							
		E	M	D	E	M	D			D	M	L		F	M				C	C	R	E	M	S	E	M	S	E	M	S	E	M	S				
ISO052-1	3699.6								X									drk gry														Sh, drk gry, sl carb, 1 vert frac, no second min					
ISO052-2	3701.8								X									gry-drk gry														Sh, gry-drk gry, sl carb, pyr incl, fissile					
ISO052-3	3707.8								X									gry-drk gry														Sh, gry-drk gry, sl carb, pyr incl, fissile, salt incl					
ISO052-4	3379.6												X					lt brn														Siltstn, lt brn, sl carb, scat sh lams, sl friable					
ISO052-5	3385												X					lt brn														Siltstn, lt brn, sl carb, scat sh lams, sl friable					
ISO052-6	3391.1												X					lt brn														Siltstn, lt brn, sl carb, scat sh lams, sl friable					
ISO052-7	3421								X									blk														Sh, blk, carb					
ISO052-8	5373								X									blk														Sh, blk, carb					
ISO052-9	5376.8								X									blk-drk gry														Sh, blk-drk gry, carb					



Core Photography

Ascent Energy, Inc

Holt 1-19, MFY 5-17, EFU 9-41, & Kirby Gilbreth 1-20



Woodford Shale

TICORA ISO052-1

3,699.6 feet



Core Photography

Ascent Energy, Inc

Holt 1-19, MFY 5-17, EFU 9-41, & Kirby Gilbreth 1-20



Woodford Shale

TICORA ISO052-2

3,701.8 feet



Core Photography

Ascent Energy, Inc

Holt 1-19, MFY 5-17, EFU 9-41, & Kirby Gilbreth 1-20



Woodford Shale

TICORA ISO052-3

3,707.8 feet



Core Photography

Ascent Energy, Inc

Holt 1-19, MFY 5-17, EFU 9-41, & Kirby Gilbreth 1-20



Woodford Shale

TICORA ISO052-4

3,379.6 feet



Core Photography

Ascent Energy, Inc

Holt 1-19, MFY 5-17, EFU 9-41, & Kirby Gilbreth 1-20



Woodford Shale

TICORA ISO052-5

3,385 feet



Core Photography

Ascent Energy, Inc

Holt 1-19, MFY 5-17, EFU 9-41, & Kirby Gilbreth 1-20



Woodford Shale

TICORA ISO052-6

3,391.1 feet



Core Photography

Ascent Energy, Inc

Holt 1-19, MFY 5-17, EFU 9-41, & Kirby Gilbreth 1-20



Woodford Shale

TICORA ISO052-7

3,421.0 feet



Core Photography

Ascent Energy, Inc

Holt 1-19, MFY 5-17, EFU 9-41, & Kirby Gilbreth 1-20



Caney Shale

TICORA ISO052-8

5,373.0 feet

Appendix VI

Ascent Energy, Inc
Holt 1-19, MFY 5-17, EFU 9-41,
& Kirby Gilbreth 1-20

Adsorption Isotherm Results

TICORA Geosciences, Inc



FINAL REPORT

Methane Adsorption Analysis Holt #1-19 (ISO052-2)

Ascent Energy, Inc

Holt 1-19 : 10N 12E-19 NW NW – Core Samples

Submitted To:

Ascent Energy
1700 Redbud Blvd., Suite 450
McKinney, TX 75069

Attention:

Mr. John Pinkerton

Submitted By:

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November 19, 2004

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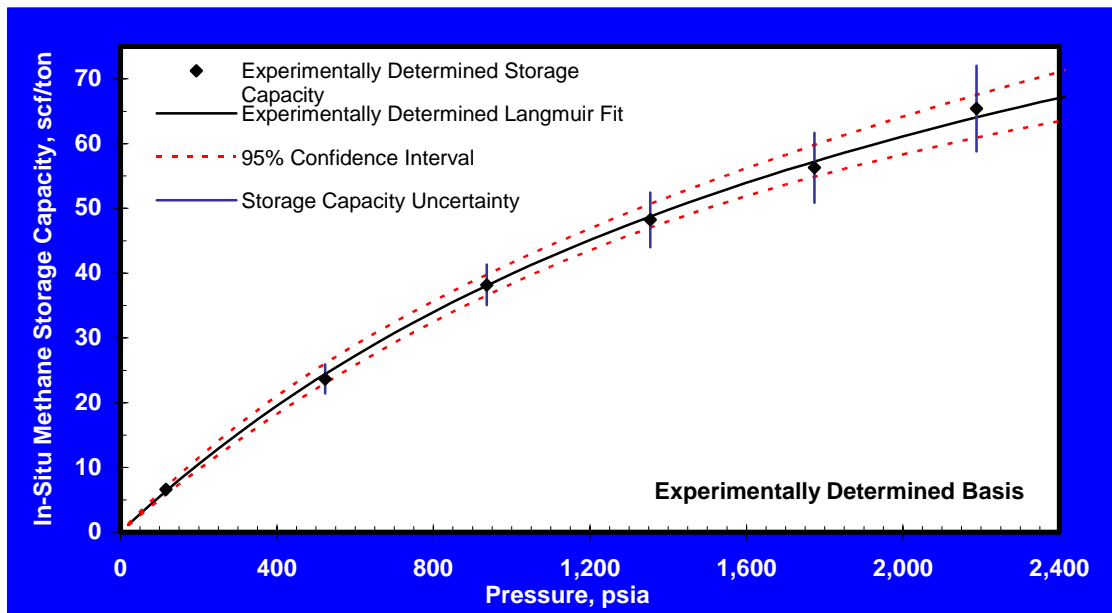
1.0 SUMMARY OF ANALYTICAL RESULTS

A methane adsorption isotherm was conducted on sample ISO052-2. Based on the adsorption isotherm analysis described herein, the resultant methane storage capacity for sample ISO052-2 on an experimental and 100% TOC basis are 53.94 and 760.81 scf/ton, respectively (at the assumed reservoir pressure of 1,602.75 psia). Figure 1 illustrates the experimental gas storage capacity data. Sample description and critical gas storage capacity data are summarized in Table 1. Because TICORA was not involved in long term desorption analysis, the in-situ gas content, initial sorbed gas saturation value, critical desorption pressure, and gas recovery factor are unknown.

Table 1. Sample Description and Critical Gas Storage Capacity Data

Parameter	Units	Value
Well	-	Holt #19 & EFU #9-41
Location	-	Unknown
County	-	Unknown
State	-	Unknown
Sample Type	-	Shale
Reservoir Depth	feet	3701.0-3702.0
Reservoir Pressure	psia	1,602.75
Reservoir Temperature	°F	130.00
Sample Characterization		
TICORA Sample Number	-	ISO052-2
Moisture holding capacity	wt. fraction	0.0080
Assumed ash content (in-situ)	wt. fraction	0.9291
TOC content (in-situ)	wt. fraction	0.0709
Mean Maximum Vitrinite reflectance	%	0.7800
Coal Rank Classification (ASTM D 388)	-	Carbonaceous Shale
In-Situ Gas Storage Capacity Data		
In-Situ Langmuir Volume	scf/ton	130.55
In-Situ Langmuir Pressure	psia	2,276.15
In-Situ Gas Storage Capacity	scf/ton	53.94

Figure 1. Gas Storage Capacity vs. Pressure



The properties of the sample aliquot used for the analysis and the experimental sorption isotherm results are provided in Table 2. The experimental sorption isotherm and the 100% TOC results are graphically presented in Figure 2 and Figure 3 respectively. Please refer to *Appendix B, Methane Gas Storage Capacity*, to review the raw methane adsorption isotherm data.

