ENERGY-FORENSICS

Strategic Oil & Gas Ltd.

Work Order-Ref #: 19084

Vapor Intrusion Assessment (VIA) Soils Outside Casing (AGM)

Strategic et al Cameron 2H-03

September 11 & 12, 2019

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FORENSIC SOLUTIONS FOR ENERGY CHALLENGES

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1.0 Executive Summary

On September 11-12, 2019, Strategic et al Cameron Hills 2H-03 was investigated for natural gas leakage in soils outside casing. Total combustible gas (%LEL) and H_2S field instruments levels were used to measure gas levels and types at test soil test sites. Gas samples were collected, contained and preserved from soils outside casing (AGM) and for baseline comparison, background locations, ~30m away from the well bore were also assessed.

Soils outside casing immediately adjacent to and S of the well bore were water saturated however, no gas bubbling was observed in standing water. A 104 site non-intrusive surface CH_4 scan was conducted in soils outside casing and at 3-background locations (N30m, E30m, and W30m). Two sites outside casing (N1m-E5m and E1m-S5m) contained elevated (6 and 10 ppm v/v, respectively) above background levels (2 ppm v/v) of methane gas. All other sites tested near the wellbore contained low CH_4 levels (2 ppm v/v) that were similar to the BKG sites. A total of 6 soil sites outside casing were assessed for gas leakage using an intrusive methodology where 5cm vapor test holes were augered into soils and Soil Vapor Probes (SVPs) were inserted into each test hole. Of the 6 soil vapor test sites outside casing, 3 sites (NE3m 15,600 ppm v/v, W5m 362 ppm v/v, and NW3m 145 ppm v/v) contained elevated, above background (N30m 22 ppm v/v and E30m 35 ppm v/v) levels of methane gas in SVPs. To aid in classifying combustible gas contents in soils, SOG selected 2 soil sites (NE3m and W5m) for chemical and $\delta^{13}C$ isotopic measurements. Soil sites NE3m and W5m contained high levels of CH_4 gas with low, similar to background levels of associated ΣC_2+ gas contents. $\delta^{13}C$ CH_4 and $\delta^{13}C$ CO_2 values were depleted when compared to thermogenic CH_4 gas and suggest that elevated %LEL values and associated CH_4 gas measured at the 2-soil sites are biogenic in origin where CH_4 is being generated via CO_2 reduction or fermentation pathways. Low levels of ΣC_2+ gases in soils outside casing at NE3m and W5m are the result of natural movement of light hydrocarbon gases from reservoirs at depth, upward through subsurface fractures and micro-fractures to surface. This is a naturally occurring process in all hydrocarbon sedimentary basins in the world.

With information available to date, soil vapor tests sites NE3m and W5m would be classified as 'Biogenic-Naturally Occurring CH_4-Non Impacted'.

2.0 Vapor Intrusion Assessment Summary

Operating Company: Strategic Oil & Gas Ltd.
Well Name: Strategic et al Cameron 2H-03
UWI: 3002H036010117300

License Number: 001992
Test Date September 11-12, 2019
GCHEM Project Number 19084

2.1 Production Casing Test Summary

Combustible Gas (CH_4) ([%LEL])	nm		
Hydrogen Sulphide (H_2S) Gas (ppm v/v)	nm		
PC Flow Rate (m^3/day)	nm		
P-T Date Logger Installed	nm		
P-T Data Logger Removed	nm		
P-T Data Logger Test Duration	nm		
MAX Pressure (kPa)	nm		
Gas Spls. Collection-Measurement	**Total Collected**	**Analysis Requested***	**Classification****
PC Samples (Total)	0		
PC Combustible Gas Class. Level-1 (Chemical)		NA	NA
PC Combustible Gas Class. Level-2 ($\delta^{13}C$)		NA	NA
PC Combustible Gas Class. Level-3 (δD)		NA	NA
PC Combustible Gas Class. Level-4 (^{14}C)		NA	NA

2.2 Surface Casing Vent Flow (SCVF) Test Summary

SCV Ten-Minute Bubble Test Result	nm		
SCV Flow Rate (m^3/day)	nm		
SCVF Pressure-Temp Logger Installed	nm		
SCV Pressure-Temp Data Logger Removed	nm		
SCV Shut-In Time (hrs)	nm		
SCV MAX-Recorded Build Up Pressure (kPa)	nm		
SCV Stabilized Build-up Pressure (kPa):	nm		
SCV Stabilized Build-up Time (hours)	nm		
SCV Standpipe Max CH_4 Content (% LEL):	nm		
SCV Standpipe Max H_2S Content	nm		
SCV Gas Spls. Collection-Measurement	**Total Collected**	**Analysis Requested***	**Classification****
SCV Samples (Total)	0		
SCV Combustible Gas Class. Level-1 (Chemical)		NA	NA
SCV Combustible Gas Class. Level-2 ($\delta^{13}C$)		NA	NA
SCV Combustible Gas Class. Level-3 (δD)		NA	NA
SCV Combustible Gas Class. Level-4 (^{14}C)		NA	NA

2.3 Soil Gas Migration-Vapor Intrusion Assessment: Soils Outside Casing (AGM) Summary

A) Non-Intrusive CH_4 Surface Soil Scan (PMD) (Figure-1 and Table-1)

Well Casing Surface CH_4 Test Sites	104
MAX Surface CH_4 Reading	10
MAX H_2S Well Soil Reading (ppm v/v)	<1
Number of Background Sites	3
MAX Background CH_4 (ppm v/v)	2
Max H_2S BKG Soil Reading (ppm v/v)	<1
Surface CH_4-PMD Gas Classification	

B) Non-Intrusive Surface Enclosed Soil Vapor FLUX Chamber Test

Surface SV-FC CH_4 Test Sites	nm
MAX SV-FC CH_4 Reading	nm

SV-FC Gas Spls. Collection-Measurement	**Total Collected**	**Analysis Requested***	**Test Site**
SV-FC Samples (Total)	0		
SV-FC & Sites Requested for Level-1 Analysis		NA	NA
Combustible Gas Classification Level-1 (Chem.)		NA	
SV-FC & Sites Requested for Level-2 Analysis		NA	NA
Combustible Gas Classification Level-2 ($\delta^{13}C$)		NA	
SV-FC & Sites Requested for Level-3 Analysis		NA	NA
Combustible Gas Classification Level-3 (δD)		NA	
SV-FC & Sites Requested for Level-4 Analysis		NA	NA
Combustible Gas Classification Level-4 (^{14}C)		NA	

C) Intrusive Auger Test Holes with Soil Vapor Probes (Figure 2 and Table 2).

Number Soil Vapor Probe (SVP) Test Sites	6
MAX SVP CH_4 Reading (%LEL)	31.2
Max H_2S SVP Field Reading (ppm v/v)	<1
Number SVP BKG Test Sites	3
MAX SVP CH_4 BKG Test Sites (ppm v/v)	35

SVPs Gas Spl. Collection & Measurement	**Total Collected**	**Analysis Requested***	**Test-Site**
Soil Vapor Probes (SVPs) AGM (Total)	3		
SVPs & Sites Requested for Level-1 Analysis		2	NE3m, W5m
Combustible Gas Classification Level-1 (Chem.)		Biogenic-Non Impacted	
SVPs & Sites Requested for Level-2 Analysis		2	NE3m, W5m
Combustible Gas Classification Level-2 ($\delta^{13}C$)		Biogenic-Non Impacted	
SVP & Sites Requested for Level-3 Analysis		0	NA
Combustible Gas Classification Level-3 (δD)		NA	
SVP & Sites Requested for Level-4 Analysis		0	NA
Combustible Gas Classification Level-4 (^{14}C)		NA	

BKG Gas Spl. Collection-Measurement	Total Collected	Analysis Requested*	Test Site
BKG Soil Vapor Probe (SVPs) (Total)	2		
SVPs & Sites Requested for Level-1 Analysis		1	BKG E30m
Combustible Gas Classification Level-1 (Chem.)		Biogenic-Naturally Occurring-Baseline	
SVPs & Sites Requested for Level-2 Analysis		0	
Combustible Gas Classification Level-2 ($\delta^{13}C$)		NA	
SVP & Sites Requested for Level-3 Analysis		0	
Combustible Gas Classification Level-3 (δD)		NA	
SVP & Sites Requested for Level-4 Analysis		0	
Combustible Gas Classification Level-4 (^{14}C)		NA	

**** Sample selection for chemical and isotopic analysis (geochemical analytical suite) selected by client/operator.***

2.4 Interpreted Source of Natural Gas Found at/near Surface: measured depth from KB of the well (Figures 3 to 6).

Sample Point	Geologic Formation	Depth Range	Source Depth
SVP NE3m & W5m	Near Surface Soil Respiration	Biogenic CH_4, NON-Impacted, Baseline	

3.0 Background of Vapor Intrusion Assessments (VIA) at Resource Wells & Tracing Gas Contents in the Environment using Energy Forensics

Undesired natural gas leakage from depth to surface at resource wells is becoming increasingly recognized and is a significant financial burden to the resource industry. When high levels of natural gas are found in the surface casing vent it is termed surface casing vent flow (SCVF) and when found in soils outside casing it is termed active gas migration (AGM). Identifying the source of leaking gas, maintaining zonal isolation and eliminating gas leakage to surface has proven to be a challenging task. Industry success rates using conventional gas leakage identification tools (e.g. noise, temperature, cement bond-integrity, ultra-sonic imaging logs, etc.) to eliminate surface gas migration in the first attempt is approximately 15% to 20%. Since 1997, through collaboration with industry, government regulators and academic institutions, GCHEM Ltd. has developed 'Energy-Forensics' and has obtained extensive expertise in field testing, gas sampling and preservation, analytical and interpretational techniques to pinpoint the geologic source of natural gases at resource wells.

