ENERGY-FORENSICS

Heli Source

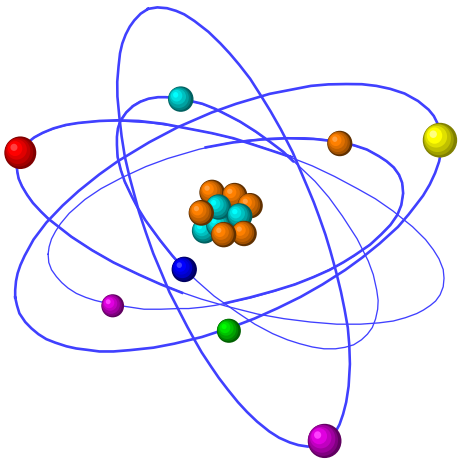
Work Order-Ref #: 21265

Vapor Intrusion Assessment (VIA)

Surface Casing Vent (SCV) Flow Test

Cameron Hills L-29

October 30, 2021



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FORENSIC SOLUTIONS FOR ENERGY CHALLENGES

1.0 Vapor Intrusions Assessment (VIA) Summary

Operating Company: Strategic Oil and Gas Ltd.
Well Name: Paramount et al Cameron Hills L-29
UWI: L-29 60-10N 117-15W

License Number: 2041
Test Date October 30, 2021
GCHEM Project Number 21265

1.1 Production Casing Assessment Summary Table

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

1.2 Surface Casing Vent Flow (SCVF) Assessment Summary Table

SCV Ten-Minute Bubble Test Result	PASS		
SCV Flow Rate (m^3/day)	0		
SCV Pressure-Temp Logger Installed	NA		
SCV Pressure-Temp Data Logger Removed	NA		
SCV Shut-In Time (hrs)	NA		
SCV MAX-Recorded Build Up Pressure (kPa)	NA		
SCV Stabilized Build-up Pressure (kPa):	NA		
SCV Stabilized Build-up Time (hours)	NA		
SCV Standpipe Max CH_4 Content (ppm v/v):	1		
SCV Standpipe Max H_2S Content	<1		
SCV Gas Spls. Collection-Measurement	**Total Collected**	**Analysis Requested***	**Classification****
SCV Samples (Total)	1		
SCV Combustible Gas Class. Level-1 (Chemical)		1	Hydrocarbon Contamination
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

1.3 Soils Outside Casing (AGM) Assessment Summary Tables

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

Well Casing Surface CH_4 Test Sites	28
MAX Surface CH_4 Reading	87.9%LEL
MAX H_2S Well Soil Reading (ppm v/v)	<1
Number of Background Sites	1
MAX Background CH_4 (ppm v/v)	1
Max H_2S BKG Soil Reading (ppm v/v)	<1
Surface CH_4-PMD Gas Classification	NON-IMPACTED

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)