Table 2. Experimental Sample Aliquot Properties and Sorption Isotherm Results

Parameter		Units	Value		
Experimental Gas		-	methane		
Experimental Temperature		°F	130.22		
Sample Mass		g	193.66		
Sample Density (Void Volume Based)		g/cc	2.54		
Pre-experiment Moisture Content		wt. fraction	0.0080		
Post-experiment Moisture Content		wt. fraction	0.0080		
Experimental Ash Content		wt. fraction	0.9291		
Minimum Experimental Pressure		psia	115.87		
Maximum Experimental Pressure		psia	2188.34		
Experimental Langmuir Volume		scf/ton	130.55		
Experimental Langmuir Pressure		psia	2276.15		
Experimental Langmuir Volume Range		scf/ton	0.06		
Experimental Langmuir Pressure		psia	337.49		
Step Number	Pressure	Experimental Gas Storage Capacity	Calculated Langmuir Fit Gas Storage Capacity	100% TOC Gas Storage Capacity	Calculated Langmuir Fit 100% TOC Gas Storage Capacity
	psia	scf/ton	scf/ton	scf/ton	scf/ton
1	115.9	6.60	6.32	93.02	89.19
2	523.5	23.64	24.41	333.42	344.27
3	936.6	38.14	38.06	537.97	536.79
4	1,354.5	48.18	48.70	679.53	686.95
5	1,773.6	56.22	57.17	792.95	806.39
6	2,188.3	65.36	63.99	921.89	902.53
Reservoir	1,602.8	-	53.94	-	760.81

Figure 2. Experimental Gas Storage Capacity Graph

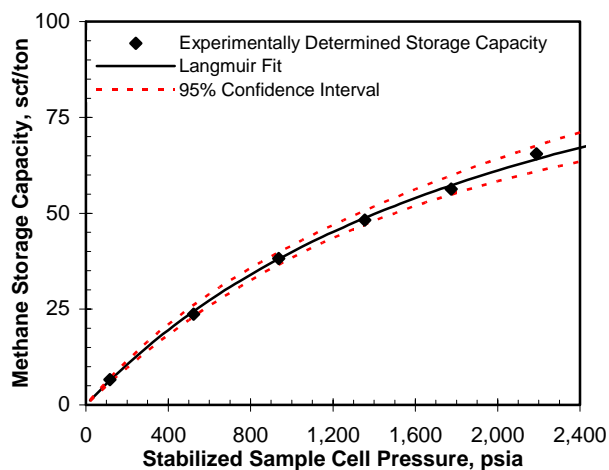
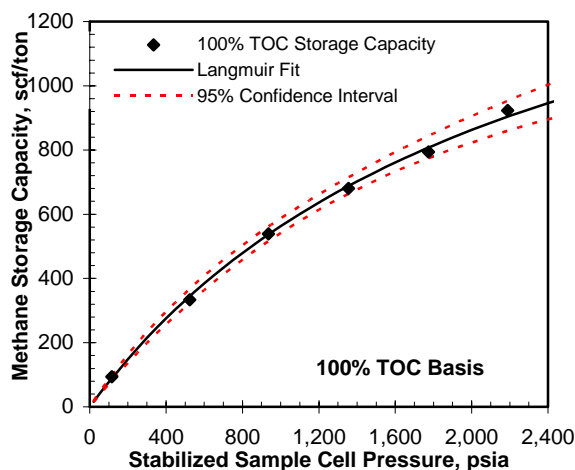


Figure 3. 100% TOC Gas Storage Capacity Graph

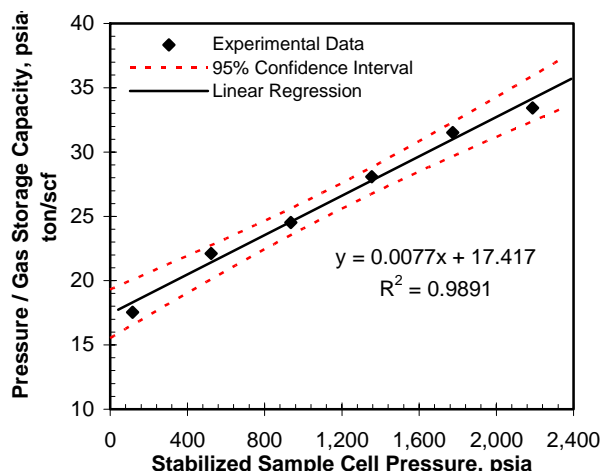


The sorption isotherm analytical results presented herein assume that the Langmuir relationship and model accurately predict the behavior of sorption reservoirs for the pressure and temperature conditions of most interest to coal and shale gas reservoir engineering. Table 3 and Figure 4 provide the results of the Langmuir regression obtained from the experimental sorption isotherm analysis data. Refer to *Appendix C, Langmuir Regression*, to review the raw Langmuir interpretation data.

Table 3. Langmuir Regression Interpretation Data

Parameter	Units	Value
Slope	ton/scf	0.0077
Intercept	psia*ton/scf	17.4171
Regression Coefficient (squared)	-	0.9891
Slope Variation	ton/scf	0.0014
Intercept Variation	psia*ton/scf	1.8922
GsL Variation	scf/ton	0.06
PL Variation	psia	337.49
Statistical Significance Level	-	0.95
Number of Data Points	-	6
T Distribution Value	-	3.50

Figure 4. Langmuir Interpretation Graph



2.0 SAMPLE PREPARATION²

One of the most significant errors in gas storage capacity measurements results from measuring isotherm data on samples that are not at in-situ moisture conditions. Poor sample handling procedures and/or preparation of a non-representative sample aliquot will also impact gas storage capacity results. A brief description of TICORA's sample preparation procedure is presented in this section.

2.1 Sample Reduction

Typically, a core sample is quickly crushed to ¼" size particles. The sample is wetted with a misting spray bottle during comminution to maintain excess surface moisture. Representative aliquots are removed for the various analyses and testing required for complete characterization of the core sample, including helium density, moisture holding capacity and sorption isotherm analysis. The remaining crushed core (Premium Sample) is sealed in a laminate bag purged with helium to prevent oxidation.

If a composite sample is required, then crushed aliquots are obtained from the premium samples of all core samples to be incorporated into the composite. These aliquots are combined and homogenized through staged grinding and riffing to produce a representative composite sample. The relative mass of each aliquot in the composite is determined on a weighted average basis. The sorption isotherm aliquot is further reduced to a particle size of minus 60 mesh.

2.2 Moisture Equilibration

Before testing, isotherm samples are equilibrated to inherent moisture content using an improved version of ASTM Method D1412-99 for determining the moisture holding capacity (MHC) of coal samples. The two most critical differences in the improved method used by TICORA are that equilibration is conducted at reservoir temperature (to more accurately reflect in-situ conditions) and the time the sample spends equilibrating at in-situ conditions is extended up to 30 days. After the equilibration process, MHC is determined on a portion of the larger (~ 200 grams) sorption isotherm sample. MHC is also determined for triplicate aliquots of the premium samples which the isotherm sample is comprised of. The results are then compared to ensure that the inherent moisture content of isotherm sample has not been affected by the differences in mass and particle size relative to the equilibrated moisture contents from the Premium Samples. The sorption isotherm sample is then sealed in a laminate bag purged with helium and placed in refrigerated storage until it is tested. Note that MHC is not conducted on shale samples due to the unique structure of the organic material found within shales, and other inherent problems when attempting to determine the MHC of shales.

3.0 SORPTION ISOTHERM ANALYSIS¹

Sorption isotherm data relate sorbed gas storage capacity to pressure and are necessary to predict the production behavior of sorption reservoirs such as found in coal seams and shale gas deposits. The difference between in-situ reservoir pressure and the critical desorption pressure defines the amount of pressure that must be decreased at the well head to enable the representative sample to begin desorbing the gas bound to its organic matter. Based upon the initial degree of saturation and the abandonment pressure, the percent recovery expresses the percentage of the gas content that can be extracted from the reservoir during the life of production. The following procedures are required to produce gas storage capacity data:

- Calculate reference and sample cell volumes using helium.
- Calculate the void volume present within the sample cell when sample is present within the vessel.
- Perform a sorption isotherm test with a given sorbing gas (CH_4 , CO_2 , N_2 , C_2H_6), using the resulting pressure and temperature data to calculate the number of molecules sorbed within the sample over a series of increasing pressure steps.

3.1 Cell Volume Determination

Before any type of sorption isotherm analysis can be conducted the volumes of the reference and sample cells must be accurately known. To determine the cell volumes a calibration test must be run twice, first with each cell empty, then with the sample cell filled with calibration bearings of a known volume. Each test is run using six pressure steps and the non-sorbing gas, helium. The calculated reference cell and sample cell volumes should be identical (relative to each individual cell) for all six pressure steps, but in reality there are slight volume variations each step (approximately $\pm 0.25 \text{ cm}^3$ deviation from the average) due to the limits of accuracy present in the various instrumental components. The highest and lowest determined cell volumes are discarded and the remaining four values are averaged. *Appendix A* includes the raw cell volume calibration data.

