[PS]Isotopic Characterization of Natural Gas Seeps Identified in Peel Plateau, Yukon Territory, Canada*

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Search and Discovery Article #50325 (2010)
Posted September 30, 2010

*Adapted from poster presentation at AAPG Annual Convention and Exhibition, New Orleans, Louisiana, April 11-14, 2010

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Abstract

Peel Plateau is a little explored potential petroleum region in Canada's northwest. Oil and gas exploration drilling during the 1960s and 1970s identified six minor gas occurrences in the Upper Paleozoic succession. New field work identified anomalous, circular, unfrozen openings in ice at the eastern structural front of the Richardson Mountains. A sample was collected from along this front on the Trail River (66°28′, 135°08.3′), where gas bubbles were not obvious, but where the water is dark grey and has a strong sulfurous odour. This gas sample contains methane with $\delta^{13}C_{CH4}$ values of -42.8 ‰ and carbon dioxide with a carbon isotopic composition of -14.9 ‰. A gas sample collected from Turner Lake (66°10.3′, 134°18.5′) contains methane with a $\delta^{13}C_{CH4}$ value of -35.2 ‰ and carbon dioxide with a $\delta^{13}C_{CO2}$ value of -31.7 ‰. The sulphurous smell on Trail River suggests that H_2S may have been present in that sample, but that it could have been oxidized during its migration through the meteoric surface waters into which the gas is seeping. The carbon isotopic composition of the Trail River sample is similar to that reported by others for unaltered thermogenic gases from the Lower Cretaceous Mannville Group in southern parts of the Western Canadian Sedimentary Basin (WCSB), however it is inferred unlikely that the Trail River gas originated in the Mesozoic succession. The possible occurrence of H_2S is consistent with both an "overmature" thermogenic origin for the gas and its subsequent thermochemical sulphate reduction in the presence of sulphate-bearing Paleozoic strata.

Thermochemical sulphate reduction is commonly observed elsewhere in the southern WCSB where gases are hosted in or have migrated through the Paleozoic succession. The very low $\delta^{13}C$ value of carbon dioxide and the high $\delta^{13}C$ value of methane of the

Turner Lake gas sample suggest that it has been altered significantly by microbial oxidation. Either the Turner Lake sample had origins like that of the Trail River sample and was subsequently moderately microbially degraded; or, it had a different, potentially even biogenic origin, and it was more extremely biodegraded. The results indicate at least one effective petroleum system is present in the Peel Plateau, probably with a source in the Paleozoic succession. The association of thermogenic petroleum seeps with structural features elsewhere in the WCSB has resulted in major petroleum discoveries, such as the Turner Valley and Norman Wells fields.

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Isotopic characterization of natural gas seeps identified in Peel Plateau, Yukon Territory, Canada

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Introduction

Peel Plateau is an under explored potential petroleum region in Canada's northwest. Oil and gas exploration drilling during the 1960s and 1970s identified eight minor gas occurrences in the Upper Paleozoic succession. Recent field investigations identified anomalous, circular, unfrozen openings in ice at the eastern structural front of the Richardson Mountains. Isotopic characterization of the gas collected confirms the presence of thermogenic natural gas in the Peel Plateau region of Yukon.

Field investigations were part of a larger study aimed at assessing the petroleum potential in frontier regions of nothern Canada, namely the Peel Plateau and Plain.

Exposure of Road River Group along the Peel River. This is an example of the type of outcrop exposure common in this region.

The Peel Plateau is a northwestern extension of the Western Canadian Sedimentary Basin (orange).