It is important to note that detection of elevated combustible gases at surface does not always mean the well is impacted with deep sourced natural gas (thermogenic). Accurate gas characterization at well sites is critical as elevated CH_4 (%LEL) contents measured at or near surface may not indicate it is leaking or impacted (false-positive) but rather the combustible gases present are the result of biogenic activity or hydrocarbon contamination (or a combination of).

Thermogenic hydrocarbon gases have unique chemical and isotopic signatures based on many variables including the starting organic material they are produced from, the chemical processes from organic origin to current form, interaction with surrounding formation rock and fluids, and effects from migrating from origin to current trap. For example, molecular and isotopic composition ($\delta^{13}C$ and $\delta^{2}H$) of a low temperature, shallow sourced natural gas is significantly different with respect to those of a high temperature deep sourced natural gas. This principle allows the geologic source of leaking natural gas at a wellbore to be determined.

3.1 Biogenically Derived Methane Gas

As a normal part of soil respiration, methane may be generated via two biotic pathways (depending on substrate availability):

CO_2 reduction reaction	$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$
Fermentation Process	$CH_3COOH \rightarrow CH_4 + CO_2$

Biogenic methane gas may be further oxidized by bacteria. Oxidizing bacteria in soils preferentially consume ^{12}C over ^{13}C resulting the residual gas enriched in ^{13}C (i.e. $\delta^{13}C$ values become less negative) with respect to the biogenic gas (isotope enriching effect). Therefore, biogenic oxidization may provide the false signature of a 'mixture of biogenic and thermogenic methane' or 'thermogenic' gas (GCHEM in prep). Biogenic CH_4 is generally prevalent in landfill or swamp gas.

3.2 Thermogenic Methane Gas

Methane gas can be generated by abiotic processes such as the thermo-degradation of organic matter at high pressure and temperature (thermogenesis). During thermogenic CH_4 generation, pending organic matter content, pressure and temperature, associated C_2+ gases may also be formed. Thermogenic CH_4 and C_2+ gases contain enriched $\delta^{13}C$ and δD values pending gas maturity, mixing and alteration and torturous pathway from source to trap.

3.3 Classification, Characterization and Geological Origins of Combustible Gases in the Environment.

Combustible gases in soils outside casing maybe classified and characterized (biogenic, thermogenic or mixed) using chemical, carbon and hydrogen and isotopic measurements and ^{14}C concentrations. Leaking thermogenic natural gas in soils outside casing is easier to scientifically prove than biogenic methane sources. Elevated %LEL measured in AGM (on location) maybe the result of naturally occurring biogenic processes, anthropogenic leaking thermogenic natural gases and mixtures of both. A systematic 4-level approach can be used to determine the origins (biogenic-thermogenic or mixed) combustible gas contents and include:

1) **Level-1 Characterization** — **High Resolution Compositional-Chemical Measurements.**

Permanent, inert and CH_4 to n-C_5H_{12} & C_6+.

See NGGC-1 CH_4 vs ΣC_2+ (Szatkowski et al 2000 & 2001).

See NGGC-2 C_2H_6 vs. c_6+ (Szatkowski et al 2000 & 2001).

2) **Level-2 Characterization** — **Stable Carbon Isotope Measurements ($\delta^{13}C$).**

$\delta^{13}C$ CH_4 to n-C_5H_{12} & CO_2 (pending concentrations-gas levels).

See NGGC-3 $CH_4/\Sigma C_2$+ vs. $\delta^{13}C$ CH_4 (Bernard 1978).

See NGGC-4 $\delta^{13}C$ CO_2 vs. $\delta^{13}C$ CH_4 (Whiticar 1993).

3) **Level-3 Characterization** — **Hydrogen in Methane (δD).**

δD CH_4 to dD C_4H_{12} (pending concentrations-gas levels).

See NGGC-5 $\delta^{13}C$ CH_4 vs δD CH_4 (Coleman 1993).

4) **Level-4 Characterization** — **^{14}C pMC concentrations (radioactive ½ life of 5750 yr).**

Pending concentrations-gas levels.

^{14}C reveals the age of the organic matter source from which CH_4 was generated but not the time of methanogenesis.

To determine the geological origins of leaking thermogenic natural gas contents, a series of plots developed by GCHEM Ltd are used and include.

1) **Chemical & Isotopic Gas Field Diagram** $C_2H_6/\Sigma C_3$+ vs $\delta^{13}C$ C_2H_6 (Szatkowski et al 2000, 2001).
2) **Isotopic Gas Field Diagram** $\delta^{13}C$ C_2H_6 vs. $\delta^{13}C$ C_3H_8 (Szatkowski et al 2000, 2001).
3) **Modified Chung Plot** $\delta^{13}C$ vs 1/n (carbon & hydrogen number) (Chung 1988, and GCHEM Ltd. Unpublished).

Additional chemical and stable carbon and hydrogen isotopic plots have been developed to aid in determining the geological origins of natural gas found in the environment however, GCHEM has not published these novel and new correlations and relationships and they will not be shown or discussed in detail at this time (GCHEM Unpublished Internal Research).

4.0 Methods and Results

4.1 Field Assessment Methods and Results

4.1.1 Non-Intrusive Vapour Intrusion Assessment

On September 11, 2019, GCHEM conducted a surface soil methane scan using a Sensit PMD (Figure 3). CH_4 readings were measured at 104 locations on a grid pattern (1m x 1m) covering approximately an 10m x 10m square area around the marked wellbore. Soils outside casing were wet (standing water in some areas) however, no gas bubbling in standing water was observed while conducting the VIA in soils outside casing.

To establish background surface CH_4 gas levels a distance away from the well bore, three locations (30m north, 30m east, and 30m west of the wellbore) were also assessed. To enhance results of the surface methane scan and reduce potential effects from industrial contamination, at each test site, an atmospheric CH_4 gas level was recorded, the PMD gas sampling wand was coupled to surface soils and the CH_4 level was recorded for that specific test site. Atmospheric CH_4 level was subtracted from the CH_4 level measured after ground coupling to derive a surface soil CH_4 level at that point of the grid.

Two sites (N1-E5 and E1-S5) contained elevated (6 and 10 ppm v/v, respectively) above background methane readings (2 ppm v/v). All other sites tested near the wellbore contained low levels of CH_4 (2 ppm v/v) that were similar to the BKG sites.