3.2 Sample Loading

The sample is weighed quickly on a precision balance accurate to .0001 grams. Regularly the sample's weight is in a continual state of flux upon the scale due to evaporation of moisture from the sample. Through experience it has been determined that subtracting ~ 0.005 grams from the last reading before removal from the scale is adequate to account for further moisture/weight loss that will occur between the time the sample is removed from the scale to the point it is loaded within the test vessel. After weighing, the sample is loaded into the sample cell and lowered into the controlled-temperature oil bath.

3.3 Void Volume Determination

Once the sample is loaded into the sample cell, the reference and sample cells are brought to reservoir temperature. The void volume is then determined similarly to cell volume calibration, using helium (a non sorbing gas) and six pressure steps. The highest and lowest determined void volumes are discarded and the remaining four are averaged. *Appendix A* also includes the raw void volume calibration data.

3.4 Sorption Isotherm Analysis

Once the void volume has been calculated, sorption isotherm analysis is conducted. The reference cell is charged with a sorbing gas to a pressure above the desired sample vessel equilibrium pressure. After the charged reference cell pressure reaches equilibrium, the valve between the sample cell and reference cell is opened and gas is allowed to flow into the sample cell. The valve between the vessels is closed and the sample and reference cell pressures are allowed to come to equilibrium. The reference cell is then recharged and the sequence of events is repeated.

The number of molecules sorbed onto a sample during a pressure step is determined based on material balance. The number of molecules sorbed is equal to the number of molecules that flow out of the reference cell into the sample cell, minus the number of remaining molecules in the void volume of the sample cell after the sample cell pressure equilibrates. The void volume includes the pore space within the sample and therefore is reduced from pressure step to pressure step as more and more porosity is filled with sorbed gas. This requires the void volume be recalculated for each step (Review Reference 1 for a more detailed discussion of this topic). The number of moles sorbed during a pressure step is converted to an equivalent scf/ton value and corrected for the change in void volume. Each individually determined pressure step storage capacity is added to the previously determined storage capacity and reported with the corresponding end sample equilibrium pressure.

Gas storage capacity results are typically converted to reflect storage capacity on a dry, ash free basis, etc. Such data, though theoretical, are useful for comparing samples that might vary in depth, ash content, moisture content, etc. The calculations to determine gas storage capacity on a moist, ash free basis, dry, ash free basis, in-situ basis, and dry, ash

and sulfur free basis are presented in Equations 1, 2, 3, and 4 respectively. *Appendix B* includes the raw gas storage capacity data.

$$G_{sma} = G_s \cdot 1/(1 - w_{ae}) \quad (1)$$

$$G_{sa} = G_s \cdot 1/(1 - w_{me} - w_{ae}) \quad (2)$$

$$G_{si} = G_{sa} \cdot (1 - w_{mi} - w_{ai}) \quad (3)$$

$$G_{sa\&s} = G_s \cdot 1/(1 - w_{me} - w_{ae} - w_{se}) \quad (4)$$

Where:

G_s	gas storage capacity, scf/ton
G_{sma}	moist, ash free gas storage capacity, scf/ton
G_{sa}	dry, ash free gas storage capacity, scf/ton
G_{si}	in-situ gas storage capacity, scf/ton
$G_{sa\&s}$	dry, ash and sulfur free gas storage capacity, scf/ton
w_{me}	experimentally determined moisture weight fraction
w_{ae}	experimentally determined ash weight fraction
w_{se}	experimentally determined total sulfur fraction
w_{mi}	in-situ moisture weight fraction
w_{ai}	in-situ ash weight fraction

To construct a mathematical fit to the resulting data, the Langmuir model is used. Plotting equilibrium pressure divided by calculated storage capacity vs. equilibrium pressure produces a linear relationship. The intercept and slope of the resulting linear function are used to produce the “Langmuir Parameters” (Langmuir pressure and Langmuir volume). Once the Langmuir parameters are determined one can model the gas storage capacity at any pressure. The mathematical model is defined by Equation 5. *Appendix C* includes the raw Langmuir regression data.

$$G_s = G_{sL} \cdot p / (p + P_L) \quad (5)$$

Where:

G_s	gas storage capacity, scf/ton
p	pressure, psia
G_{sL}	Langmuir Volume, scf/ton
P_L	Langmuir Pressure, psia

3.5 Sample Unloading

Once the sorption isotherm test has been completed, the sample cell pressure is reduced to slightly above atmospheric pressure. The sample begins to desorb the gas sorbed during the sorption isotherm test, causing the pressure inside the sample cell to rise. The pressure build up reduces repeatedly until all gas has been desorbed. The sample is then unloaded and a small aliquot is removed for post-isotherm MHC determination. Post-isotherm MHC is conducted in triplicate and the moisture content is compared to the MHC determined prior to isotherm analysis. This is done to ensure that the moisture content has remained stable and to ensure that the storage capacity results do indeed reflect in-situ conditions.

4.0 GAS STORAGE CAPACITY UNCERTAINTY AND ERROR PROPAGATION ¹

There are systematic and random errors associated with isotherm measurements. The systematic errors result from improper sample preparation and handling, use of an experimental temperature different from the actual reservoir temperature, errors in gas z factor estimates, and poor equipment calibration practices. Condensation of the sorbing gas of interest within the sample or reference cells can also occur when testing relatively high critical temperature gases (CO₂, C₂H₆, C₃H₈ for example), even at temperatures below the critical temperature. Examples of random errors are those that result from unintended exceptions to standard sample preparation procedures, cell pressure and temperature variations caused by laboratory condition and oil bath temperature variations, and temperature and pressure measurement fluctuations caused by electronic equipment and electrical power variations.

In an effort to reduce these errors, TICORA uses the most accurate gas density correlations available. All pressure transducers, thermocouples, and mass balances are calibrated or checked before each measurement. TICORA requests that the clients take special care in estimating reservoir temperature before requesting sorption isotherm analysis. The condensation conditions for gases are accurately known and avoided. We have reduced random errors by construction of an isolated, insulated, and temperature controlled isotherm laboratory that includes high quality (and expensive)

electrical control and battery backup systems. All of the electronic equipment used in the isotherm apparatus are the best quality available.

Independent and random uncertainties can be computed by differentiating the isotherm interpretation equations. The uncertainty estimated in this manner is generally expected to be a maximum uncertainty as it is unlikely that each parameter will be at its maximum accuracy limit during any one measurement. Equation 6 is the general error equation for a function of n variables, x_1 through x_n . The derivative values and the associated errors are computed for each parameter in the equations used to compute the reference cell, sample cell, and void volumes and the equation used to calculate the gas storage capacity for each isotherm step.

$$df(x_1, x_2, \dots, x_n) = \sqrt{\left(\frac{\partial f}{\partial x_1} dx_1\right)^2 + \left(\frac{\partial f}{\partial x_2} dx_2\right)^2 + \dots + \left(\frac{\partial f}{\partial x_n} dx_n\right)^2} \quad (6)$$

The calibration errors are used to estimate the uncertainty in each step of the isotherm measurements. The individual items are the combination of the partial derivative of the total gas storage capacity with respect to the parameter times the maximum error in the parameter. These parameters were squared and added in accordance with Equation 6 to estimate the total uncertainty. Refer to *Appendix B, Methane Gas Storage Capacity*, pp. 12, to review the total gas storage capacity uncertainty associated with the isotherm conducted for sample ISO052-2.

TICORA emphasizes that gas storage capacity data are not measured directly but are computed from measured pressure and temperature conditions. By taking great care to maximize measurement accuracy while minimizing systematic and random errors TICORA has found that we can measure gas storage capacity data with an average uncertainty of $\pm 5\%$ or less. TICORA takes pride in full disclosure of all data involved with sorption isotherm measurements.

5.0 REFERENCES

1. Mavor, M.J., Hartman, C., and Pratt, T.J.: "Uncertainty in Sorption Isotherm Measurements", paper 411, *Proceedings 2004 International Coalbed Methane Symposium*, University of Alabama, Tuscaloosa, AL (May 2004)
2. Testa, S.M. and Pratt, T.J.: "Sample Preparation for Coal and Shale Gas Resource Assessment", paper 356, *2003 International Coalbed Methane Symposium*, University of Alabama, Tuscaloosa, AL (May 5-9, 2003)
3. 2001 Annual Book of ASTM Standards, Volume 05.05 Gaseous Fuels; Coal and Coke, American Society for Testing and Materials, Philadelphia, PA (2001).