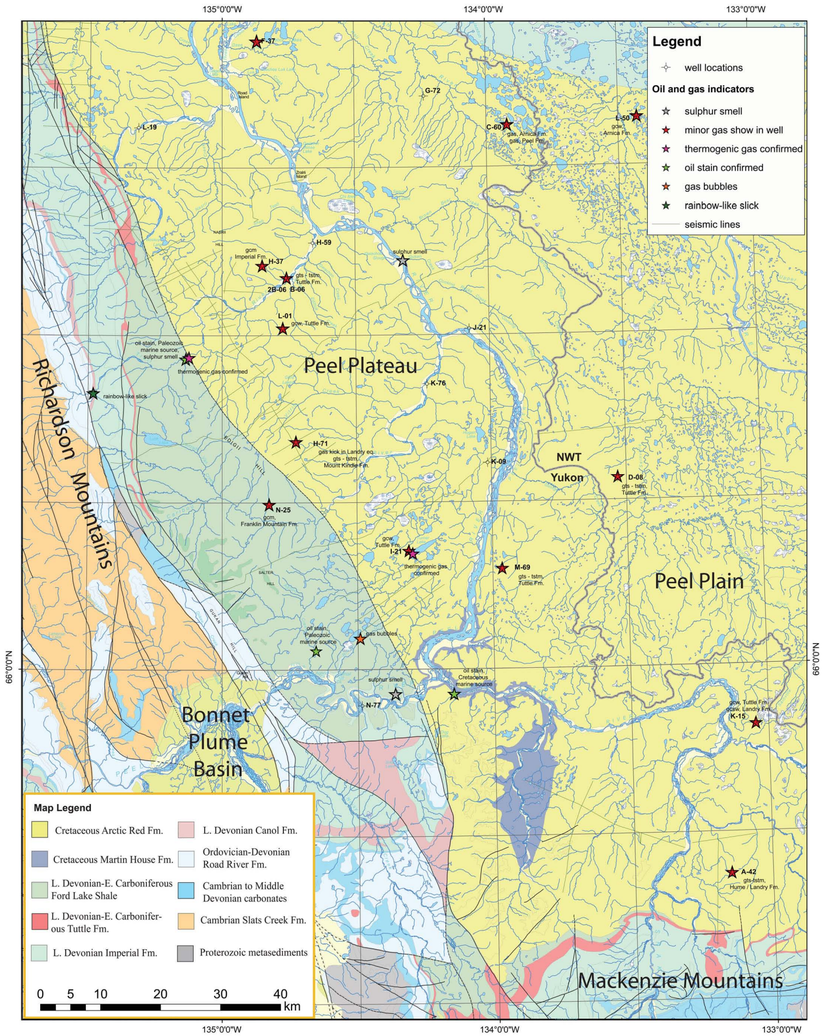
The red polygon marks the approximate study area.

Study Area

The Yukon Territory is in the northwestern corner of Canada, adjacent to Alaska. It occurs between latitudes 60ºN and 70ºN, and longitudes 124ºW and 141ºW. The Yukon is bordered by British Columbia to the south and the Northwest Territories to the east.

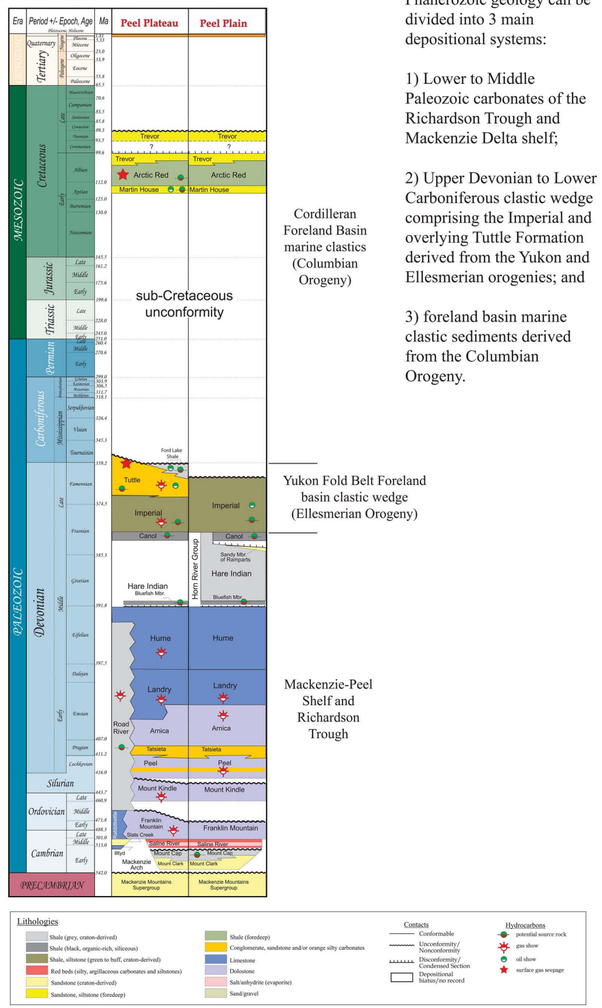
Peel Plain extends eastward into the Northwest Territories.