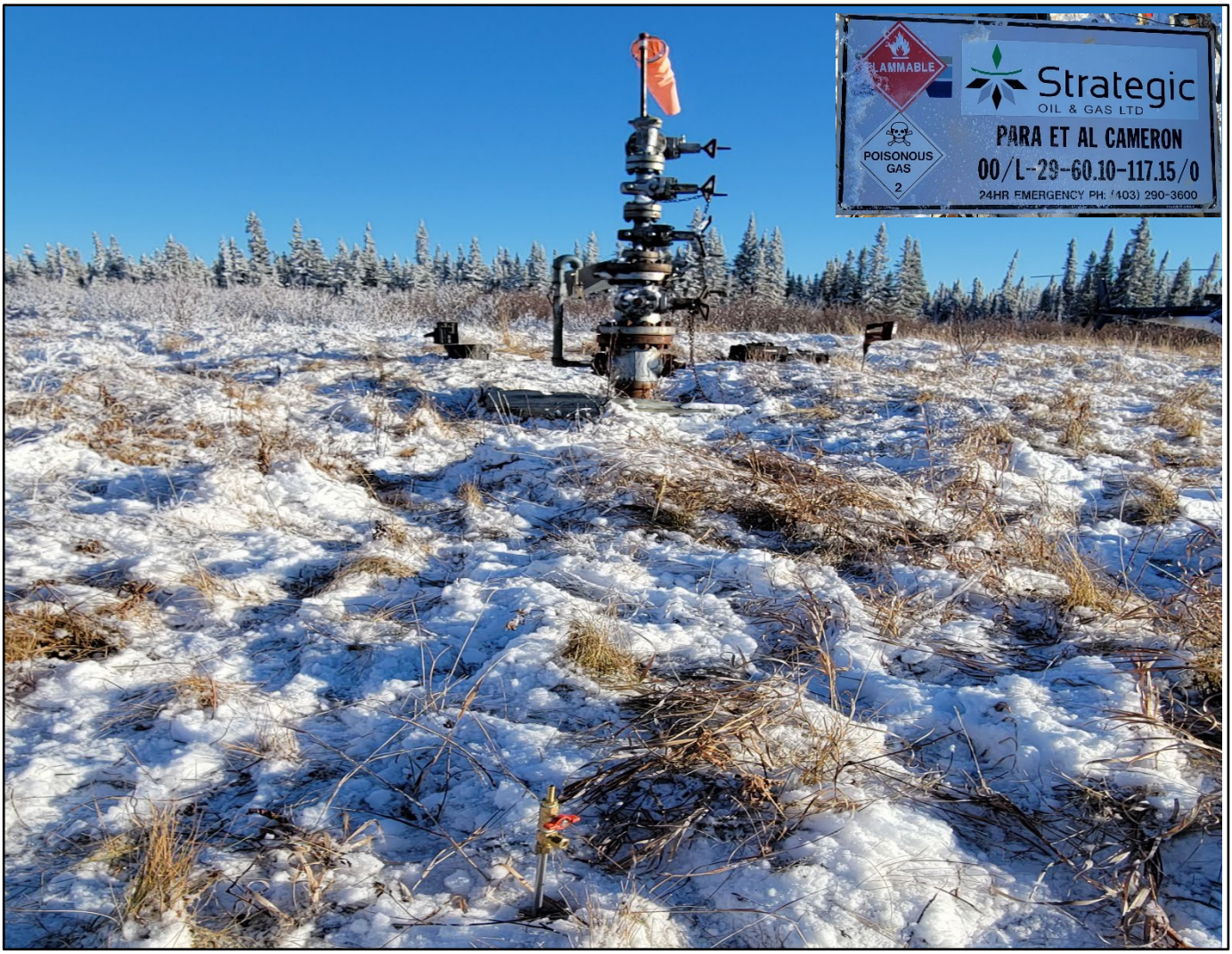
Number Soil Vapor Probe (SVP) Test Sites	20		
MAX SVP CH_4 Reading (ppm v/v)	1113		
Max H_2S SVP Field Reading (ppm v/v)	<1		
Number SVP BKG Test Sites	1		
MAX SVP CH_4 BKG Test Sites (ppm v/v)	1		
SVPs Gas Spl. Collection & Measurement	**Total Collected**	**Analysis Requested***	**Test Site**
Soil Vapor Probes (SVPs) AGM (Total)	8		
SVP &Sites Requested for Level-1 Analysis		8	N0.3, E0.3, S0.3, W0.3, NE0.3, SE0.3, SW0.3 & NW0.3
Combustible Gas Classification Level-1 (Chem.)		IMPACTED	
SVP &Sites Requested for Level-2 Analysis		0	NA
Combustible Gas Classification Level-2 ($\delta^{13}C$)		NA	
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)	1		
BKG &Sites Requested for Level-1 Analysis		1	BKG S15
Combustible Gas Classification Level-1 (Chem.)		BASELINE	
BKG &Sites Requested for Level-2 Analysis		0	NA
Combustible Gas Classification Level-2 ($\delta^{13}C$)		NA	
BKG &Sites Requested for Level-3 Analysis		0	NA
Combustible Gas Classification Level-3 (δD)		NA	
BKG &Sites Requested for Level-4 Analysis		0	NA
Combustible Gas Classification Level-4 (^{14}C)		NA	

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

1.4 Interpreted Source of Migrating Gases

Sample Point	Geologic Formation	Depth Range	Source Depth
No samples submitted for stable isotope composition analysis.			



3.0 Vapor Intrusion and Surface Casing Vent Flow Testing and Sampling Comments

Assessment-Collection Date: October 30, 2021

1) The Surface Casing Vent passed the ten-minute bubble test (1 ppm v/v methane).
2) A surface combustible gas scan was performed near the wellbore using a Sensit Portable Methane Detector (PMD). Reading were elevated within 0.3m of wellbore (up to 87.9 % LEL) all other readings were comparable to background (1 ppm v/v) established 15m south from the wellbore (Figure 1, Table 1).
3) An intrusive soil gas migration test was then performed by drilling test holes and inserting Soil Vapor Probes (SVPs). Combustible gas readings in the SVPs were low (1 ppm v/v, except 1113 ppm v/v at N0.3m), comparable to the background probe (1 ppm v/v methane) installed approximately 15m south of the wellbore to establish background levels in the area and for comparison to other samples collected during this investigation (Figure 2, Table 2).
4) Eight soil gas samples from SVPs (N0.3, E0.3, S0.3, W0.3, NE0.3, SE0.3, SW0.3 & NW0.3) and gases from background (BKG S15) were collected, contained, and preserved for geochemical analysis and characterization, classification, geologic origin (source) and depth measured from the KB (Table 3).
5) Methane and C2 + light alkane gas levels in soil gases collected near the wellbore at N0.3, E0.3, S0.3) are elevated, comparable to background established 15m south of the wellbore (Figure 3) and consistent with migrating natural gases from a thermogenic source at depth.
6) Soil gases collected at NW0.3 and from the SCV are consistent with gases from the breakdown/decomposition/weathering of hydrocarbon or chemical spills and not the result of migrating thermogenic natural gases.
7) C_{6+} contents in the soil samples are elevated compared to background levels indicting the presence of hydrocarbon contamination and/or chemical spills (Figure 4).
8) This well is likely impacted by gas migration at the time of this investigation.