Figure 1. AGM Non-Intrusive Surface PMD

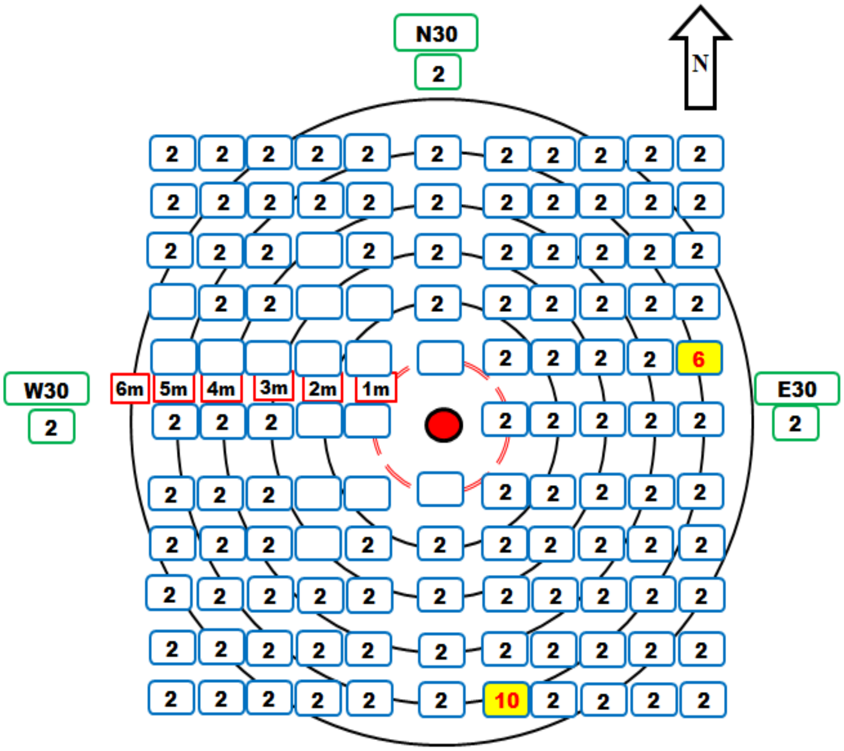


Figure-1A. NON-Intrusive CH_4 Surface Scan Well Casing Detail VIEW

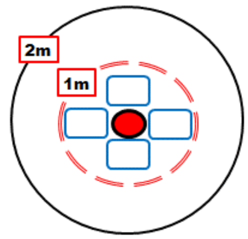


Table 1. AGM Non-Intrusive Surface PMD

WELL CASING (AGM) Non-Intrusive Surface PMD (CH_4) Soil Scan

Test Site (m)	PMD CH_4 (ppm v/v)	(% Vol)	Test Site (m)	PMD CH_4 (ppm v/v)	(% Vol)	Test Site (m)	PMD CH_4 (ppm v/v)	(% Vol)	Test Site (m)	PMD CH_4 (ppm v/v)	(% Vol)
N.5			E.5			S.5			W.5		
N1			E1	2		S1			W1		
N2	2		E2	2		S2	2		W2		
N3	2		E3	2		S3	2		W3	2	
N4	2		E4	2		S4	2		W4	2	
N5	2		E5	2		S5	2		W5	2	
N5-E1	2		E5-S1	2		S5-W1	2		W5-N1		
N4-E1	2		E5-S2	2		S4-W1	2		W5-N2		
N3-E1	2		E5-S3	2		S3-W1	2		W5-N3	2	
N2-E1	2		E5-S4	2		S2-W1	2		W5-N4	2	
N1-E1	2		E5-S5	2		S1-W1			W5-N5	2	
N1-E2	2		E4-S5	2		S1-W2			W4-N5	2	
N2-E2	2		E4-S4	2		S2-W2			W4-N4	2	
N3-E2	2		E4-S3	2		S3-W2	2		W4-N3	2	
N4-E2	2		E4-S2	2		S4-W2	2		W4-N2	2	
N5-E2	2		E4-S1	2		S5-W2	2		W4-N1		
N5-E3	2		E3-S1	2		S5-W3	2		W3-N1		
N4-E3	2		E3-S2	2		S4-W3	2		W3-N2	2	
N3-E3	2		E3-S3	2		S3-W3	2		W3-N3	2	
N2-E3	2		E3-S4	2		S2-W3	2		W3-N4	2	
N1-E3	2		E3-S5	2		S1-W3	2		W3-N5	2	
N1-E4	2		E2-S5	2		S1-W4	2		W2-N5	2	
N2-E4	2		E2-S4	2		S2-W4	2		W2-N4	2	
N3-E4	2		E2-S3	2		S3-W4	2		W2-N3		
N4-E4	2		E2-S2	2		S4-W4	2		W2-N2		
N5-E4	2		E2-S1	2		S5-W4	2		W2-N1		
N5-E5	2		E1-S1	2		S5-W5	2		W1-N1		
N4-E5	2		E1-S2	2		S4-W5	2		W1-N2		
N3-E5	2		E1-S3	2		S3-W5	2		W1-N3	2	
N2-E5	2		E1-S4	2		S2-W5	2		W1-N4	2	
N1-E5	6		E1-S5	10		S1-W5	2		W1-N5	2	

BACKGROUND Non-Intrusive Surface PMD (CH_4) Soil Scan

Test Site (m)	PMD CH_4 (ppm v/v)	(%)	Test Site (m)	PMD CH_4 (ppm v/v)	(%)	Test Site (m)	PMD CH_4 (ppm v/v)	(%)	Test Site (m)	PMD CH_4 (ppm v/v)	(%)
N30	2		E30	2		W30	2				

4.1.2 Intrusive Vapor Intrusion Assessment

A total of 6 soil sites outside casing were assessed for gas leakage using an intrusive methodology where a series of 5cm soil vapor test holes were augered into soils and Soil Vapor Probes (SVPs) were inserted into each test hole. The SVPs were allowed to stabilize for approximately 30-minutes prior to combustible gas content measurement with the PMD (Figure 4). Soils were water saturated at some sites at depths below 1.5m thus a full intrusive 16-auger hole test pattern could not be conducted. Of the 6 soil vapor test sites outside casing, 3 sites (NE3m 15,600 ppm v/v, W5m 362 ppm v/v, and NW3m 145 ppm v/v) contained elevated, above background levels (N30m 22 ppm v/v and E30 35 ppm v/v) of methane gas.

Figure 2. AGM Intrusive SVPs

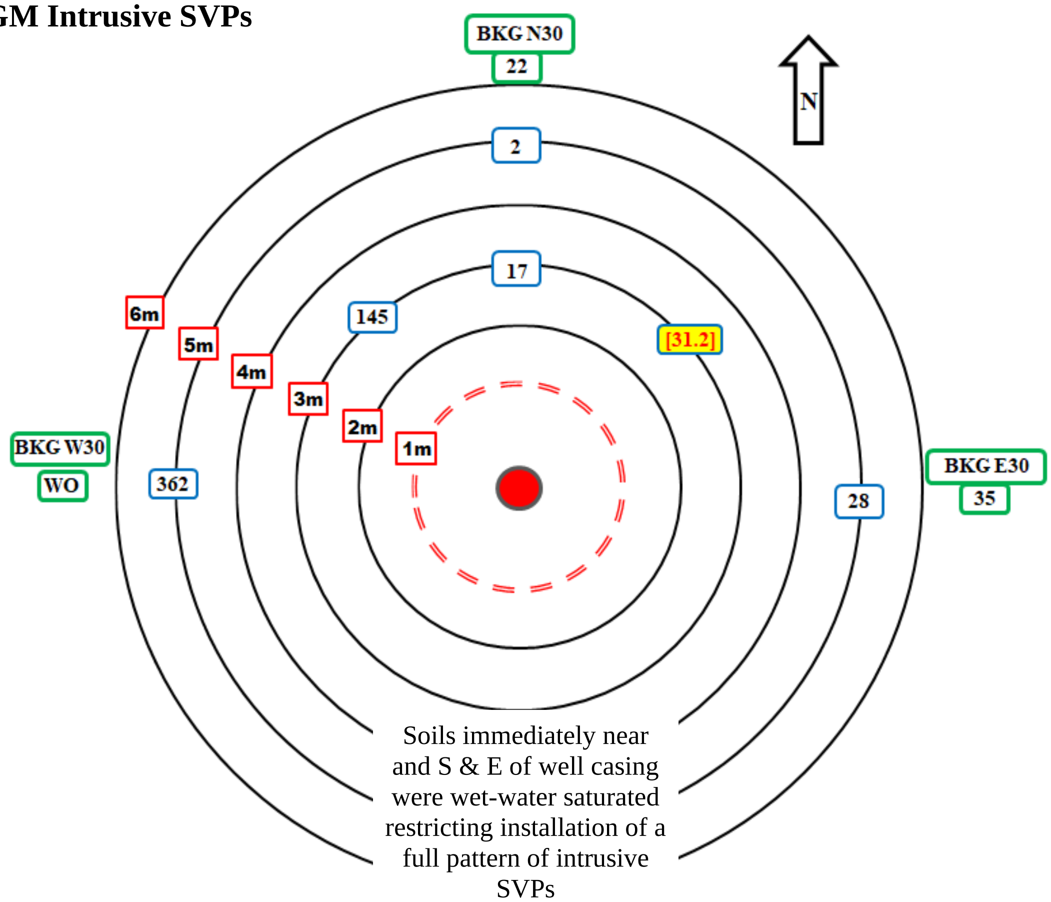


Table 2. AGM Intrusive SVPs

Intrusive AGM - Hand Auger-Test Hole-Install Soil Vapor Probes (SVPs) ATM-Isolated

Test Site (m)	Soil Vapor Probes IR-CH_4 (ppm v/v)	IR-CH_4 (% LEL)	H_2S (ppm v/v)	Soil Parameters Type	Moist. (1-5)	HC-CONT (Y-N)	Gas Sample (Y-N)	Site Assessment Comments
N1			<1.0	Si	5	No		
N3	17		<1.0	Si	5	No		
N5	2		<1.0	Si	5	No		
NE3	15600	[31.2]	<1.0	Si	5	No	Yes	
E1								
E3								
E5	28		<1.0	Si	5	No		
S.5								
S1								
S3								
S5								
W.5								
W1								
W3								
W5	362		<1.0	Si	5	No	Yes	
NW3	145		<1.0	Si	5	No	Yes	

Test Site (m)	Soil Vapor Probes IR-CH_4 (ppm v/v)	IR-CH_4 (% Vol)	H_2S (ppm v/v)	Soil Parameters Type	Moist. (1-5)	HC-CONT (Y-N)	Gas Sample (Y-N)	Site Assessment Comments
BKG E30	35		<1.0	Si	5	No		
BKG N30	22		<1.0	Si	5	No		
BKG W30	WO		<1.0	Si	5	No		Final SVP -Watered Out

4.2 Analytical Methods

a. High Resolution Compositional Analysis (HRCA).

   i. He, H_2, O_2, N_2, CO_2, CH_4 to n-C_5H_{12} & C_6+

b. Stable Carbon ($\delta^{13}C$) and Hydrogen (δD) Isotopic Analysis.

   i. $\delta^{13}C$ CH_4 to n-C_5H_{12} and CO_2, and δD CH_4 to n-C_5H_{12}

Compositional (molecular) analyses were conducted at GCHEM's Analytical Laboratory using Hewlett Packard 5890 and Agilent 7890 Gas Chromatographs (GCs) configured for low (ppb v/v to ppm v/v) too high (vol. %) level detection of light alkane/alkene gases and atmospheric gas components. Chemical analysis of gases measured, and analytical error are shown in Table-1.

Stable carbon ($\delta^{13}C$) isotope ratios of light hydrocarbon gases (LHG) and carbon dioxide and hydrogen isotope ratios (δD) of LHG were also measured at GCHEM's Analytical Laboratory on a Thermo-Scientific MAT-253 Gas Chromatograph-Combustion-Continuous Flow-Isotope Ratio Mass Spectrometer (GC-C-CF-IRMS). Carbon isotope ratios are reported in delta (δ) notation and per mil (‰, parts per thousand) with respect to VPDB (Vienna Pee Dee Belemnite). Hydrogen isotope ratios are reported in delta (δ) notation and per mil (‰) with respect to VSMOW (Vienna Standard Mean Ocean Water).