Yukon Territory is highlighted in red.
The yellow polygon marks the approximate study area.



Simplified geological map and legend for the Peel Plateau and Plain, Richardson Mountains and northern Mackenzie Mountains (from Gordey and Makepeace, 2001).

Stratigraphy



Phanerozoic geology can be divided into 3 main depositional systems:

1) Lower to Middle Paleozoic carbonates of the Richardson Trough and Mackenzie Delta shelf;

2) Upper Devonian to Lower Carboniferous clastic wedge comprising the Imperial and overlying Tuttle Formation derived from the Yukon and Ellesmerian orogenies; and

3) foreland basin marine clastic sediments derived from the Columbian Orogeny.

Stratigraphic column for the Peel Plateau and Peel Plain (modified from Morrow et al., 2006).

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Introduction

Peel Plateau, a northern extension of the Western Canadian Sedimentary Basin (WCSB), is a poorly understood petroleum region in Canada's northwest with an estimated potential of approximately 3 Tcf natural gas raw in-place (Osadetz *et al*., 2005). Oil and gas exploration drilling during the 1960s and 1970s identified minor gas occurrences in the Upper Paleozoic succession. Recent field investigations identified anomalous, circular, unfrozen openings in ice at the eastern structural front of the Richardson Mountains, where gas bubble streams were noted in water. Carbon-13 isotopes of the gas confirms the presence of thermogenic gas in the Yukon's Peel Plateau.

These field investigations were part of a larger study aimed at assessing the petroleum potential in frontier regions of northern Canada, namely the Peel Plateau and Plain. This study, which recently concluded, was entitled "Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain" (Pyle and Jones, 2009).

Analytical Techniques

Carbon isotope analyses of methane (CH_4) and carbon dioxide (CO_2) were conducted at the Isotope Science Lab - University of Calgary, Canada.

Samples were analyzed using a gas chromatography combustion system coupled in continuous flow mode to an isotope ratio mass spectrometer (GC-C-IRMS). $\delta^{13}C$ values are recorded in per mil (‰) relative to the internationally accepted standard V-PDB. Accuracy and precision for $\delta^{13}CCH_4$, $\delta^{13}CC_2$, and $\delta^{13}CCO_2$ values is better than ±0.5 ‰.

Gas sample collected from Turner Lake.

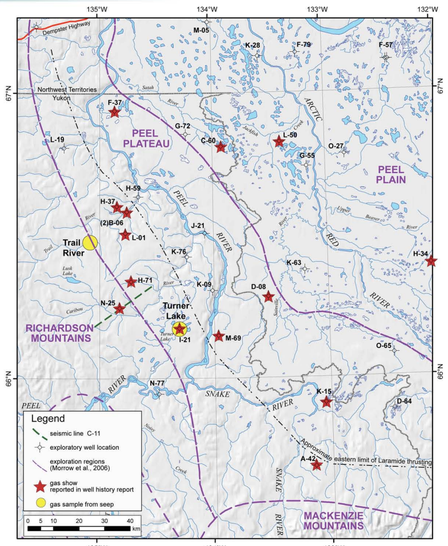
On the lake, gas samples were collected using a water displacement method from the bubble streams. While on the river, bulk water samples were collected and isotopic analyses were conducted.