Figure 1. AGM Non-Intrusive Surface PMD

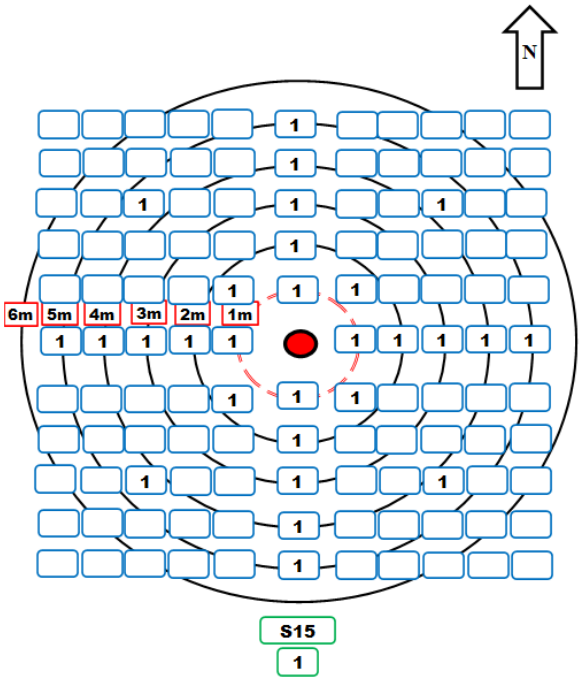


Figure 1A. Non-Intrusive CH_4 Surface Well Casing Detail VIEW

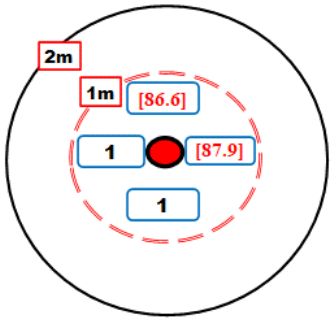


Table 1. AGM Non-Intrusive Surface PMD

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

Test Site (m)	PMD CH_4 (ppm v/v)	PMD CH_4 (% Vol)	Test Site (m)	PMD CH_4 (ppm v/v)	PMD CH_4 (% Vol)	Test Site (m)	PMD CH_4 (ppm v/v)	PMD CH_4 (% Vol)	Test Site (m)	PMD CH_4 (ppm v/v)	PMD CH_4 (% Vol)
N.5		[86.6]	E.5		[87.9]	S.5	1		W.5	1	
N1	1		E1	1		S1	1		W1	1	
N2	1		E2	1		S2	1		W2	1	
N3	1		E3	1		S3	1		W3	1	
N4	1		E4	1		S4	1		W4	1	
N5	1		E5	1		S5	1		W5	1	
N5-E1			E5-S1			S5-W1			W5-N1		
N4-E1			E5-S2			S4-W1			W5-N2		
N3-E1			E5-S3			S3-W1			W5-N3		
N2-E1			E5-S4			S2-W1			W5-N4		
N1-E1	1		E5-S5			S1-W1	1		W5-N5		
N1-E2			E4-S5			S1-W2			W4-N5		
N2-E2			E4-S4			S2-W2			W4-N4		
N3-E2			E4-S3			S3-W2			W4-N3		
N4-E2			E4-S2			S4-W2			W4-N2		
N5-E2			E4-S1			S5-W2			W4-N1		
N5-E3			E3-S1			S5-W3			W3-N1		
N4-E3			E3-S2			S4-W3			W3-N2		
N3-E3	1		E3-S3	1		S3-W3	1		W3-N3	1	
N2-E3			E3-S4			S2-W3			W3-N4		
N1-E3			E3-S5			S1-W3			W3-N5		
N1-E4			E2-S5			S1-W4			W2-N5		
N2-E4			E2-S4			S2-W4			W2-N4		
N3-E4			E2-S3			S3-W4			W2-N3		
N4-E4			E2-S2			S4-W4			W2-N2		
N5-E4			E2-S1			S5-W4			W2-N1		
N5-E5			E1-S1	1		S5-W5			W1-N1	1	
N4-E5			E1-S2			S4-W5			W1-N2		
N3-E5			E1-S3			S3-W5			W1-N3		
N2-E5			E1-S4			S2-W5			W1-N4		
N1-E5			E1-S5			S1-W5			W1-N5		

BACKGROUND Non-Intrusive Surface PMD (CH_4) Soil Scan

Test Site (m)	PMD CH_4 (ppm v/v)	PMD CH_4 (%)	Test Site (m)	PMD CH_4 (ppm v/v)	PMD CH_4 (%)	Test Site (m)	PMD CH_4 (ppm v/v)	PMD CH_4 (%)	Test Site (m)	PMD CH_4 (ppm v/v)	PMD CH_4 (%)
S15	1										