Gas Component (ppmv)	Molecular Formula	Analytical Error (%)	Stable Carbon Isotopic Composition ($\delta^{13}C$)	Analytical Error (‰ VPDB)	Hydrogen Isotopic Composition (δD)	Analytical Error (‰ VSMOW)
Hydrogen	H_2	±7%	-	-	δD H_2	±10
Helium	He	±7%	-	-	-	-
Nitrogen	N_2	±7%	-	-	-	-
Oxygen	O_2	±7%	-	-	-	-
Carbon Dioxide	CO_2	±7%	$\delta^{13}C$ CO_2	±0.2	-	-
Hydrogen Sulphide	H_2S	±7%	-	-	-	-
Methyl Mercaptan	CH_4S	±7%	-	-	-	-
Ethyl Mercaptan	C_2H_6S	±7%	-	-	-	-
Thiophene	C_4H_4S	±7%	-	-	-	-
Dimethyl Disulfide	$C_2H_6S_2$	±7%	-	-	-	-
Methane	CH_4	±7%	$\delta^{13}C$ CH_4	±0.1	δD CH_4	±10
Ethane	C_2H_6	±7%	$\delta^{13}C$ C_2H_6	±0.2	δD C_2H_6	±10
Ethene	C_2H_4	±7%	$\delta^{13}C$ C_2H_4	±0.2	δD C_2H_4	±10
Propane	C_3H_8	±7%	$\delta^{13}C$ C_3H_8	±0.2	δD C_3H_8	±10
Propene	C_3H_6	±7%	$\delta^{13}C$ C_3H_6	±0.2	δD C_3H_6	±10
iso-Butane	i-C_4H_{10}	±7%	$\delta^{13}C$ i-C_4H_{10}	±0.2	δD i-C_4H_{10}	±10
normal-Butane	n-C_4H_{10}	±7%	$\delta^{13}C$ n-C_4H_{10}	±0.2	δD n-C_4H_{10}	±10
iso-Pentane	i-C_5H_{12}	±7%	$\delta^{13}C$ i-C_5H_{12}	±0.2	δD i-C_5H_{12}	±10
normal-Pentane	n-C_5H_{12}	±7%	$\delta^{13}C$ n-C_5H_{12}	±0.2	δD n-C_5H_{12}	±10
Hexane and higher	C_6+	±7%	-	-	-	-

Table 3. Gas components, isotopic compositions measured and the analytical error of the measurements at GCHEM's Analytical Laboratory.

5.0 Geochemical Measurements-Laboratory Results.

As part of this VIA (AGM), a total of 3 gas samples were collected, contained and preserved from the following locations or sample points: SVPs-soils outside casing (NE3m, W5m, and NW3m) and 2-BKG locations (N30m and E30m).

At the request of the Strategic Oil and Gas, chemical and $\delta^{13}C$ isotopic compositions were measured for gases obtained from two (NE3m and W5m) of the SVPs that contained elevated, above background, levels of combustible gases and one BKG SVP (E30m). High Resolution chemical and $\delta^{13}C$ isotopic compositions were measured at GCHEM's Forensic Lab and are provided in Table 4.

5.1 Gases Obtained from Soil Vapor Probes (SVPs).

Gases measured in two SVPs in soils near the well bore (NE3m and W5m) contain above atmospheric levels of CO_2 (32,153 and 2648 ppm v/v, respectively). Methane gas was elevated (106,535 and 324.7 ppm v/v, respectively) when compared to background level measured at BKG E30m (23.53 ppm v/v) (Table 4 and Figure 3). C_2+ gas levels in SVPs NE3m and W5m were low (2.19 ppm v/v and 0.21 respectively) and were similar to background levels (0.47 ppm v/v). High methane with low, associated C_2+ thermogenic gases suggests a biogenic or biotic source via CO_2 reduction or fermentation reactions for methane gas (Figure 3 and Figure 5). C_{6+} gas contents at SVPs sites NE3m and W5m were low (0.19 and 0.10 ppm v/v respectively) and suggest hydrocarbon contamination was not present at SVP test sites (Figure 4).

C_2+ gas levels at SVP sites NE3 and W5 were too low to measure $\delta^{13}C$ isotopic compositions. Sufficient levels of CO_2 were available for $\delta^{13}C$ at both sites and CH_4 at site NE3. $\delta^{13}C$ CO_2 at SVP W5 was -20.94 ‰ VPDB. $\delta^{13}C$ CH_4 and $\delta^{13}C$ CO_2 at SVP NE3 was -75.48 and -10.19 ‰ VPDB respectively (Table 4). These values are consistent with gases originating from a biogenic source (Figures 5 and 6).

Table 4. High resolution molecular and stable carbon isotopic compositions of gas samples collected as part of the VIA at Strategic et al Cameron 2H-03. Hydrogen isotopic compositions were not measured at the request of SOG.

Sample Point Date Collected Gas Component	NE3 Sept. 11-19 (ppm v/v)	W5 Sept. 11-19 (ppm v/v)	BKG E30 Sept. 11-19 (ppm v/v)
Hydrogen	14.33	4.88	4.39
Helium	2.01	2.25	2.37
Nitrogen	728523	778715	777048
Oxygen	132770	218305	220541
Carbon Dioxide	32153	2648	2380
Methane	106535	324.7	23.53
Ethane	<0.01	<0.01	<0.01
Ethene	<0.01	<0.01	<0.01
Propane	1.77	<0.01	<0.01
Propene	<0.01	<0.01	<0.01
iso-Butane	0.26	<0.01	<0.01
n-Butane	0.31	0.21	0.47
iso-Pentane	0.20	0.13	0.24
n-Pentane	0.11	<0.01	<0.01
C_6+	0.19	0.10	0.16
C1 Index (C1/ΣC2+)	48735	1547	50.02
C2 Index (C2/ΣC3+)	N/A	N/A	N/A
C3 Index (C3/ΣC4+)	4.31	N/A	N/A
C4 Index (C4/C5)	2.91	N/A	N/A
ΣC2+	2.19	0.21	0.47
ATM Ratio (N2/O2)	5.49	3.57	3.52
Vol % CO2 of TG	3.22	0.26	0.24
Vol % Lt. Alk. of TG	10.65	0.03	0.00
Vol % Lt. Alk. CH4	100.0	99.90	97.08
Vol % Lt. Alk. C2+	0.002	0.10	2.92
Vol % C2+ of TG	0.00	0.00	0.00
Stable Carbon Isotope Compositions (‰ VPDB)			
δ13C CH4	-75.48	nm	nm
δ13C C2H6	nm	nm	nm
δ13C C2H4	nm	nm	nm
δ13C C3H8	nm	nm	nm
δ13C C3H6	nm	nm	nm
δ13C i-C4H10	nm	nm	nm
δ13C n-C4H10	nm	nm	nm
δ13C i-C5H12	nm	nm	nm
δ13C n-C5H12	nm	nm	nm
δ13C CO2	-10.19	-20.94	nm
Stable Hydrogen Isotopic Compositions (‰ VSMOW)			
δD H2	nm	nm	nm
δD CH4	nm	nm	nm
δD C2H6	nm	nm	nm
δD C3H8	nm	nm	nm
δD i-C4H10	nm	nm	nm
δD n-C4H10	nm	nm	nm
14C Concentration (pMC)	nm	nm	nm