Appendix A

Cell Volume and Void Volume Calibration

Calibration Data with Empty Sample Cell									
Reference Cell									
Step Number	Step Start Time	Step Stop Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	0.48	2.13	1.65	148.54	97.02	1.00452	55.32	97.03	1.00168
2	2.78	3.28	0.50	314.52	97.03	1.00958	149.43	97.01	1.00455
3	3.88	4.44	0.57	508.42	97.02	1.01551	279.23	97.02	1.00851
4	20.13	21.13	1.00	1006.40	96.96	1.03078	640.99	96.93	1.01957
5	21.70	23.01	1.31	1526.87	97.00	1.04680	894.54	97.00	1.02735
6	23.97	25.87	1.90	2077.83	97.01	1.06379	1,317.10	97.02	1.04034
Sample Cell									
Step Number	Step Start Time	Step End Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	0.48	2.78	2.30	1.93	97.25	1.00006	55.14	97.30	1.00168
2	2.78	3.88	1.09	55.14	97.30	1.00168	148.99	97.30	1.00453
3	3.88	20.13	16.26	148.99	97.30	1.00453	279.28	97.24	1.00851
4	20.13	21.70	1.56	279.28	97.24	1.00851	540.31	97.27	1.01648
5	21.70	23.97	2.28	540.31	97.27	1.01648	892.58	97.29	1.02727
6	23.97	25.87	1.90	892.58	97.29	1.02727	1,314.50	97.30	1.04023
Calibration Data with Calibration Bearinas in Sample Cell									
Reference Cell									
Step Number	Step Start Time	Step End Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	1.07	1.78	0.72	160.95	97.02	1.00490	85.44	97.01	1.00260
2	2.20	3.00	0.80	305.10	97.02	1.00930	199.20	97.01	1.00607
3	3.38	4.12	0.74	502.14	97.03	1.01532	356.17	96.97	1.01086
4	16.42	17.71	1.30	1006.03	97.03	1.03077	691.46	97.01	1.02112
5	18.46	21.83	3.37	1607.49	97.02	1.04928	1,161.40	97.03	1.03554
6	22.99	23.86	0.87	2409.68	97.04	1.07403	1,798.73	97.02	1.05518
Sample Cell									
Step Number	Step Start Time	Step End Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	1.07	2.20	1.13	3.17	96.89	1.00010	84.30	96.90	1.00257
2	2.20	3.38	1.18	84.30	96.90	1.00257	197.93	96.88	1.00603
3	3.38	16.42	13.03	197.93	96.88	1.00603	353.71	96.93	1.01078
4	16.42	18.46	2.04	353.71	96.93	1.01078	685.83	96.91	1.02095
5	18.46	22.99	4.53	685.83	96.91	1.02095	1,153.42	96.92	1.03531
6	22.99	23.86	0.87	1153.42	96.92	1.03531	1,787.92	96.93	1.05485

Appendix A (continued)

Sample Cell Void Volume Calibration Data									
Reference Cell									
Step Number	Step Start Time	Step End Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	1.15	18.36	17.21	165.14	129.92	1.00471	80.35	129.91	1.00229
2	19.09	19.57	0.48	316.26	129.92	1.00903	192.37	129.93	1.00549
3	20.07	22.44	2.38	517.45	129.93	1.01479	346.42	129.92	1.00989
4	23.03	24.36	1.32	987.58	129.93	1.02830	648.83	129.93	1.01856
5	25.02	43.51	18.50	1562.58	129.94	1.04489	1,077.25	129.95	1.03088
6	44.11	45.27	1.17	2388.27	129.93	1.06879	1,689.94	129.92	1.04857
Sample Cell									
Step Number	Step Start Time	Step End Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	1.15	19.09	17.94	3.59	130.05	1.00010	80.72	130.01	1.00230
2	19.09	20.07	0.98	80.72	130.01	1.00230	192.86	130.03	1.00550
3	20.07	23.03	2.97	192.86	130.03	1.00550	347.01	130.05	1.00991
4	23.03	25.02	1.98	347.01	130.05	1.00991	649.40	130.03	1.01857
5	25.02	44.11	19.09	649.40	130.03	1.01857	1,077.94	130.01	1.03090
6	44.11	45.27	1.17	1077.94	130.01	1.03090	1,690.74	130.01	1.04859

Cell Volume Calibration Data			
Step Number	Reference Cell Volume	Sample Cell Volume	Void Volume
	cm3	cm3	cm3
1	117.87	205.69	129.56
2	117.64	205.40	129.95
3	118.81	206.79	130.16
4	220.47	301.18	130.26
5	118.31	206.30	130.70
6	118.54	206.48	130.12
Average	135.27	221.97	130.12
Parameter			
Parameter	Value	Deviation From Average	
	cm3	%	
Interpretation Reference Cell Volume	118.38	-12.4857	
Interpretation Sample Cell Volume	206.32	-7.0538	
Interpretation Void Volume	130.12	-0.0016	

Interpretation Parameters		
Parameter	Units	Value
Sample Mass	g	193.66
Sample Density (Void Volume Based)	g/cm3	2.54
Total Calibration Bearings Volume	cm3	96.53
Helium Molecular Weight	g/gmole	4.0026
The <i>N.I.S.T Pure Fluids Data Base</i> was the Equation of State used to calculate all free gas densities.		

Appendix B

Methane Gas Storage Capacity

Methane Sorption End Point Data									
Reference Cell									
Step Number	Step Start Time	Step Stop Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	0.69	3.38	2.69	243.01	130.17	0.98026	115.78	130.13	0.99047
2	5.24	6.47	1.23	957.93	130.14	0.92931	523.35	130.13	0.95883
3	8.18	10.68	2.50	1,380.45	130.16	0.90631	936.97	130.17	0.93063
4	22.28	24.47	2.20	1,809.09	130.16	0.89019	1,354.17	130.15	0.90754
5	25.24	27.01	1.77	2,240.92	130.16	0.88236	1,772.86	130.16	0.89123
6	27.81	32.03	4.22	2,665.71	130.16	0.88316	2,187.63	130.16	0.88286
Sample Cell									
Step Number	Step Start Time	Step Stop Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	0.69	5.24	4.55	2.85	130.23	0.99976	115.87	130.22	0.99047
2	5.24	8.18	2.93	115.87	130.22	0.99047	523.45	130.22	0.95885
3	8.18	22.28	14.10	523.45	130.22	0.95885	936.61	130.22	0.93068
4	22.28	25.24	2.97	936.61	130.22	0.93068	1,354.54	130.22	0.90757
5	25.24	27.81	2.57	1354.54	130.22	0.90757	1,773.61	130.20	0.89125
6	27.81	32.03	4.22	1773.61	130.20	0.89125	2,188.34	130.22	0.88291
Average Temperature								130.22	

Experimentally Determined Storage Capacity Data						
Step Number	Stabilized Sample Cell Pressure	Stabilized Sample Cell Gas Density	Gibbs Storage Capacity Correction Factor	Gibbs Storage Capacity	True Storage Capacity	100% TOC Storage Capacity
	psia	g/cm3	-	scf/ton	scf/ton	scf/ton
1	115.87	0.00475	1.0114	6.52	6.60	93.02
2	523.45	0.02216	1.0554	22.40	23.64	333.42
3	936.61	0.04085	1.1071	34.45	38.14	537.97
4	1,354.54	0.06059	1.1675	41.27	48.18	679.53
5	1,773.61	0.08079	1.2366	45.47	56.22	792.95
6	2,188.34	0.10061	1.3128	49.79	65.36	921.89

Appendix B (continued)

Propagated Uncertainty			
Step Number	Stabilized Sample Cell Pressure	Storage Capacity Uncertainty	100% TOC Storage Capacity Uncertainty
	psia	scf/ton	scf/ton
1	115.87	0.49	6.93
2	523.45	4.50	63.51
3	936.61	6.26	88.34
4	1354.54	8.45	119.25
5	1773.61	10.87	153.29
6	2188.34	13.28	187.33

Interpretation Parameters			
Parameter		Units	Value
Methane molecular weight		g/gmole	16.0428
Methane sorbed density		g/cm3	0.4234
Reference Cell Volume		cm3	118.26
Sample Cell Volume		cm3	206.20
Sample Cell Void Volume		cm3	129.98
The N.I.S.T Pure Fluids Data Base was the Equation of State used to calculate all free gas densities.			