Figure 2. AGM Intrusive SVPs-

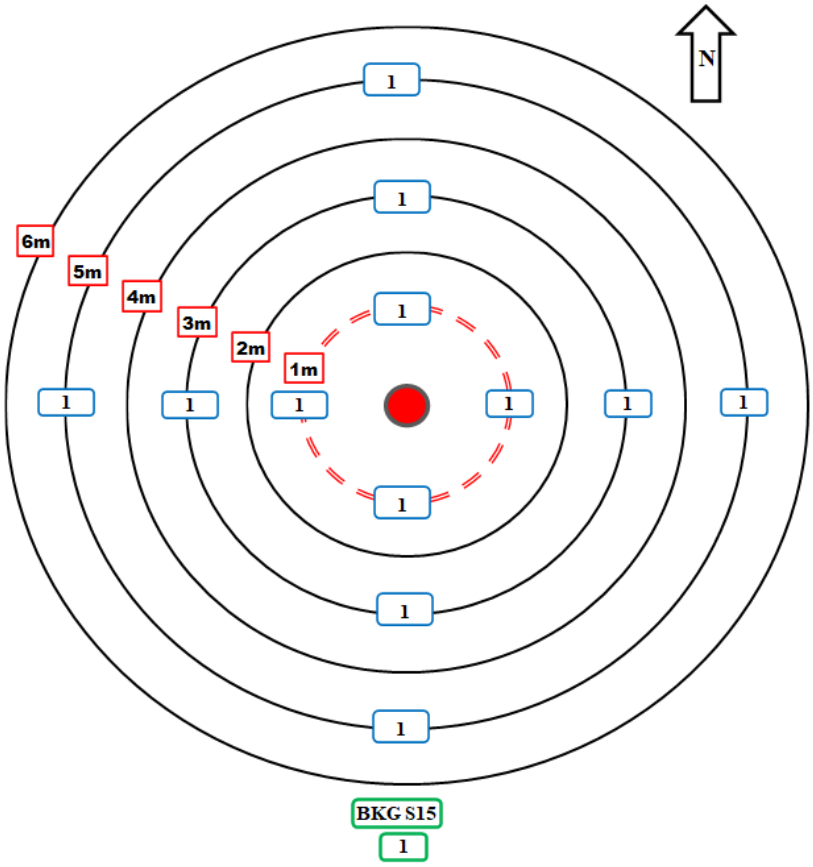


Table 2. AGM Intrusive SVPs

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)	(%LEL)	H_2S (ppm v/v)	Soil Parameters Type	Moist. (1-5)	HC-CONT (Y-N)	Gas Sample (Y-N)	Site Assessment Comments
N0.3	1113		<1.0	Slit	5	No	Yes	
N2	1		<1.0	Slit	5	No	No	
N4	1		<1.0	Slit	5	No	No	
N6	1		<1.0	Slit	5	No	No	
E0.3	1		<1.0	Slit	5	No	Yes	
E2	1		<1.0	Slit	5	No	No	
E4	1		<1.0	Slit	5	No	No	
E6	1		<1.0	Slit	5	No	No	
S0.3	31		<1.0	Slit	5	No	Yes	
S2	1		<1.0	Slit	5	No	No	
S4	1		<1.0	Slit	5	No	No	
S6	1		<1.0	Slit	5	No	No	
W0.3	N/F		<1.0	Slit	5	No	Yes	No Flow
W2	1		<1.0	Slit	5	No	No	
W4	1		<1.0	Slit	5	No	No	
W6	1		<1.0	Slit	5	No	No	
NE	1		<1.0	Slit	5	No	Yes	
SE	1		<1.0	Slit	5	No	Yes	
NW	1		<1.0	Slit	5	No	Yes	
SW	1		<1.0	Slit	5	No	Yes	

Test Site (m)	Soil Vapor Probes IR-CH_4 (ppm v/v)	(% Vol)	H_2S (ppm v/v)	Soil Parameters Type	Moist. (1-5)	HC-CONT (Y-N)	Gas Sample (Y-N)	Site Assessment Comments
BKG S15	1		<1.0	Clay	5	No	Yes	

Table 1. **High resolution molecular compositions of gas samples collected as part of the VIA Heli Source L-29.**

