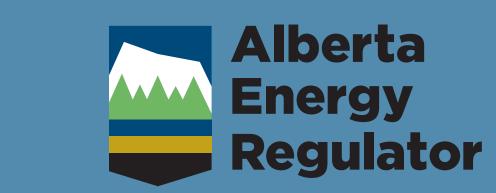
# Using a 3-D Geological Model and Petroleum Data Analyses to Help Mitigate Environmental Impacts of Heavy Oil and Bitumen Production





## Petroleum Sampling and Analysis Program

The regional petroleum sampling and analysis program was primarily designed to better understand the chemistry of the gas coming from the oil sands designated heavy oil and bitumen as it relates to odorous compounds and to discern regional source-rock contributions to PROS-area hydrocarbons. Sampling concentrated on gathering data about the fluids coming from the ground before any treatment occurred at the surface and before the compounds were dispersed in air. A regional sampling approach was necessary to be able to compare fluids from the PROS area with source type oils from outside the area and fluids from other OSAs. The relatively small sample set was chosen in order to help address the objectives of this study within a relatively short timeframe. It provides data for broadly characterizing the oil sands designated heavy oil and bitumen in the PROS area.

Twelve wells were sampled: nine producing from designated oil sands deposits throughout the province and three producing oils known to be sourced from specific source rocks (i.e., the Duvernay, Exshaw, and Gordondale, respectively) (Figure 1). For eight of the designated oil sands wells and the Gordondale and Exshaw oil type wells, both casing gas and liquid samples were collected. The other two wells (Two Creek and AOS Brintnell) were sampled for only liquids.

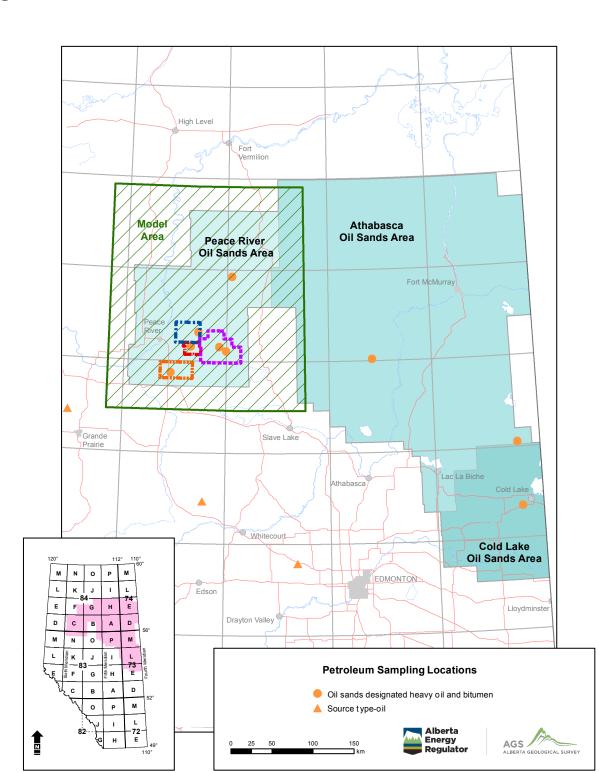


Table 1. Table showing sample locations and information.

Figure 2. Total sulphur versus δ<sup>34</sup>S data.

Location UWI	Well Name	Area	Geological Unit	Sample Type
102/16-30-091-12W5/0	ANDORA 1L SAWN LK 16-30-91-12	PROS Sawn Lake	Bluesky-Gething	casing gas and liquids
100/13-09-062-03W4/0	BAYTEX 13D HZBEAVRDM 13-9-62-3	CLOS Beaverdam	Grand Rapids	casing gas and liquids
100/01-29-079-20W5/0	BAYTEX N317 KIMIWAN 1-29-79-20	PROS Reno	Bluesky-Gething	casing gas and liquids
100/05-13-081-21W4/4	CNRL CBP39-5D BRINT 8-13-81-21	AOS Brintnell	Wabiskaw-McMurray	liquids
100/16-24-063-17W5/0	COPRC 100 HZ TWOCK 16-24-63-17	Two Creek	Duvernay	liquids
125/03-17-070-03W4/0	CVE FCCL E12W04 FISHER 3-17-70-3	AOS Foster Creek	Wabiskaw-McMurray	casing gas and liquids
100/04-29-074-07W6/0	ECA HZ LA GLACE 4-29-74-7	La Glace	Gordondale	casing gas and liquids
105/16-32-082-14W5/0	MURPHY 16-31HZ S280 SEAL 16-32-82-14	PROS Seal Lake	Bluesky-Gething	casing gas and liquids
102/12-17-082-13W5/0	MURPHY SEAL 12-17-82-13	PROS Seal Lake	Pekisko	casing gas and liquids
102/02-01-083-18W5/8	PENN WEST HZ PEACE RVR 2-1-83-18	PROS Walrus	Bluesky-Gething	casing gas and liquids
103/16-26-084-17W5/2	SCL HZ S343 CLIFFD 16-26-84-17	PROS Three Creeks	Bluesky-Gething	casing gas and liquids
100/08-35-055-05W5/0	VH1 ALEXIS 8-35-55-5	St. Anne	Exshaw	casing gas and liquids