Evidence of Gas

Exploration drilling programs during the 1960s and 1970s identified minor gas shows in Yukon's Peel region. These shows were predominantly in the Upper Devonian Tuttle Formation (see map to the right and table below).

Natural gas seeps form anomalously unfrozen openings in ice due to the agitation of water by gas bubbling to the surface. These openings are best seen on lake surfaces during fall freeze and spring breakup. The source of the gas may be biogenic (created by microbiological oxidation) or thermogenic (related to a petroleum system). Recent carbon-13 isotope analyses conducted as part of this study suggest that the gas seepages identified in this region are thermogenic in origin.

In areas where water is discoloured and the air smells of hydrogen sulphide (H_2S), it is important to confirm if gas is naturally occurring, and then determine its source. H_2S, a component of natural gas, is water soluble and turns water black. Methane (CH_4), a colourless, odourless gas which is not very water soluble, is a principal component of natural gas.



Short Name	Well	UWI	Formation	Gas recovery from test
A-42	Amoco PCP B-1 Cranswick A-42	300A426550133001	Landry	gas to surface in 30 min, TSTM
A-42	Amoco PCP B-1 Cranswick A-42	300A426550133001	Hume	gas to surface in 30 sec, TSTM
B-06	Shell Peel River Y.T. B-06	300B066640134450	Tuttle	gas to surface in 30 sec, TSTM
B-06A	Shell Peel River Y.T. B-06A	302B066640134450	Tuttle	gas to surface in 45 min, gasified salt water
C-60	Skelly Getty Mobile Arctic Red YT C-60	300C606650133450	Arnica	1390 c.c. gas
C-60	Skelly Getty Mobile Arctic Red YT C-60	300C606650133450	Peel	5450 c.c. gas
F-37	Pacific et al Peel YT F-37	300F376700134450	Mount Kindle	gassy salt water, gasified mud
H-37	Shell Trail River YT H-37	300H376640134450	Imperial	gas cut mud
H-71	Mobil Gulf Peel YT H-71	300H716630134300	Road River - Landry equivalent	gas kick while drilling
H-71	Mobil Gulf Peel YT H-71	303H716630134300	Road River - Peel equivalent /Mt Kindle	gas to surface in 32 min at 65 mcfpd
I-21	Shell Peel River Y.T. I-21	300I216620134150	Tuttle	fresh water, slightly gasified
K-15	McD GCO Northup Taylor Lake Y.T. K-15	300K156600133000	Tuttle	mud-cut gassy fresh water
K-15	McD GCO Northup Taylor Lake Y.T. K-15	300K156600133300	Landry	muddy gassy salt water
L-01	Shell Canada Peel River Y.T. L-01	300L016640134450	Tuttle	slightly gasified water
M-69	Shell Peel River Y.T. M-69	300M696610133450	Tuttle	gas to surface, TSTM; 3 foot flare
N-25	Caribou River YT N-25	300N256620134450	Road River - Landry equivalent	gas cut mud
N-25	Caribou River YT N-25	300N256620134450	Franklin Mt	slightly gassy mud
D-08	Arco Shell Sainville River D-08	300D086620133330	Tuttle	gas to surface in 25 min, too small to measure

Table of gas shows reported in drill stem tests and well history reports. The location of the shows are displayed on the above map.

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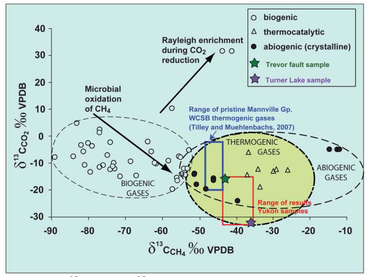
Results

The $\delta^{13}C$ composition of the Trail River sample is similar to that reported by others for unaltered thermogenic gases from the Lower Cretaceous Mannville Group in southern parts of the WCSB, however it is inferred that the Trail River gas unlikely originated in the Mesozoic succession.