Sample Point / Date Collected / Gas Component	SCV Oct. 30-21 ppm v/v	N0.3 Oct. 30-21 ppm v/v	E0.3 Oct. 30-21 ppm v/v	S0.3 Oct. 30-21 ppm v/v	W0.3 Oct. 30-21 ppm v/v	NE0.3 Oct. 30-21 ppm v/v	SE0.3 Oct. 30-21 ppm v/v	NW0.3 Oct. 30-21 ppm v/v	SW0.3 Oct. 30-21 ppm v/v	BKG Oct. 30-21 ppm v/v
Neon	21.78	20.08	22.85	20.81	21.04	21.60	22.45	22.09	21.86	21.20
Hydrogen	241.8	137.6	151.4	146.3	158.3	232.0	199.9	165.6	165.9	311.6
Helium	1.12	0.55	0.84	0.70	1.62	1.43	0.56	0.63	0.54	0.78
Nitrogen	778117	774760	775488	774003	776881	775800	776161	775205	775647	775417
Oxygen	215625	223144	223434	223058	221709	222997	223044	222587	223570	223065
Carbon Dioxide	5260	1272	864.1	1101	1222	930.9	590.9	1867	614.8	1159
Methane	90.29	606.2	52.54	1624	23.45	26.52	2.88	113.7	2.14	43.34
Ethane	151.8	33.64	4.37	41.17	0.89	2.20	<0.01	7.02	<0.01	1.25
Ethene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Propane	218.6	24.82	2.23	15.21	0.39	3.17	<0.01	11.24	<0.01	1.56
Propene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
iso-Butane	82.65	6.04	0.70	4.70	0.18	1.45	0.19	8.39	0.00	1.13
n-Butane	137.6	8.97	0.56	3.41	<0.01	2.69	0.15	10.53	0.00	0.15
iso-Pentane	43.36	3.18	0.30	1.22	<0.01	0.92	<0.01	6.36	<0.01	0.21
n-Pentane	29.93	2.06	0.14	0.84	<0.01	0.63	<0.01	5.60	<0.01	<0.01
C6+	0.39	0.68	0.93	0.56	2.45	0.38	0.82	11.92	0.24	0.18
C1 Index (C1/ΣC2+)	0.17	8.72	7.20	26.78	18.38	3.06	18.70	3.31	N/A	14.67
C2 Index (C2/ΣC3+)	0.39	0.94	1.49	2.11	2.29	0.34	N/A	0.26	N/A	0.73
C3 Index (C3/ΣC4+)	1.30	2.25	3.19	3.57	N/A	0.96	N/A	0.70	N/A	10.30
C4 Index (C4/C5)	4.60	4.36	3.94	4.06	N/A	4.29	N/A	1.88	N/A	N/A
ΣC2+	537.9	69.49	7.29	60.64	1.28	8.68	0.15	34.39	N/A	2.95
ATM Ratio (N2/O2)	3.61	3.47	3.47	3.47	3.50	3.48	3.48	3.48	3.47	3.48
Vol % CO2 of TG	0.53	0.13	0.09	0.11	0.12	0.09	0.06	0.19	0.06	0.12
Vol % Lt. Alk. of TG	0.08	0.07	0.01	0.17	0.00	0.00	0.00	0.02	0.00	0.00
Vol % Lt. Alk. CH4	11.97	88.51	86.36	96.06	94.14	70.61	89.39	69.83	100.0	90.98
Vol % Lt. Alk. C2+	88.03	11.49	13.64	3.94	5.86	29.39	10.61	30.17	0.00	9.02
Vol % C2+ of TG	0.05	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Stable Carbon Isotope Compositions (‰ VPDB)										
d13C CH4	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
d13C C2H6	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
d13C C2H4	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
d13C C3H8	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
d13C C3H6	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
d13C i-C4H10	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
d13C n-C4H10	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
d13C i-C5H12	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
d13C n-C5H12	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
d13C CO2	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
Stable Hydrogen Isotopic Compositions (‰ VSMOW)										
dD H2	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
dD CH4	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
dD C2H6	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
dD C3H8	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
dD i-C4H10	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
dD n-C4H10	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
14C Concentration (pMC)	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm