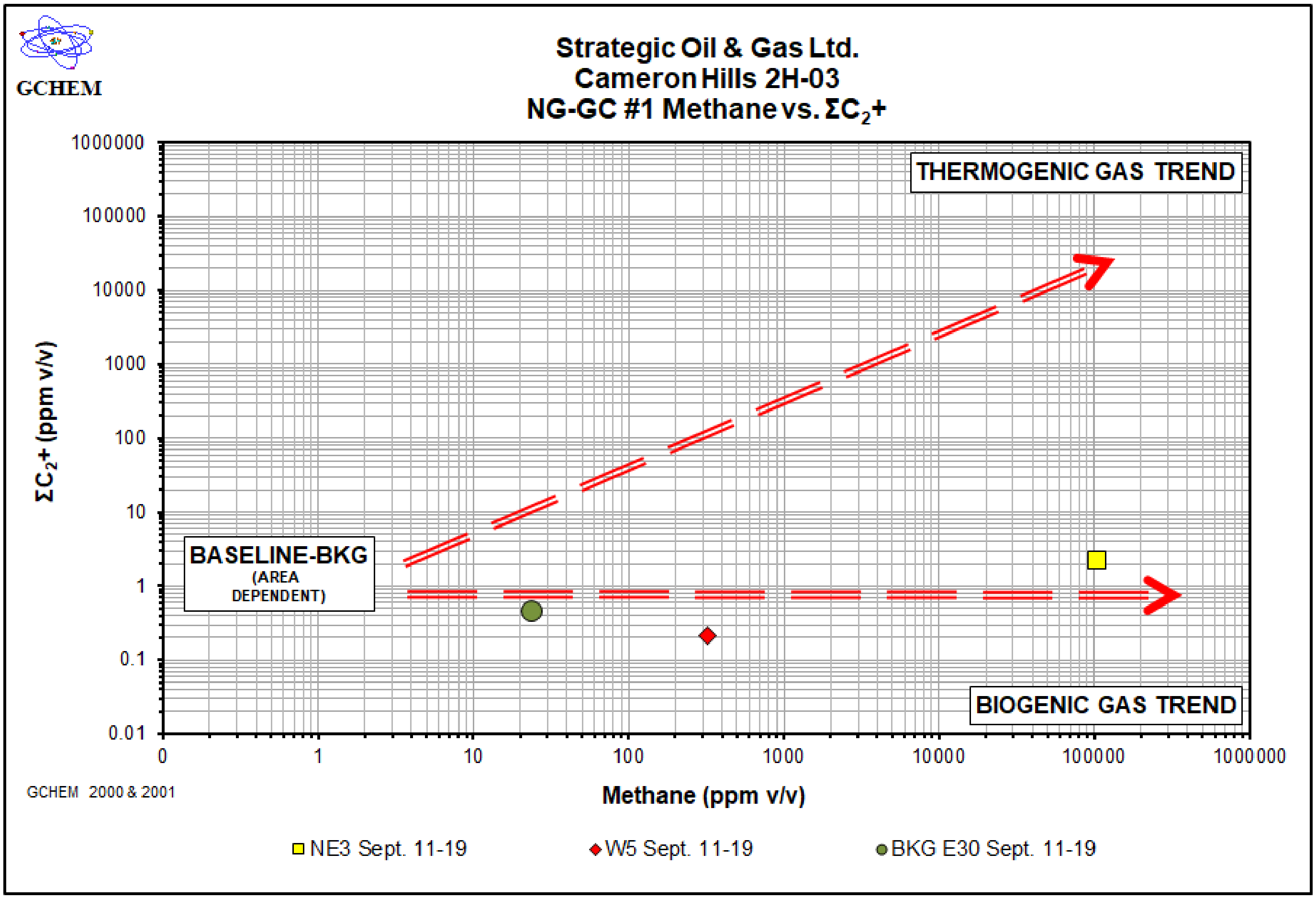


Figure-3. ΣC_2+ vs Methane. Combustible gases detected in soils and SCVs at a wellhead may result from several origins. Natural gases indicative of SCVF or AGM are thermogenic in origin (natural gas in deep reservoirs), contain high methane and C_2+ contents and plot in the Upper RH Quadrant. Low natural gas levels in background, off lease areas are naturally present in soils, vary from region to region and plot in the Lower LH Quadrant. Biogenic gases (swamp-gas) are produced by bacteria, are comprised of predominantly methane and plot in Lower RH Quadrant. Samples plotting in the Lower LH and RH do not contain SCVF or AGM and would not require down-hole remediation.

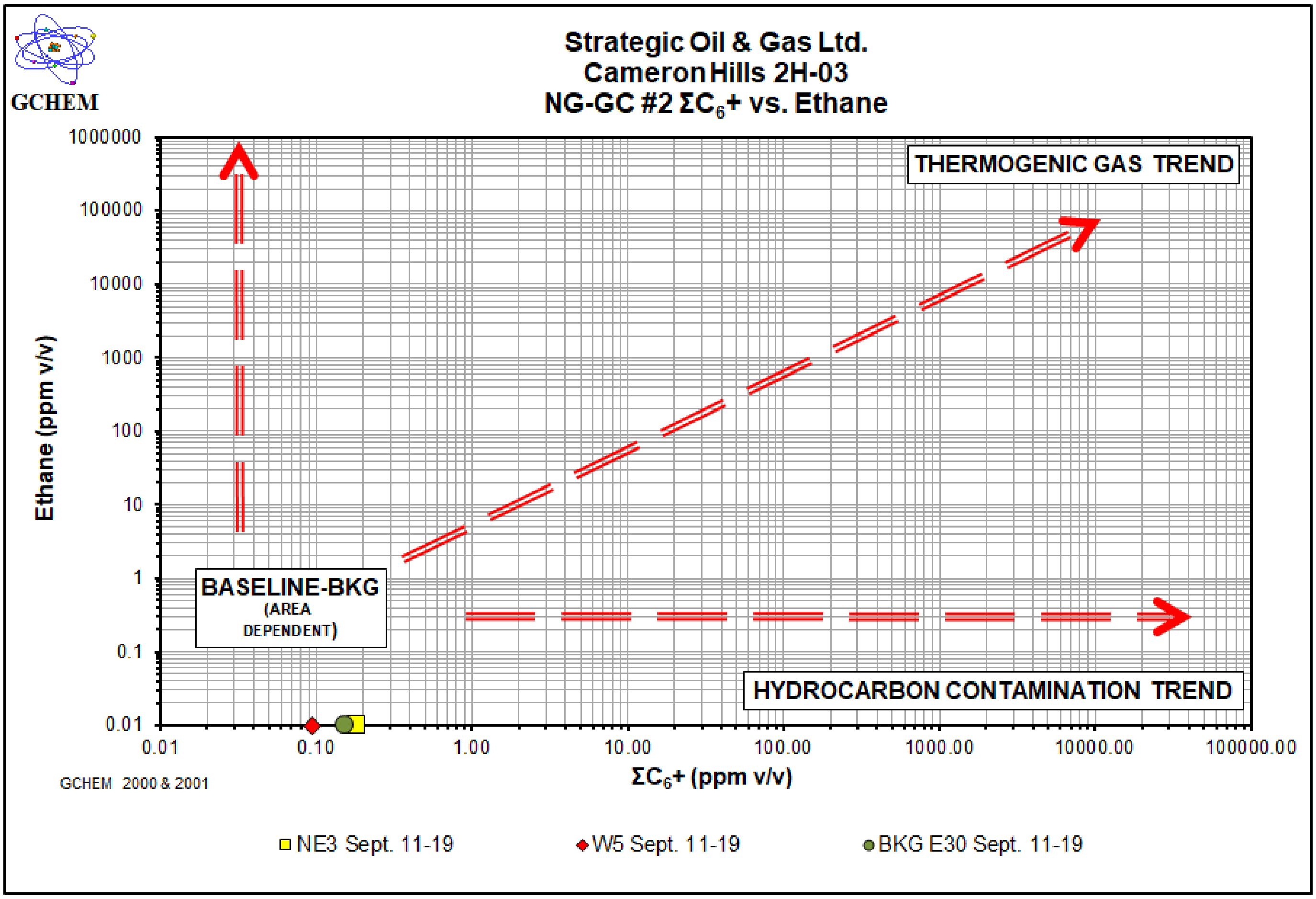


Figure 4. ΣC_6+ vs Ethane. C_6+ gases are relatively large molecules that do not readily or easily migrate in large quantities from depth upwards through subsurface fractures or micro-fractures to surface. Contamination by oil spills, fuels, and solvents is indicated by soil vapor samples that have high contents of C_6+ compounds and plot in the Lower RH Quadrant**.** Samples plotting in the Lower LH and RH Quadrants do not contain evidence of either SCVF or AGM and would not require downhole repair operations.