Appendix C

Langmuir Regression

Experimental Storage Capacity Data			
Step Number	Stabilized Sample Cell Pressure	Storage Capacity	100% TOC Storage Capacity
	psia	scf/ton	scf/ton
1	115.87	6.60	93.02
2	523.45	23.64	333.42
3	936.61	38.14	537.97
4	1,354.54	48.18	679.53
5	1,773.61	56.22	792.95
6	2,188.34	65.36	921.89

Langmuir Regression Data		
Parameters	Storage Capacity	100% TOC Storage Capacity
Slope	0.0077	0.0005
Intercept	17.4355	1.2362
Regression Coefficient (squared)	0.9891	0.9891
Intercept Variation, psia*ton/scf	1.8942	0.1343
Slope Variation, ton/scf	0.0014	0.0001
GsL Variation, scf/ton	0.06	0.80
PL Variation, psia	337.49	337.49
Langmuir Volume, scf/ton	130.55	1841.28
Langmuir Pressure, psia	2276.15	2276.15

Calculated Langmuir Fit Storage Capacity Data			
Step Number	Stabilized Sample Cell Pressure	Storage Capacity	100% TOC Storage Capacity
	psia	scf/ton	scf/ton
1	115.87	6.32	89.19
2	523.45	24.41	344.27
3	936.61	38.06	536.79
4	1,354.54	48.70	686.95
5	1,773.61	57.17	806.39
6	2,188.34	63.99	902.53
Reservoir Pressure	1,602.75	53.94	760.81



FINAL REPORT

Methane Adsorption Analysis EFU #9-41 (ISO052-7)

Ascent Energy, Inc
EFU 9-41 : 2N 7E-27 NW NE NE NW – Core Samples

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November 19, 2004

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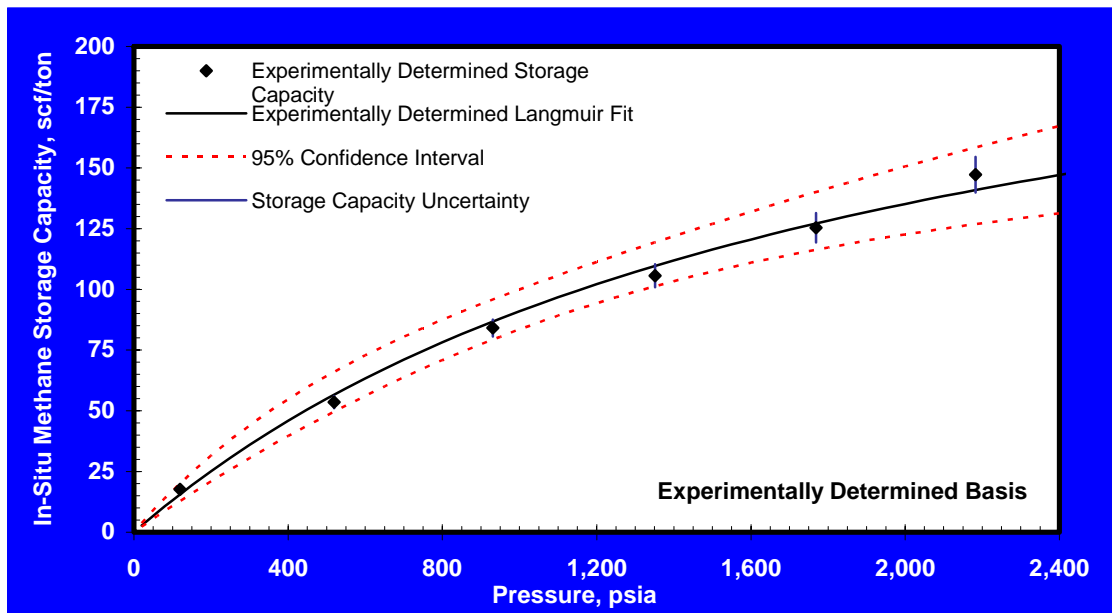
1.0 SUMMARY OF ANALYTICAL RESULTS

A methane adsorption isotherm was conducted on sample ISO052-7. Based on the adsorption isotherm analysis described herein, the resultant methane storage capacity for sample ISO052-7 on an experimental and 100% TOC basis are 115.53 and 957.17 scf/ton, respectively (at the assumed reservoir pressure of 1,481.51 psia). Figure 1 illustrates the experimental gas storage capacity data. Sample description and critical gas storage capacity data are summarized in Table 1. Because TICORA was not involved in long term desorption analysis, the in-situ gas content, initial sorbed gas saturation value, critical desorption pressure, and gas recovery factor are unknown.

Table 1. Sample Description and Critical Gas Storage Capacity Data

Parameter	Units	Value
Well	-	Holt #19 & EFU #9-41
Location	-	Unknown
County	-	Unknown
State	-	Unknown
Sample Type	-	Shale
Reservoir Depth	feet	3421.0-3422.0
Reservoir Pressure	psia	1,481.51
Reservoir Temperature	°F	130.00
Sample Characterization		
TICORA Sample Number	-	ISO052-7
Moisture holding capacity	wt. fraction	0.0152
Assumed ash content (in-situ)	wt. fraction	0.8793
TOC content (in-situ)	wt. fraction	0.1207
Mean Maximum Vitrinite reflectance	%	0.6200
Coal Rank Classification (ASTM D 388)	-	Carbonaceous Shale
In-Situ Gas Storage Capacity Data		
In-Situ Langmuir Volume	scf/ton	262.60
In-Situ Langmuir Pressure	psia	1,885.97
In-Situ Gas Storage Capacity	scf/ton	115.53

Figure 1. Gas Storage Capacity vs. Pressure



The properties of the sample aliquot used for the analysis and the experimental sorption isotherm results are provided in Table 2. The experimental sorption isotherm and the 100% TOC results are graphically presented in Figure 2 and Figure 3 respectively. Please refer to *Appendix B, Methane Gas Storage Capacity*, to review the raw methane adsorption isotherm data.

Table 2. Experimental Sample Aliquot Properties and Sorption Isotherm Results

Parameter		Units	Value		
Experimental Gas		-	methane		
Experimental Temperature		°F	130.15		
Sample Mass		g	169.62		
Sample Density (Void Volume Based)		g/cc	2.22		
Pre-experiment Moisture Content		wt. fraction	0.0152		
Post-experiment Moisture Content		wt. fraction	0.0152		
Experimental Ash Content		wt. fraction	0.8793		
Minimum Experimental Pressure		psia	119.22		
Maximum Experimental Pressure		psia	2182.34		
Experimental Langmuir Volume		scf/ton	262.60		
Experimental Langmuir Pressure		psia	1885.97		
Experimental Langmuir Volume Range		scf/ton	0.85		
Experimental Langmuir Pressure		psia	653.23		
Step Number	Pressure	Experimental Gas Storage Capacity	Calculated Langmuir Fit Gas Storage Capacity	100% TOC Gas Storage Capacity	Calculated Langmuir Fit 100% TOC Gas Storage Capacity
	psia	scf/ton	scf/ton	scf/ton	scf/ton
1	119.2	17.59	15.61	145.71	129.35
2	519.5	53.64	56.71	444.37	469.85
3	930.9	84.13	86.79	697.01	719.02
4	1,351.0	105.57	109.60	874.66	908.05
5	1,768.3	125.34	127.07	1,038.41	1052.81
6	2,182.3	147.24	140.87	1,219.87	1167.08
Reservoir	1,481.5	-	115.53	-	957.17