AOS Wabiskaw-McMurray
CLOS Grand Rapids

◆ CLOS - Grand Rapids

 $\delta^{34}$ S (‰ CDT)

Figure 3. Vanadium to nickel ratio (V/Ni) versus  $\delta^{34}$ S data.

Figure 1. Map of

sampling locations.

## Sample Program Details

The AER hired Core Laboratories to collect the samples from ten wells where both casing gas and liquids were collected (Table 1) Casing gas samples were collected from the well casing into evacuated SilcoCan canisters. Canisters containing casing gas samples were sent to Core Laboratories for routine gas analysis and RSC analysis, which they refer to as trace sulphur analysis (TSA). Duplicate casing gas samples were also sent to Alberta Innovates Technology Futures (AITF), which offers C1 to C4, inert gas, RSC, and VOC analyses. The main differences between the RSC analyses of the two laboratories are the number of compounds analyzed and the detection limit ranges routinely used. Liquid samples were collected into stainless steel canisters and analyzed at Core Laboratories for routine oil composition as well as nickel and vanadium trace metal analyses. A portion of each liquid sample was sent to the G.G. Hatch Stable Isotope Laboratory at the University of Ottawa for sulphur and nitrogen isotope analyses.

Gas emitted from liquid samples was also analyzed. Ten liquid samples were heated to 25°C (25-flash) for 24 hours; gas emitted during the test was subjected to routine gas analysis and TSA. A portion of this gas was captured into evacuated SilcoCan canisters and analyzed for VOCs. Three of the ten samples were also heated to 80°C (80-flash) for 24 hours and subjected to routine gas analysis and TSA.

## Volatile Organic Compounds and Reduced Sulphur Compounds

In casing gas samples, RSCs appear to be significantly more odorous than the majority of VOCs detected (Figure 4). RSC concentrations commonly exceeded 1000 times the odour threshold when present in the sample, while VOCs are most commonly less than 100 times the odour threshold (Tables 2–6). This is in part due to sulphur compounds having lower threshold ranges on average than hydrocarbon compounds, making it easier for the threshold to be exceeded (Nagata, 2003).

The total concentration of RSCs and VOCs was analyzed for trends that would indicate that there could be differences between oil sands designated heavy oil and bitumen regionally across all OSAs or locally within the PROS area. The following observations were made:

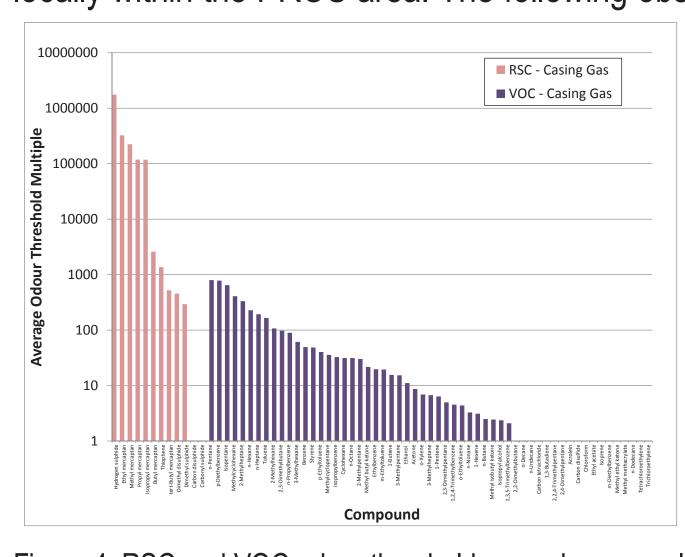


Table 2. Casing gas results exceeding odour thresholds for C1-C7 hydrocarbons, inert gases,

Figure 4. RSC and VOC odour threshold exceedances multiples compared.