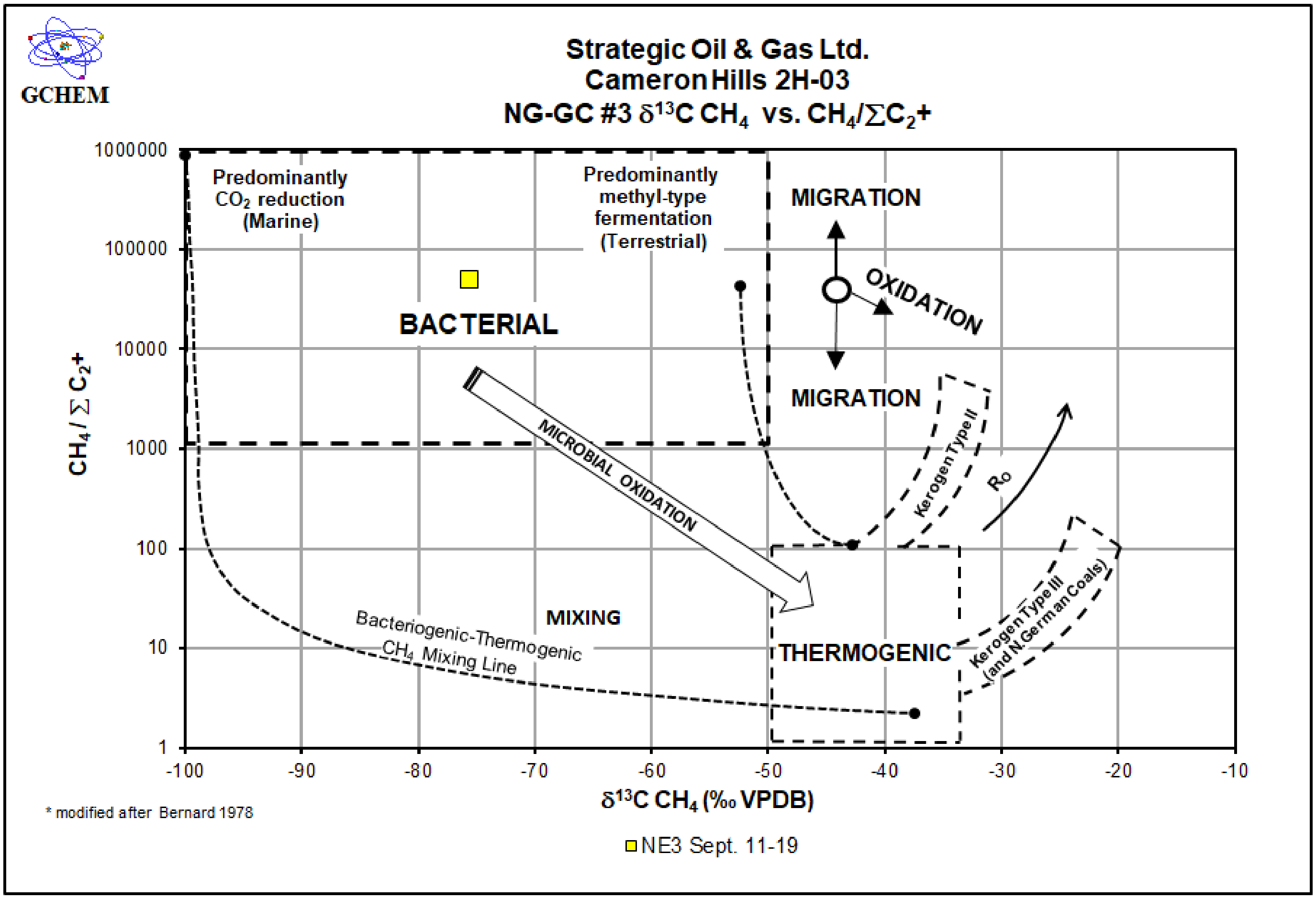


Figure 5. CH_4 / ΣC_{2+} vs. $\delta^{13}C$ CH_4. Thermogenic methane or methane generated by abiotic processes such as the thermal degradation of organic matter at high temperature and pressure (thermogenesis) contains enriched (less negative) $\delta^{13}C$ values ranging from -50 to -20‰ VPDB and methane relative to C_{2+} gas contents (gas wetness) less than 100. Methane gas can be generated by biotic processes such as the degradation of organic matter via CO_2 reduction or fermentation reactions generating biogenic methane. It should be noted that as a normal part of soil respiration, methane may be generated or destroyed by variable biotic pathways. Biogenic methane gas may be oxidized by bacteria resulting in an 'isotopic enriching effect' (i.e. $\delta^{13}C$ values become less negative as a result of oxidizing bacteria in soils that preferentially consume ^{12}C over ^{13}C, leaving the remaining gas enriched in ^{13}C). Since biogenic oxidization decreases the ratio between ^{12}C and ^{13}C, it may result in enriched $\delta^{13}C$ CH_4 values that overlap with the MIXING or THERMOGENIC-GAS TREND. Biogenic methane may therefore contain $\delta^{13}C$ values greater than -50‰ VPDB (GCHEM Internal RD).

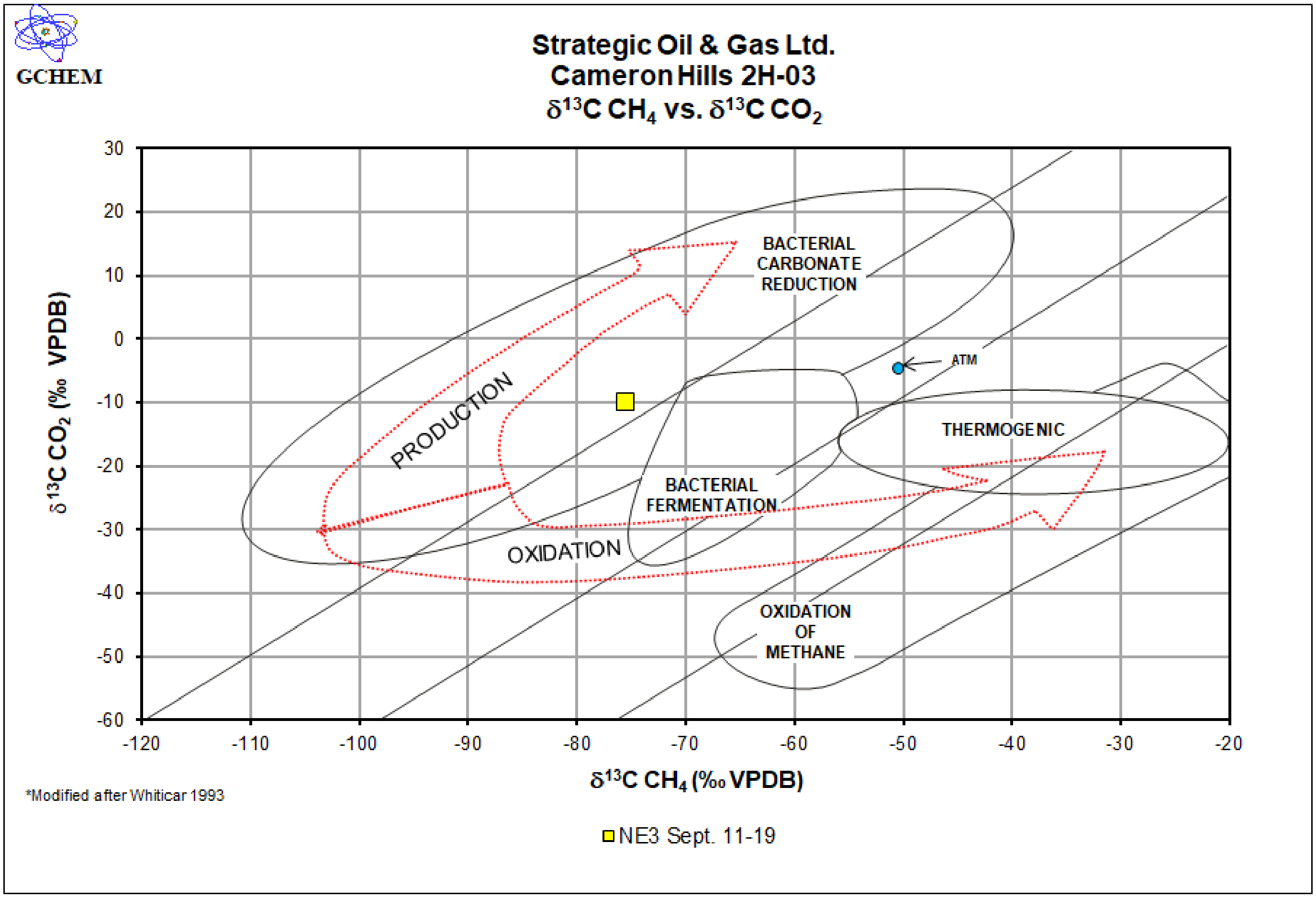


Figure 6. δ^{13}C CO_2 vs. δ^{13}C CH_4. Thermogenic methane or methane generated by abiotic processes such as the degradation of organic matter at high temperature and pressure contains enriched (less negative) δ^{13}C values ranging from -55 to -20‰ VPDB (or higher) and δ^{13}C CO_2 values in the range of -25 to 4‰ VPDB. Methane gas may be generated by biotic processes such as the degradation of organic matter via CO_2 reduction or fermentation reactions generating biogenic methane. Biogenic methane may contain δ^{13}C values greater than -40‰ VPDB due to biogenic oxidation processes (GCHEM, in prep).

6.0 Conclusions

Soils outside casing at SOG Cameron Hills 2H-03 are wet and provides challenges for AGM vapor intrusion assessments. 3 of the 6 intrusive soil sites outside casing assessed for combustible gas contents contained elevated methane levels that ranged from 145 to 15,600 ppm v/v. H_2S was not detected (< 1.0 ppm v/v) at any of the soil test hole sites. SOG selected sites NE3m (15,600 ppm v/v) and W5m (362 ppm v/v) for high resolution chemical and stable carbon isotope measurements to classify combustible gas contents. Light hydrocarbon gases were dominated by methane gas while associated C_2+ gases were low and similar to background levels measured at test site BKG E30m. Sufficient levels of methane gas were not available for $\delta^{13}C$ CH_4 or $\delta^{13}C$ C_2+ at test site W5m however, $\delta^{13}C$ CH_4 of -75.48 ‰ VPDB at soil test site NE3m is consistent with naturally occurring biogenic methane generation (bacterial degradation of organic matter generating biogenic CH_4 gas).

With information available to date, SVP soil test sites NE3m and W5m are classified as 'biogenic-baseline' where CH_4 gas is the result of natural soil respirations processes via CO_2 reduction or fermentation processes generating biogenic CH_4. C_2+ gases in soils near the well are low, similar to background levels and the result of natural movement of thermogenic natural gas, from reservoirs at depth, upward through fractures and micro-fractures to surface. This is a naturally occurring process prevalent in every hydrocarbon sedimentary basin in the world.