Figure 2. Experimental Gas Storage Capacity Graph

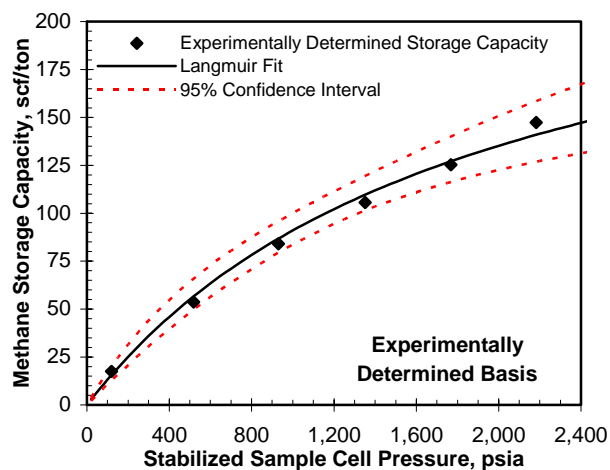
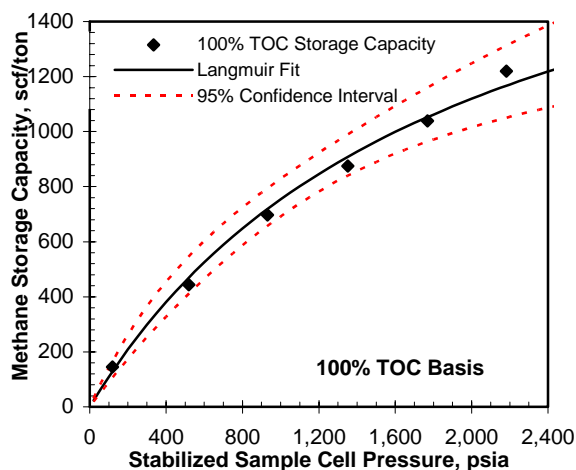


Figure 3. 100% TOC Gas Storage Capacity Graph

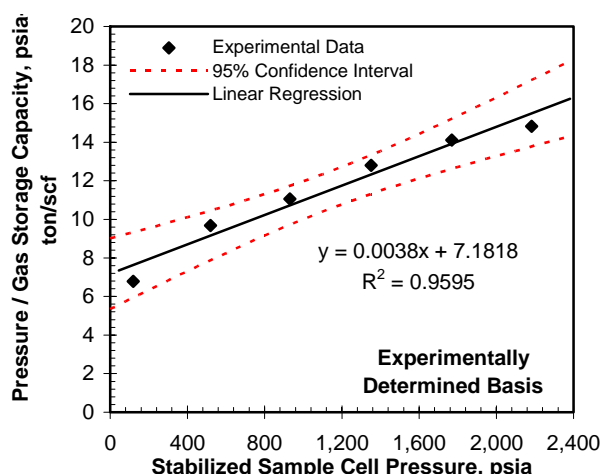


The sorption isotherm analytical results presented herein assume that the Langmuir relationship and model accurately predict the behavior of sorption reservoirs for the pressure and temperature conditions of most interest to coal and shale gas reservoir engineering. Table 3 and Figure 4 provide the results of the Langmuir regression obtained from the experimental sorption isotherm analysis data. Refer to *Appendix C, Langmuir Regression*, to review the raw Langmuir interpretation data.

Table 3. Langmuir Regression Interpretation Data

Parameter	Units	Value
Slope	ton/scf	0.0038
Intercept	psia*ton/scf	7.1818
Regression Coefficient (squared)	-	0.9595
Slope Variation	ton/scf	0.0014
Intercept Variation	psia*ton/scf	1.8398
GsL Variation	scf/ton	0.85
PL Variation	psia	653.23
Statistical Significance Level	-	0.95
Number of Data Points	-	6
T Distribution Value	-	3.50

Figure 4. Langmuir Interpretation Graph



2.0 SAMPLE PREPARATION²

One of the most significant errors in gas storage capacity measurements results from measuring isotherm data on samples that are not at in-situ moisture conditions. Poor sample handling procedures and/or preparation of a non-representative sample aliquot will also impact gas storage capacity results. A brief description of TICORA's sample preparation procedure is presented in this section.

2.1 Sample Reduction

Typically, a core sample is quickly crushed to ¼" size particles. The sample is wetted with a misting spray bottle during comminution to maintain excess surface moisture. Representative aliquots are removed for the various analyses and testing required for complete characterization of the core sample, including helium density, moisture holding capacity and sorption isotherm analysis. The remaining crushed core (Premium Sample) is sealed in a laminate bag purged with helium to prevent oxidation.

If a composite sample is required, then crushed aliquots are obtained from the premium samples of all core samples to be incorporated into the composite. These aliquots are combined and homogenized through staged grinding and riffing to produce a representative composite sample. The relative mass of each aliquot in the composite is determined on a weighted average basis. The sorption isotherm aliquot is further reduced to a particle size of minus 60 mesh.

2.2 Moisture Equilibration

Before testing, isotherm samples are equilibrated to inherent moisture content using an improved version of ASTM Method D1412-99 for determining the moisture holding capacity (MHC) of coal samples. The two most critical differences in the improved method used by TICORA are that equilibration is conducted at reservoir temperature (to more accurately reflect in-situ conditions) and the time the sample spends equilibrating at in-situ conditions is extended up to 30 days. After the equilibration process, MHC is determined on a portion of the larger (~ 200 grams) sorption isotherm sample. MHC is also determined for triplicate aliquots of the premium samples which the isotherm sample is comprised of. The results are then compared to ensure that the inherent moisture content of isotherm sample has not been affected by the differences in mass and particle size relative to the equilibrated moisture contents from the Premium Samples. The sorption isotherm sample is then sealed in a laminate bag purged with helium and placed in refrigerated storage until it is tested. Note that MHC is not conducted on shale samples due to the unique structure of the organic material found within shales, and other inherent problems when attempting to determine the MHC of shales.

3.0 SORPTION ISOTHERM ANALYSIS¹

Sorption isotherm data relate sorbed gas storage capacity to pressure and are necessary to predict the production behavior of sorption reservoirs such as found in coal seams and shale gas deposits. The difference between in-situ reservoir pressure and the critical desorption pressure defines the amount of pressure that must be decreased at the well head to enable the representative sample to begin desorbing the gas bound to its organic matter. Based upon the initial degree of saturation and the abandonment pressure, the percent recovery expresses the percentage of the gas content that can be extracted from the reservoir during the life of production. The following procedures are required to produce gas storage capacity data:

- Calculate reference and sample cell volumes using helium.
- Calculate the void volume present within the sample cell when sample is present within the vessel.
- Perform a sorption isotherm test with a given sorbing gas (CH_4 , CO_2 , N_2 , C_2H_6), using the resulting pressure and temperature data to calculate the number of molecules sorbed within the sample over a series of increasing pressure steps.

3.1 Cell Volume Determination

Before any type of sorption isotherm analysis can be conducted the volumes of the reference and sample cells must be accurately known. To determine the cell volumes a calibration test must be run twice, first with each cell empty, then with the sample cell filled with calibration bearings of a known volume. Each test is run using six pressure steps and the non-sorbing gas, helium. The calculated reference cell and sample cell volumes should be identical (relative to each individual cell) for all six pressure steps, but in reality there are slight volume variations each step (approximately $\pm 0.25 \text{ cm}^3$ deviation from the average) due to the limits of accuracy present in the various instrumental components. The highest and lowest determined cell volumes are discarded and the remaining four values are averaged. *Appendix A* includes the raw cell volume calibration data.

3.2 Sample Loading

The sample is weighed quickly on a precision balance accurate to .0001 grams. Regularly the sample's weight is in a continual state of flux upon the scale due to evaporation of moisture from the sample. Through experience it has been determined that subtracting ~ 0.005 grams from the last reading before removal from the scale is adequate to account for further moisture/weight loss that will occur between the time the sample is removed from the scale to the point it is loaded within the test vessel. After weighing, the sample is loaded into the sample cell and lowered into the controlled-temperature oil bath.

3.3 Void Volume Determination

Once the sample is loaded into the sample cell, the reference and sample cells are brought to reservoir temperature. The void volume is then determined similarly to cell volume calibration, using helium (a non sorbing gas) and six pressure steps. The highest and lowest determined void volumes are discarded and the remaining four are averaged. *Appendix A* also includes the raw void volume calibration data.

3.4 Sorption Isotherm Analysis

Once the void volume has been calculated, sorption isotherm analysis is conducted. The reference cell is charged with a sorbing gas to a pressure above the desired sample vessel equilibrium pressure. After the charged reference cell pressure reaches equilibrium, the valve between the sample cell and reference cell is opened and gas is allowed to flow into the sample cell. The valve between the vessels is closed and the sample and reference cell pressures are allowed to come to equilibrium. The reference cell is then recharged and the sequence of events is repeated.

The number of molecules sorbed onto a sample during a pressure step is determined based on material balance. The number of molecules sorbed is equal to the number of molecules that flow out of the reference cell into the sample cell, minus the number of remaining molecules in the void volume of the sample cell after the sample cell pressure equilibrates. The void volume includes the pore space within the sample and therefore is reduced from pressure step to pressure step as more and more porosity is filled with sorbed gas. This requires the void volume be recalculated for each step (Review Reference 1 for a more detailed discussion of this topic). The number of moles sorbed during a pressure step is converted to an equivalent scf/ton value and corrected for the change in void volume. Each individually determined pressure step storage capacity is added to the previously determined storage capacity and reported with the corresponding end sample equilibrium pressure.