Sample Name	$\delta^{13}C_{CH4}$	$\delta^{13}C_{CO2}$	Comments
Trail River	-42.8	-14.9	may contain H_2S
Turner Lake	-35.2	-31.7	may contain H_2S



Variation of $\delta^{13}CCH_4$ and $\delta^{13}CCO_2$ values for Turner Lake (purple star), Trail River (green star) and other natural gases of various origins and alteration pathways (modified from Clark and Fritz, 1997).

Turner Lake

The gas sample collected from Turner Lake (see map) contains methane with a $\delta^{13}CCH_4$ value of -35.2 ‰ and carbon dioxide with a $\delta^{13}CCO_2$ value of -31.7 ‰.

Note the small depression in the ice created by gas bubbling to the water's surface. The hole is approximately 40 cm in diameter. Gas bubble circled in red. Photo taken on March 27, 2008.

The very low $\delta^{13}CCO_2$ and the high $\delta^{13}C$ value of methane of the Turner Lake gas sample suggest that it has been altered significantly by microbial oxidation. Either the Turner Lake sample had origins like that of the Trail River sample and was subsequently moderately microbially degraded, or it had a different, potentially even biogenic origin, and it had undergone more extreme biodegradation.

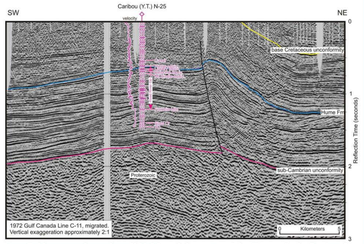
Trail River

A sample was collected along the Cordilleran deformation zone of the Richardson Mountains along the Trail River (see map). At this location, gas bubbles were not obvious; however the water was dark grey and had a strong sulfurous odour. The sulphurous smell on Trail River suggests that H_2S may have been present, but that it could have been oxidized during its migration through the meteoric surface waters into which the gas is seeping.

The Trail River gas sample contains methane with a $\delta^{13}CCH_4$ value of -42.8 ‰ and carbon dioxide with a carbon isotopic composition of -14.9 ‰.

Naturally occurring discoloured water on Trail River as noted in summer. Also at this locality, the rocks are coated with a greyish slime and a strong sulphur smell is evident for kilometres.

Same locality as above photo as seen in winter. Note the dark grey colour of the water under the ice.



Line C-11 passes through well N-25 and the trace of the Trevor fault. Setting for gas seepage . The Trail River sample was collected in the vicinity of the mapped Trevor fault, a thrust fault that involves the Paleozoic succession.(from Osadetz et al., 2005).

H_2S

Thermochemical sulphate reduction is commonly observed elsewhere in the southern WCSB where gases are hosted in, or have migrated through, the Paleozoic succession.

The possible occurrence of H_2S is consistent with both an 'overmature' thermogenic origin for the gas and its subsequent thermochemical sulphate reduction in the presence of sulphate-bearing Paleozoic strata.

Conclusions

- Carbon isotopes indicate that the gas examined is thermogenic and demonstrates that at least one effective petroleum system is present in the Peel Plateau, probably with a source in the Paleozoic succession. The association of thermogenic petroleum seeps with structural features elsewhere in the Western Canadian Sedimentary Basin has resulted in major petroleum discoveries, such as the Turner Valley and Norman Wells fields.
- Coupled with recent confirmation of oil stains in the region, new carbon isotope data improves the petroleum resource prospectivity of the Peel region and will enhance future resource assessments.
- The origin of the gas is unresolved. The general understanding of the facies and their deformation in this region is poorly understood and requires more study.

Future Work

Research in the Peel region will continue in 2010 with emphasis on evaluating the petroleum potential as part of the Geological Survey of Canada's Geo-mapping for Energy and Minerals (GEM-Energy) initiative. Participants will include the GSC, Yukon Geological Survey and university affiliates (University of Calgary, Carleton University).

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