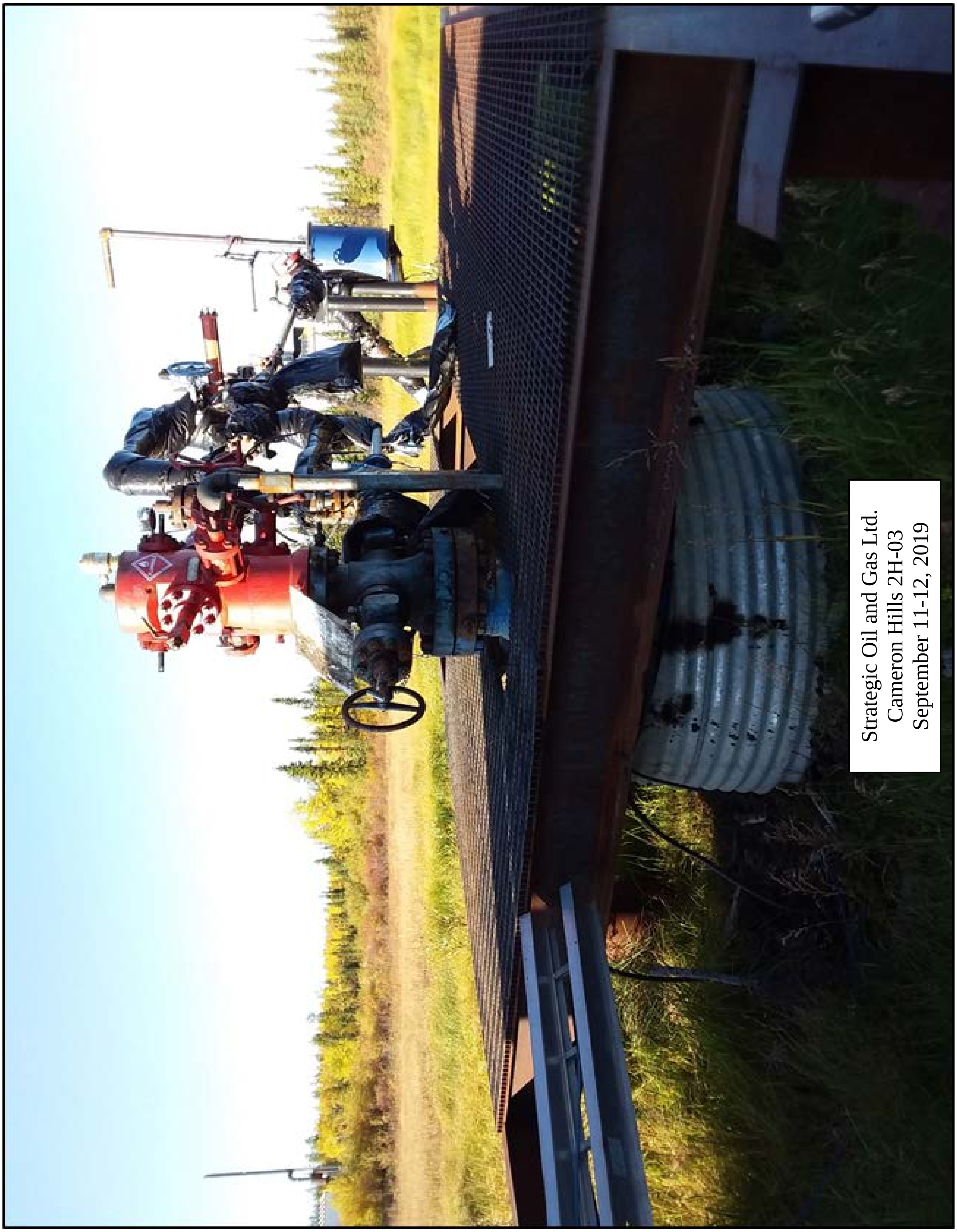
Attachment-1

Strategic Oil & Gas Ltd.

Strategic Cameron 2H-03

Well Site Photographs

Strategic Oil and Gas Ltd.
Cameron Hills 2H-03
September 11-12, 2019


Strategic Oil and Gas Ltd.
Cameron Hills 2H-03
September 11-12, 2019


Strategic Oil and Gas Ltd.
Cameron Hills 2H-03
September 11-12, 2019

Attachment-2

Strategic Oil & Gas Ltd.

Strategic Cameron 2H-03

Chain of Custody (COC)

GCHEM LTD. Bay#1, 4810-62nd Ave, Lloydminster, Alberta T9V 2E9
E:info@gchem.ca
Tel:(780) 871-4668
Fax:(780) 808-8883

CHAIN OF CUSTODY

ENERGY FORENSICS

Sample Submission Form

GCHEM Ltd. Project#______

Client Information

Company Strategic
Address
City,Prov.
Postal Code
Client Contact
Phone #
Fax #
E-Mail

Sampled By Walker, Brian

Billing/Report Information

Company
Address
City,Prov.
Postal Code
Client Contact
Phone #
Fax #
E-mail

AFE/PO #

Services Needed (TAT)

*Standard 5-7 Days ✓
**Rush 48hrs.____
**Priority Rush 24hrs.____

(*) Working Days
(**) Call for Pricing and Advance Notice

No.	Location	Sample Identifier	Sample Time	Date Sampled	Pressure Received	Actual Pressure	Container Type	Qty.	Sample Volume	Media Type	High Resolution Compositional Analysis	IRMS δ^2H (δD) Analysis	IRMS $\delta^{13}C$ Analysis	Produced Water Forensic Suite	High Resolution Compositional H_2S Analysis
1	2H 03	SoilGas - Initial		Sep 11/19			glass	3							
2		Background - Initial		Sep 11/19			glass	2							
3		SoilGas - final		Sep 12/19			glass	2							
4		Background - final		Sep 12/19			glass	1							
5															
6															
7															
8															
9															
10															

Comments

Relinquished By: [signature] Date/Time: Sep 16 2019 Relinquished To: Date/Time:
Relinquished By: Date/Time: Relinquished To: Date/Time:

Attachment-3

Strategic Oil & Gas Ltd.

Strategic Cameron 2H-03

Gas Sample Containers

Photographs

(red boxed pictures are samples measured for chemical and/or isotopic compositions)

NE3m
September 11, 2019

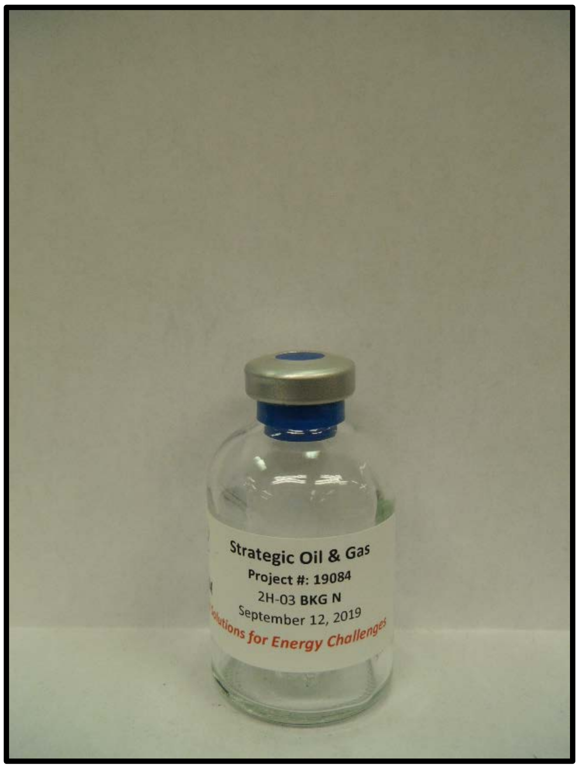
NW3m
September 11, 2019

W5m
September 11, 2019

BKG N30m
September 11, 2019

BKG E30m
September 11, 2019

NE3m
September 12, 2019



BKG N30m
September 12, 2019

Attachment-4

Strategic Oil & Gas Ltd.

Strategic Cameron 2H-03

Gas Analysis Data Sheets (GADS)

GCHEM LTD.

HIGH RESOLUTION GAS ANALYSIS
CARBON ISOTOPE ANALYSIS
HYDROGEN ISOTOPE ANALYSIS

Sampling Company	GCHEM Ltd.	**Lab Sample No.**	19084-03
Date Tested	September 11, 2019	**Test Type**	Soil gas
Operator Name	Strategic Oil & Gas	**Sample Container Type**	Glass Botlte
Unique Well Identifier	2H-03	**Sampling Point**	NE3
Well Name	not provided	**Test Intervals or Perfs mKB**	N/A
Field or Area	not provided	**Date Received**	September 16, 2019
Pool or Zone	not provided	**Date Reported**	October 1, 2019
Well License	not provided	**Entered By**	Xiaolong Wang
H2S Level (Observed at Site)	not provided	**Reviewed By**	Brad Johnston

Sample Handling Conditions

	Source/Sampled	Received
Pressure (kPa)	N/A	26
Temperature (°C)	N/A	20

Other Information:

Laboratory Analysis

Component	HRGC Analysis As Received Mol Frac.	Air Free As received Mol Frac.	Air Free / Acid Free As Received Mol Frac.	Carbon Isotope Analysis ‰ VPDB	Hydrogen Isotope Analysis ‰ VSMOW	HRGC Analysis As Received ppm v/v
Neon	0.000012	0.000087	0.000087			12.10
Hydrogen	0.000014	0.000103	0.000103			14.33
Helium	0.000002	0.000015	0.000015			2.01
Nitrogen	0.728523	0.000002	0.000002			728523
Oxygen	0.132770	0.000000	0.000000			132770
Carbon Dioxide	0.032153	0.231805	0.231805	-10.19		32153
Carbonyl Sulphide	nm	nm	nm			nm
Hydrogen Sulphide	nm	nm	nm			nm
Methyl Mercaptan	nm	nm	nm			nm
Ethyl Mercaptan	nm	nm	nm			nm
Thiophene	nm	nm	nm			nm
Dimethyl Disulphide	nm	nm	nm			nm
Methane	0.106535	0.768055	0.768055	-75.48		106535
Ethane	0.000000	0.000000	0.000000			<0.01
Ethene	0.000000	0.000000	0.000000			<0.01
Propane	0.000002	0.000013	0.000013			1.77
Propene	0.000000	0.000000	0.000000			<0.01
iso-Butane	0.000000	0.000002	0.000002			0.26
n-Butane	0.000000	0.000002	0.000002			0.31
iso-Pentane	0.000000	0.000001	0.000001			0.20
n-Pentane	0.000000	0.000001	0.000001			0.11
C_6+	0.000000	0.000001	0.000001			0.19
TOTAL	**1.000000**	**1.000000**	**1.000000**			1000000