Gas storage capacity results are typically converted to reflect storage capacity on a dry, ash free basis, etc. Such data, though theoretical, are useful for comparing samples that might vary in depth, ash content, moisture content, etc. The calculations to determine gas storage capacity on a moist, ash free basis, dry, ash free basis, in-situ basis, and dry, ash

and sulfur free basis are presented in Equations 1, 2, 3, and 4 respectively. *Appendix B* includes the raw gas storage capacity data.

$$G_{sma} = G_s \cdot 1/(1 - w_{ae}) \quad (1)$$

$$G_{sa} = G_s \cdot 1/(1 - w_{me} - w_{ae}) \quad (2)$$

$$G_{si} = G_{sa} \cdot (1 - w_{mi} - w_{ai}) \quad (3)$$

$$G_{sa\&s} = G_s \cdot 1/(1 - w_{me} - w_{ae} - w_{se}) \quad (4)$$

Where:

G_s	gas storage capacity, scf/ton
G_{sma}	moist, ash free gas storage capacity, scf/ton
G_{sa}	dry, ash free gas storage capacity, scf/ton
G_{si}	in-situ gas storage capacity, scf/ton
$G_{sa\&s}$	dry, ash and sulfur free gas storage capacity, scf/ton
w_{me}	experimentally determined moisture weight fraction
w_{ae}	experimentally determined ash weight fraction
w_{se}	experimentally determined total sulfur fraction
w_{mi}	in-situ moisture weight fraction
w_{ai}	in-situ ash weight fraction

To construct a mathematical fit to the resulting data, the Langmuir model is used. Plotting equilibrium pressure divided by calculated storage capacity vs. equilibrium pressure produces a linear relationship. The intercept and slope of the resulting linear function are used to produce the “Langmuir Parameters” (Langmuir pressure and Langmuir volume). Once the Langmuir parameters are determined one can model the gas storage capacity at any pressure. The mathematical model is defined by Equation 5. *Appendix C* includes the raw Langmuir regression data.

$$G_s = G_{sL} \cdot p / (p + P_L) \quad (5)$$

Where:

G_s	gas storage capacity, scf/ton
p	pressure, psia
G_{sL}	Langmuir Volume, scf/ton
P_L	Langmuir Pressure, psia

3.5 Sample Unloading

Once the sorption isotherm test has been completed, the sample cell pressure is reduced to slightly above atmospheric pressure. The sample begins to desorb the gas sorbed during the sorption isotherm test, causing the pressure inside the sample cell to rise. The pressure build up reduces repeatedly until all gas has been desorbed. The sample is then unloaded and a small aliquot is removed for post-isotherm MHC determination. Post-isotherm MHC is conducted in triplicate and the moisture content is compared to the MHC determined prior to isotherm analysis. This is done to ensure that the moisture content has remained stable and to ensure that the storage capacity results do indeed reflect in-situ conditions.

4.0 GAS STORAGE CAPACITY UNCERTAINTY AND ERROR PROPAGATION ¹

There are systematic and random errors associated with isotherm measurements. The systematic errors result from improper sample preparation and handling, use of an experimental temperature different from the actual reservoir temperature, errors in gas z factor estimates, and poor equipment calibration practices. Condensation of the sorbing gas of interest within the sample or reference cells can also occur when testing relatively high critical temperature gases (CO₂, C₂H₆, C₃H₈ for example), even at temperatures below the critical temperature. Examples of random errors are those that result from unintended exceptions to standard sample preparation procedures, cell pressure and temperature variations caused by laboratory condition and oil bath temperature variations, and temperature and pressure measurement fluctuations caused by electronic equipment and electrical power variations.

In an effort to reduce these errors, TICORA uses the most accurate gas density correlations available. All pressure transducers, thermocouples, and mass balances are calibrated or checked before each measurement. TICORA requests that the clients take special care in estimating reservoir temperature before requesting sorption isotherm analysis. The condensation conditions for gases are accurately known and avoided. We have reduced random errors by construction of an isolated, insulated, and temperature controlled isotherm laboratory that includes high quality (and expensive)

electrical control and battery backup systems. All of the electronic equipment used in the isotherm apparatus are the best quality available.

Independent and random uncertainties can be computed by differentiating the isotherm interpretation equations. The uncertainty estimated in this manner is generally expected to be a maximum uncertainty as it is unlikely that each parameter will be at its maximum accuracy limit during any one measurement. Equation 6 is the general error equation for a function of n variables, x_1 through x_n . The derivative values and the associated errors are computed for each parameter in the equations used to compute the reference cell, sample cell, and void volumes and the equation used to calculate the gas storage capacity for each isotherm step.

$$df(x_1, x_2, \dots, x_n) = \sqrt{\left(\frac{\partial f}{\partial x_1} dx_1\right)^2 + \left(\frac{\partial f}{\partial x_2} dx_2\right)^2 + \dots + \left(\frac{\partial f}{\partial x_n} dx_n\right)^2} \quad (6)$$

The calibration errors are used to estimate the uncertainty in each step of the isotherm measurements. The individual items are the combination of the partial derivative of the total gas storage capacity with respect to the parameter times the maximum error in the parameter. These parameters were squared and added in accordance with Equation 6 to estimate the total uncertainty. Refer to *Appendix B, Methane Gas Storage Capacity*, pp. 12, to review the total gas storage capacity uncertainty associated with the isotherm conducted for sample ISO052-7.

TICORA emphasizes that gas storage capacity data are not measured directly but are computed from measured pressure and temperature conditions. By taking great care to maximize measurement accuracy while minimizing systematic and random errors TICORA has found that we can measure gas storage capacity data with an average uncertainty of $\pm 5\%$ or less. TICORA takes pride in full disclosure of all data involved with sorption isotherm measurements.

5.0 REFERENCES

1. Mavor, M.J., Hartman, C., and Pratt, T.J.: "Uncertainty in Sorption Isotherm Measurements", paper 411, *Proceedings 2004 International Coalbed Methane Symposium*, University of Alabama, Tuscaloosa, AL (May 2004)
2. Testa, S.M. and Pratt, T.J.: "Sample Preparation for Coal and Shale Gas Resource Assessment", paper 356, *2003 International Coalbed Methane Symposium*, University of Alabama, Tuscaloosa, AL (May 5-9, 2003)
3. 2001 Annual Book of ASTM Standards, Volume 05.05 Gaseous Fuels; Coal and Coke, American Society for Testing and Materials, Philadelphia, PA (2001).

Appendix A

Cell Volume and Void Volume Calibration

Calibration Data with Empty Sample Cell									
Reference Cell									
Step Number	Step Start Time	Step Stop Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	0.48	0.48	0.01	143.75	97.03	1.00438	53.08	97.04	1.00162
2	2.78	3.24	0.47	315.82	97.05	1.00962	148.19	97.04	1.00451
3	3.88	4.43	0.56	504.11	97.05	1.01538	276.66	97.02	1.00843
4	20.36	21.11	0.75	1008.02	97.05	1.03083	539.23	97.05	1.01645
5	21.69	23.01	1.32	1575.27	97.07	1.04828	913.93	97.05	1.02794
6	23.97	25.85	1.88	2069.77	97.06	1.06353	1,320.52	97.03	1.04044
Sample Cell									
Step Number	Step Start Time	Step End Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	0.48	2.78	2.30	1.40	97.09	1.00004	52.99	97.11	1.00161
2	2.78	3.88	1.10	52.99	97.11	1.00161	147.90	97.13	1.00450
3	3.88	20.36	16.48	147.90	97.13	1.00450	276.38	97.12	1.00842
4	20.36	21.69	1.33	276.38	97.12	1.00842	538.09	97.14	1.01641
5	21.69	23.97	2.28	538.09	97.14	1.01641	904.10	97.15	1.02763
6	23.97	25.85	1.88	904.10	97.15	1.02763	1,317.48	97.16	1.04034
Calibration Data with Calibration Bearinas in Sample Cell									
Reference Cell									
Step Number	Step Start Time	Step End Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	1.07	1.78	0.72	168.89	96.82	1.00514	89.32	96.76	1.00272
2	2.19	2.68	0.48	322.76	96.77	1.00984	210.63	96.76	1.00642
3	3.13	3.44	0.31	500.41	96.76	1.01527	361.06	96.74	1.01101
4	4.10	16.84	12.75	1001.19	96.72	1.03064	691.83	96.87	1.02113
5	18.46	21.83	3.37	1582.85	96.87	1.04854	1,150.68	96.87	1.03523
6	22.99	23.86	0.88	2398.39	96.84	1.07371	1,790.35	96.82	1.05494
Sample Cell									
Step Number	Step Start Time	Step End Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	1.07	2.19	1.13	3.39	96.95	1.00010	89.63	96.95	1.00273
2	2.19	3.13	0.93	89.63	96.95	1.00273	210.79	96.96	1.00642
3	3.13	4.10	0.97	210.79	96.96	1.00642	360.90	96.92	1.01100
4	4.10	18.46	14.36	360.90	96.92	1.01100	690.79	97.03	1.02110
5	18.46	22.99	4.53	690.79	97.03	1.02110	1,148.06	97.01	1.03514
6	22.99	23.86	0.88	1148.06	97.01	1.03514	1,785.66	97.01	1.05478