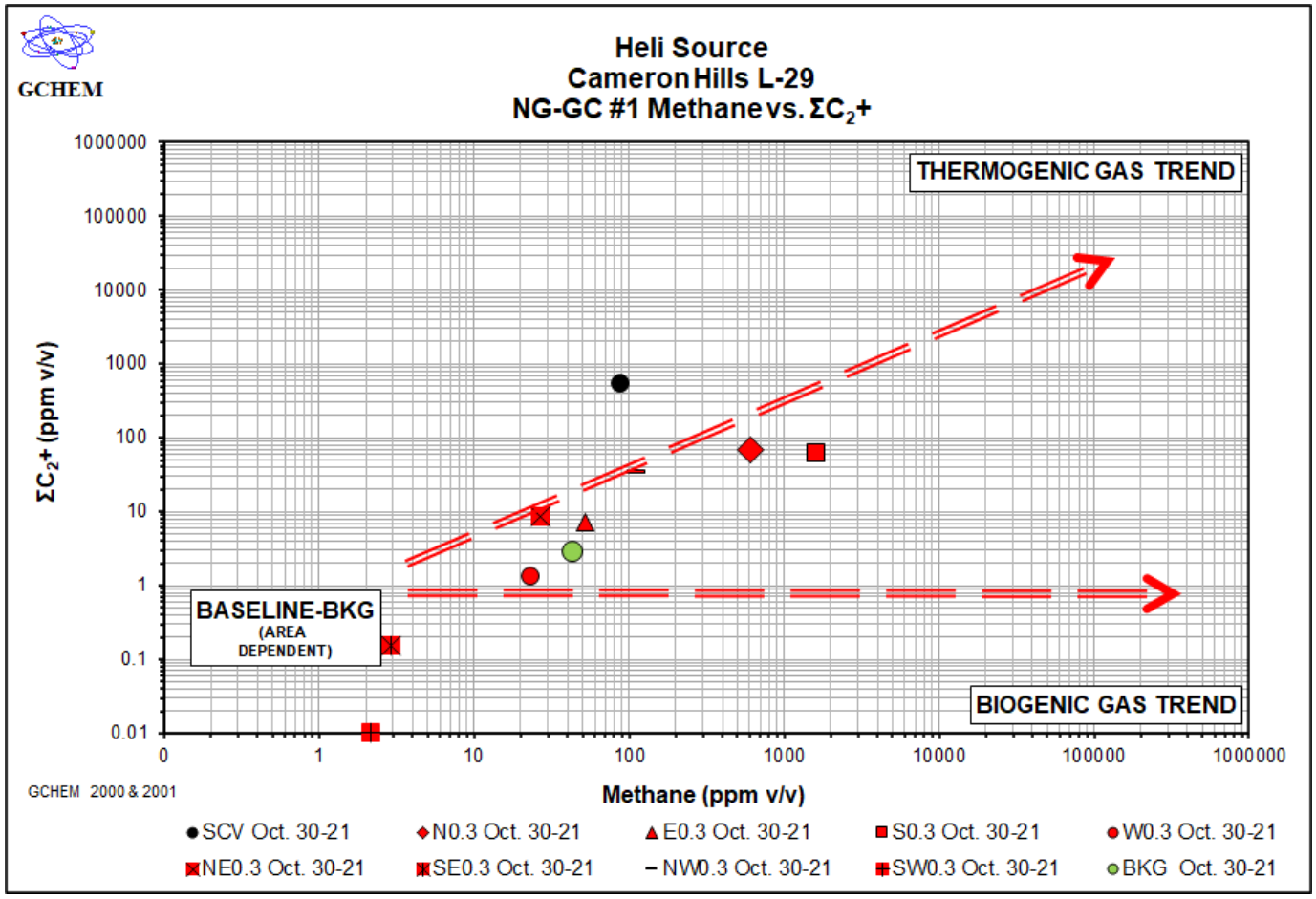


Figure 3: ΣC2+ vs Methane. Combustible gases detected in soils and SCVs at a wellhead may result from several origins. Natural gases indicative of SCVF or AGM are thermogenic in origin (natural gas in deep reservoirs), contain high methane and C_2+ contents and plot in the Upper RH Quadrant. Low natural 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

NG-GC-1 Comments

1) Natural gases in the SCV and soils near the wellbore contain elevated levels of C2+ gases indicating that this well is likely impacted with leaking thermogenic natural gases.