Properties

Compositional Indicies	
Vol % Hydrocarbons	10.65
Vol % CH_4	100.00
Vol % C_2+	0.00
CH_4 / $\sum C_2$+	48735
C_2 / $\sum C_3$+	N/A
C_3 / $\sum$n-C_{4+}	4.31

Real Gross Heating Value (mj/m3) @15°C and 101.35 kPa	
Air Free as received	Moisture and Acid Gas Free
4.02	29.04

Relative Density	
Calc. Mol. Mass Ratio	Calc. Relative Density
0.9592	0.9594

Pseudo Critical Properties	As Received	Acid Gas Free
pPc (kPa)	3867	5248
pTc (°K)	143	217

Geological Origin of Natural Gas

Geological Formation	Depth Range (MD from KB of Well)	Probable Depth (MD from KB of Well)

Comments

Forensic Solutions for Oilfield Challenges

GCHEM Ltd. Bay #1, 4810-62 Avenue Lloydminster, AB T9V 2E9 Tel: (780) 871-4668 Fax: (780) 808-8883 e-mail: info@gchem.ca www.gchem.ca
GPA 2145-09. Revision 1.3, August 1, 2016

GCHEM LTD.

HIGH RESOLUTION GAS ANALYSIS
CARBON ISOTOPE ANALYSIS
HYDROGEN ISOTOPE ANALYSIS

Sampling Company	GCHEM Ltd.	**Lab Sample No.**	19084-05
Date Tested	September 11, 2019	**Test Type**	Soil gas
Operator Name	Strategic Oil & Gas	**Sample Container Type**	Glass Botlte
Unique Well Identifier	2H-03	**Sampling Point**	W5
Well Name	not provided	**Test Intervals or Perfs mKB**	N/A
Field or Area	not provided	**Date Received**	September 16, 2019
Pool or Zone	not provided	**Date Reported**	October 1, 2019
Well License	not provided	**Entered By**	Xiaolong Wang
H2S Level (Observed at Site)	not provided	**Reviewed By**	Brad Johnston

Sample Handling Conditions

	Source/Sampled	Received
Pressure (kPa)	N/A	56
Temperature (°C)	N/A	20

Other Information:

Laboratory Analysis

Component	HRGC Analysis As Received Mol Frac.	Air Free As received Mol Frac.	Air Free / Acid Free As Received Mol Frac.	Carbon Isotope Analysis ‰ VPDB	Hydrogen Isotope Analysis ‰ VSMOW	HRGC Analysis As Received ppm v/v
Neon	0.000015	0.005003	0.005003			14.91
Hydrogen	0.000005	0.001638	0.001638			4.88
Helium	0.000002	0.000755	0.000755			2.25
Nitrogen	0.778715	0.000000	0.000000			778715
Oxygen	0.218305	0.000003	0.000003			218305
Carbon Dioxide	0.002648	0.888513	0.888513	-20.94		2648
Carbonyl Sulphide	nm	nm	nm			nm
Hydrogen Sulphide	nm	nm	nm			nm
Methyl Mercaptan	nm	nm	nm			nm
Ethyl Mercaptan	nm	nm	nm			nm
Thiophene	nm	nm	nm			nm
Dimethyl Disulphide	nm	nm	nm			nm
Methane	0.000325	0.108946	0.108946			324.7
Ethane	0.000000	0.000000	0.000000			<0.01
Ethene	0.000000	0.000000	0.000000			<0.01
Propane	0.000000	0.000000	0.000000			<0.01
Propene	0.000000	0.000000	0.000000			<0.01
iso-Butane	0.000000	0.000000	0.000000			<0.01
n-Butane	0.000000	0.000070	0.000070			0.21
iso-Pentane	0.000000	0.000043	0.000043			0.13
n-Pentane	0.000000	0.000000	0.000000			<0.01
C_6+	0.000000	0.000032	0.000032			0.10
TOTAL	**1.000000**	**1.000000**	**1.000000**			1000000

Properties

Compositional Indicies	
Vol % Hydrocarbons	0.03
Vol % CH_4	99.90
Vol % C_2+	0.00
CH_4 / $\sum C_2$+	1547
C_2 / $\sum C_3$+	N/A
C_3 / $\sum$n-C_{4+}	N/A

Real Gross Heating Value (mj/m3) @15°C and 101.35 kPa	
Air Free as received	Moisture and Acid Gas Free
0.01	4.17

Relative Density	
Calc. Mol. Mass Ratio	Calc. Relative Density
0.9986	0.9986

Pseudo Critical Properties	As Received	Acid Gas Free
pPc (kPa)	3762	7063
pTc (°K)	133	291

Geological Origin of Natural Gas

Geological Formation	Depth Range (MD from KB of Well)	Probable Depth (MD from KB of Well)

Comments

Forensic Solutions for Oilfield Challenges

GCHEM Ltd. Bay #1, 4810-62 Avenue Lloydminster, AB T9V 2E9 Tel: (780) 871-4668 Fax: (780) 808-8883 e-mail: info@gchem.ca www.gchem.ca
GPA 2145-09. Revision 1.3, August 1, 2016

GCHEM LTD.

HIGH RESOLUTION GAS ANALYSIS
CARBON ISOTOPE ANALYSIS
HYDROGEN ISOTOPE ANALYSIS

Sampling Company	GCHEM Ltd.	**Lab Sample No.**	19084-02
Date Tested	September 11, 2019	**Test Type**	Soil gas
Operator Name	Strategic Oil & Gas	**Sample Container Type**	Glass Bottle
Unique Well Identifier	2H-03	**Sampling Point**	BKG E
Well Name	not provided	**Test Intervals or Perfs mKB**	N/A
Field or Area	not provided	**Date Received**	September 16, 2019
Pool or Zone	not provided	**Date Reported**	October 1, 2019
Well License	not provided	**Entered By**	Xiaolong Wang
H2S Level (Observed at Site)	not provided	**Reviewed By**	Brad Johnston

Sample Handling Conditions

	Source/Sampled	Received
Pressure (kPa)	N/A	53
Temperature (°C)	N/A	20

Other Information:

Laboratory Analysis

Component	HRGC Analysis As Received Mol Frac.	Air Free As received Mol Frac.	Air Free / Acid Free As Received Mol Frac.	Carbon Isotope Analysis ‰ VPDB	Hydrogen Isotope Analysis ‰ VSMOW	HRGC Analysis As Received ppm v/v
Neon	0.000014	0.005888	0.005888			14.20
Hydrogen	0.000004	0.001822	0.001822			4.39
Helium	0.000002	0.000982	0.000982			2.37
Nitrogen	0.777048	0.000000	0.000000			777048
Oxygen	0.220541	0.000005	0.000005			220541
Carbon Dioxide	0.002380	0.987075	0.987075			2380
Carbonyl Sulphide	nm	nm	nm			nm
Hydrogen Sulphide	nm	nm	nm			nm
Methyl Mercaptan	nm	nm	nm			nm
Ethyl Mercaptan	nm	nm	nm			nm
Thiophene	nm	nm	nm			nm
Dimethyl Disulphide	nm	nm	nm			nm
Methane	0.000024	0.009759	0.009759			23.53
Ethane	0.000000	0.000000	0.000000			<0.01
Ethene	0.000000	0.000000	0.000000			<0.01
Propane	0.000000	0.000000	0.000000			<0.01
Propene	0.000000	0.000000	0.000000			<0.01
iso-Butane	0.000000	0.000000	0.000000			<0.01
n-Butane	0.000000	0.000195	0.000195			0.47
iso-Pentane	0.000000	0.000098	0.000098			0.24
n-Pentane	0.000000	0.000000	0.000000			<0.01
C_6+	0.000000	0.000064	0.000064			0.16
TOTAL	**1.000000**	**1.000000**	**1.000000**			1000000

Properties

Compositional Indicies	
Vol % Hydrocarbons	0.00
Vol % CH_4	97.08
Vol % C_2+	0.00
CH_4 / ΣC_2+	50.02
C_2 / ΣC_3+	N/A
C_3 / Σn-C_{4+}	N/A

Real Gross Heating Value (mj/m3) @15°C and 101.35 kPa	
Air Free as received	Moisture and Acid Gas Free
0.00	0.44

Relative Density	
Calc. Mol. Mass Ratio	Calc. Relative Density
0.9989	0.9989

Pseudo Critical Properties	As Received	Acid Gas Free
pPc (kPa)	3764	7335
pTc (°K)	133	302

Geological Origin of Natural Gas

Geological Formation	Depth Range (MD from KB of Well)	Probable Depth (MD from KB of Well)

Comments

Forensic Solutions for Oilfield Challenges

GCHEM Ltd. Bay #1, 4810-62 Avenue Lloydminster, AB T9V 2E9 Tel: (780) 871-4668 Fax: (780) 808-8883 e-mail: info@gchem.ca www.gchem.ca
GPA 2145-09. Revision 1.3, August 1, 2016