Appendix A (continued)

Sample Cell Void Volume Calibration Data									
Reference Cell									
Step Number	Step Start Time	Step End Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	1.14	18.35	17.21	164.45	129.98	1.00469	80.55	129.93	1.00230
2	19.08	19.56	0.48	350.65	129.93	1.01001	208.93	129.93	1.00596
3	20.06	22.43	2.38	512.75	129.94	1.01465	353.21	129.94	1.01008
4	23.02	24.35	1.32	990.98	129.94	1.02840	654.60	129.94	1.01872
5	43.97	45.31	1.34	1613.63	129.94	1.04637	1,105.39	129.92	1.03169
6	45.95	46.48	0.53	2377.77	129.93	1.06849	1,701.89	129.98	1.04891
Sample Cell									
Step Number	Step Start Time	Step End Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	1.14	19.08	17.94	3.53	129.96	1.00010	80.17	129.95	1.00229
2	19.08	20.06	0.98	80.17	129.95	1.00229	208.92	129.95	1.00596
3	20.06	23.02	2.97	208.92	129.95	1.00596	353.36	129.96	1.01009
4	23.02	43.97	20.94	353.36	129.96	1.01009	654.33	129.95	1.01872
5	43.97	45.95	1.98	654.33	129.95	1.01872	1,106.76	129.95	1.03173
6	45.95	46.48	0.53	1106.76	129.95	1.03173	1,704.10	130.01	1.04898

Cell Volume Calibration Data			
Step Number	Reference Cell Volume	Sample Cell Volume	Void Volume
	cm3	cm3	cm3
1	116.00	203.03	126.49
2	115.85	203.02	126.80
3	116.15	203.42	127.12
4	116.11	203.48	127.41
5	116.14	203.42	126.94
6	116.04	203.21	126.87
Average	116.05	203.26	126.94
Parameter		Value	Deviation From Average
		cm3	%
Interpretation Reference Cell Volume		116.07	0.0210
Interpretation Sample Cell Volume		203.27	0.0037
Interpretation Void Volume		126.93	-0.0048

Interpretation Parameters		
Parameter	Units	Value
Sample Mass	g	169.62
Sample Density (Void Volume Based)	g/cm3	2.22
Total Calibration Bearings Volume	cm3	96.53
Helium Molecular Weight	g/gmole	4.0026
The N.I.S.T Pure Fluids Data Base was the Equation of State used to calculate all free gas densities.		

Appendix B

Methane Gas Storage Capacity

Methane Sorption End Point Data									
Reference Cell									
Step Number	Step Start Time	Step Stop Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	0.69	3.38	2.69	257.54	130.09	0.97910	119.77	130.08	0.99014
2	5.23	6.46	1.22	955.58	130.09	0.92944	519.87	130.10	0.95907
3	8.17	10.67	2.51	1,378.94	130.10	0.90633	931.99	130.09	0.93090
4	22.38	24.50	2.12	1,808.96	130.09	0.89012	1,349.91	130.10	0.90771
5	25.24	27.00	1.77	2,233.79	130.08	0.88235	1,766.51	130.12	0.89139
6	27.80	32.05	4.25	2,658.40	130.11	0.88302	2,179.62	130.09	0.88288
Sample Cell									
Step Number	Step Start Time	Step Stop Time	Step Elapsed Time	Pre-Open Pressure	Pre-Open Temp.	Pre-Open z Factor	Stabilized Pressure	Stabilized Temp.	Stabilized z Factor
	hours	hours	hours	psia	F	-	psia	F	-
1	0.69	5.23	4.54	2.58	130.12	0.99979	119.22	130.14	0.99019
2	5.23	8.17	2.93	119.22	130.14	0.99019	519.47	130.13	0.95911
3	8.17	22.38	14.21	519.47	130.13	0.95911	930.94	130.17	0.93101
4	22.38	25.24	2.86	930.94	130.17	0.93101	1,351.01	130.15	0.90769
5	25.24	27.80	2.57	1351.01	130.15	0.90769	1,768.34	130.16	0.89137
6	27.80	32.05	4.25	1768.34	130.16	0.89137	2,182.34	130.16	0.88291
Average Temperature								130.15	

Experimentally Determined Storage Capacity Data						
Step Number	Stabilized Sample Cell Pressure	Stabilized Sample Cell Gas Density	Gibbs Storage Capacity Correction Factor	Gibbs Storage Capacity	True Storage Capacity	100% TOC Storage Capacity
	psia	g/cm3	-	scf/ton	scf/ton	scf/ton
1	119.22	0.00489	1.0117	17.38	17.59	145.71
2	519.47	0.02199	1.0549	50.84	53.64	444.37
3	930.94	0.04060	1.1064	76.04	84.13	697.01
4	1,351.01	0.06043	1.1670	90.46	105.57	874.66
5	1,768.34	0.08054	1.2357	101.43	125.34	1,038.41
6	2,182.34	0.10035	1.3117	112.25	147.24	1,219.87

Appendix B (continued)

Propagated Uncertainty			
Step Number	Stabilized Sample Cell Pressure	Storage Capacity Uncertainty	100% TOC Storage Capacity Uncertainty
	psia	scf/ton	scf/ton
1	119.22	0.58	4.82
2	519.47	5.01	41.54
3	930.94	6.97	57.76
4	1351.01	9.43	78.13
5	1768.34	12.11	100.34
6	2182.34	14.79	122.55

Interpretation Parameters		
Parameter	Units	Value
Methane molecular weight	g/gmole	16.0428
Methane sorbed density	g/cm3	0.4234
Reference Cell Volume	cm3	116.07
Sample Cell Volume	cm3	203.27
Sample Cell Void Volume	cm3	126.93
The N.I.S.T Pure Fluids Data Base was the Equation of State used to calculate all free gas densities.		

Appendix C

Langmuir Regression

Experimental Storage Capacity Data			
Step Number	Stabilized Sample Cell Pressure	Storage Capacity	100% TOC Storage Capacity
	psia	scf/ton	scf/ton
1	119.22	17.59	145.71
2	519.47	53.64	444.37
3	930.94	84.13	697.01
4	1,351.01	105.57	874.66
5	1,768.34	125.34	1,038.41
6	2,182.34	147.24	1,219.87

Langmuir Regression Data		
Parameters	Storage Capacity	100% TOC Storage Capacity
Slope	0.0038	0.0005
Intercept	7.1818	0.8668
Regression Coefficient (squared)	0.9595	0.9595
Intercept Variation, psia*ton/scf	1.8398	0.2221
Slope Variation, ton/scf	0.0014	0.0002
GsL Variation, scf/ton	0.85	7.04
PL Variation, psia	653.23	653.23
Langmuir Volume, scf/ton	262.60	2175.66
Langmuir Pressure, psia	1885.97	1885.97

Calculated Langmuir Fit Storage Capacity Data			
Step Number	Stabilized Sample Cell Pressure	Storage Capacity	100% TOC Storage Capacity
	psia	scf/ton	scf/ton
1	119.22	15.61	129.35
2	519.47	56.71	469.85
3	930.94	86.79	719.02
4	1,351.01	109.60	908.05
5	1,768.34	127.07	1,052.81
6	2,182.34	140.87	1,167.08
Reservoir Pressure	1,481.51	115.53	957.17