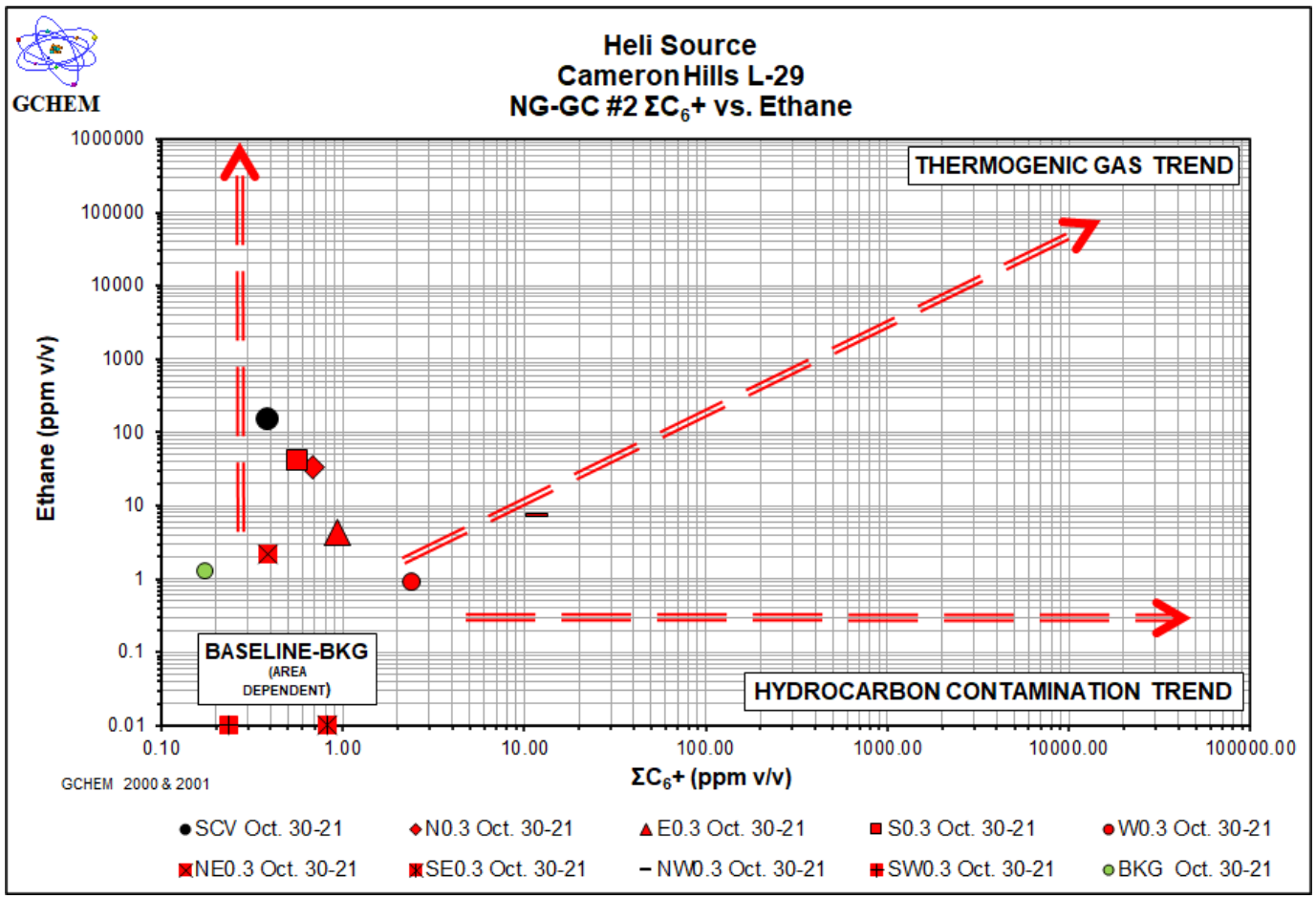


Figure 4: ΣC_6+ vs Ethane. C_6+ gases are relatively large molecules that do not readily or easily migrate in large quantities from depth upwards through subsurface fractures or micro-fractures to surface. Contamination by oil spills, fuels, and solvents is indicated by soil vapor samples that have high 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.

NG-GC-2 Comments

1) C_6+ contents of the SCV and soil gas samples are elevated compared to expected baseline readings indicating the presence of hydrocarbon or chemical contamination.

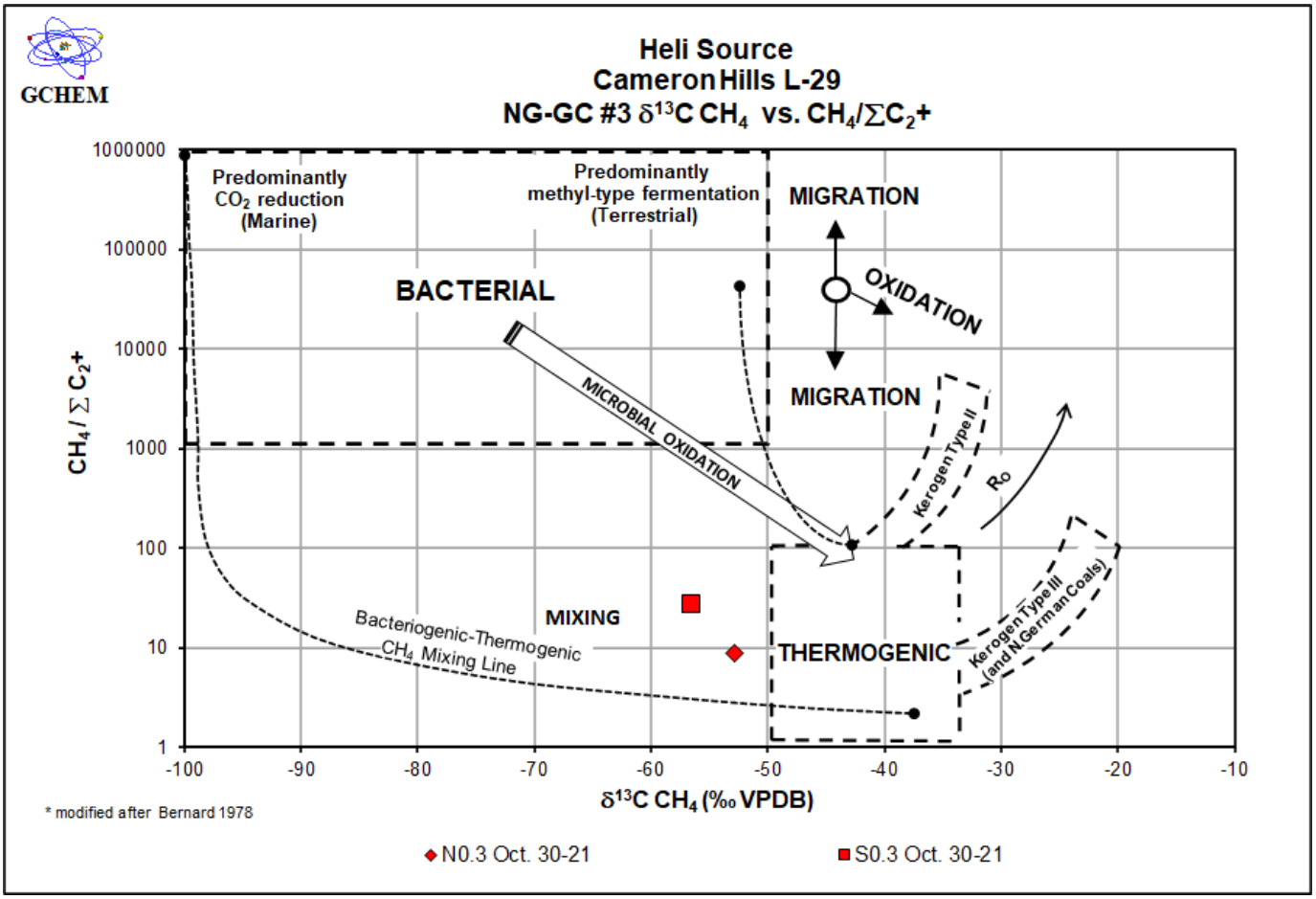


Figure-5. NG-GC #3 CH_4 / ΣC_{2+} vs. $\delta^{13}C$ CH_4. Thermogenic methane or methane generated by abiotic processes such as the thermal degradation of organic matter at high temperature and pressure (thermogenesis) contains enriched (less negative) $\delta^{13}C$ values ranging from -50 to -20‰ 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).

NG-GC-3 Comments

1) Methane in the SCV and soils near the wellbore is consistent with a mixture of gases of biogenic and thermogenic origins.

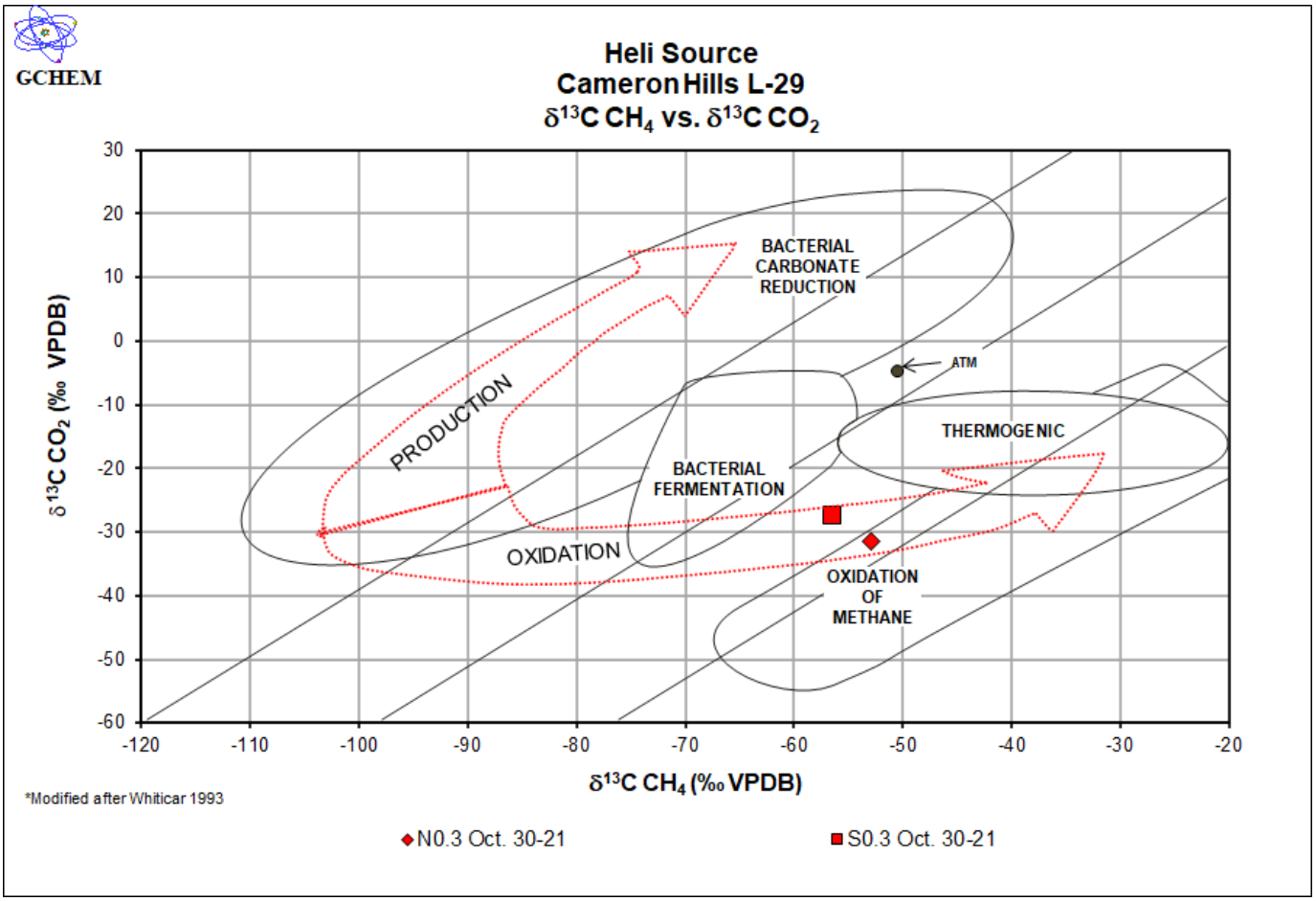


FIGURE-6. NG-GC #4 $\delta^{13}C\ CO_2$ vs. $\delta^{13}C\ CH_4$. Thermogenic methane or methane generated by abiotic processes such as the degradation of organic matter at high temperature and pressure contains enriched (less negative) $\delta^{13}C$ values ranging from -55 to -20‰ VPDB (or higher) and $\delta^{13}C\ CO_2$ 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 $\delta^{13}C$ values greater than -40‰ VPDB due to biogenic oxidation processes (GCHEM, in prep).

NG-GC-4 Comments

1) Methane in the SCV and soils near the wellbore is consistent with a mixture of gases of biogenic and thermogenic origins.