## Total VOC and RSC concentrations in casing and 25-flash gas show no regional trend in the oil sands designated heavy oil and

bitumen (Figure 5). No trend is observed to indicate that oils from the PROS area emit greater RSC or VOC concentrations than those in other OSAs.

- There is a broad relationship (due to the regional nature of the sample data) between the amount of total VOCs and the oil density: less dense oil corresponds with more total VOCs (Figure 6), which is expected as lower density oils have higher concentrations of more volatile compounds.
- Total VOC and RSC concentrations in casing and 25-flash gas do not correlate to the total sulphur content in the oils (Figure 7).
- Total RSC concentrations in casing gas samples are highest in wells undergoing thermal production (Figure 8).

The data indicate that regionally, the oil sands designated heavy oil and bitumen is similar with respect to total RSC and VOC concentrations, and that the total RSC concentrations cannot be directly correlated to the total sulphur content, contrary to what was hypothesized in the Peace River proceedings.

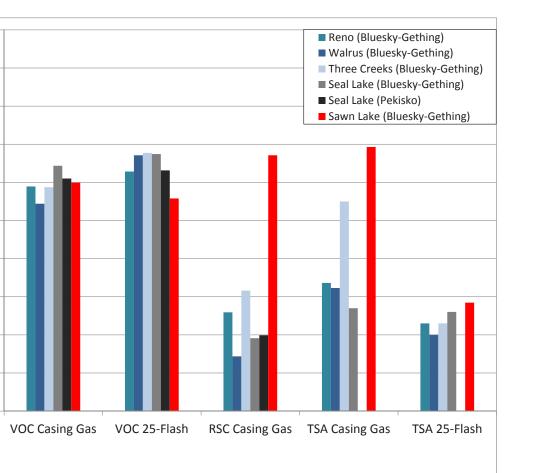


Figure 5. Total VOC and RSC concentrations in casing gas and 25-flash gas samples in the PROS

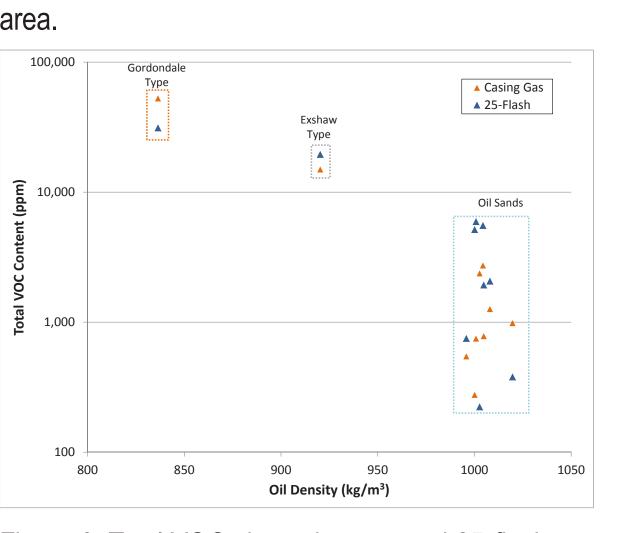


Figure 6. Total VOCs in casing gas and 25-flash gas versus 15°C post-cleaning absolute oil density.

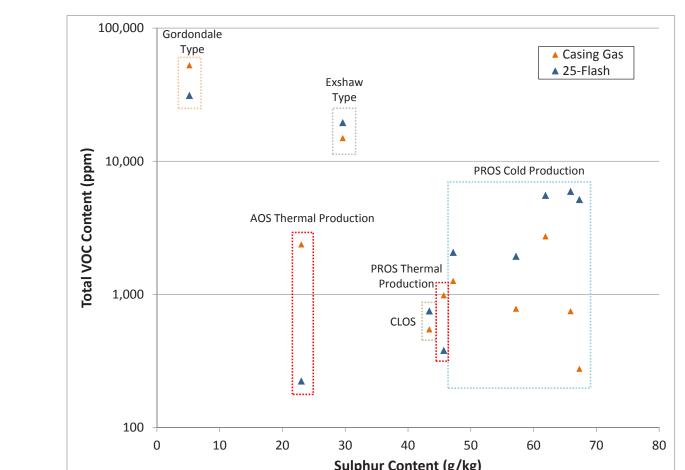


Figure 7. Total sulphur versus total VOCs.

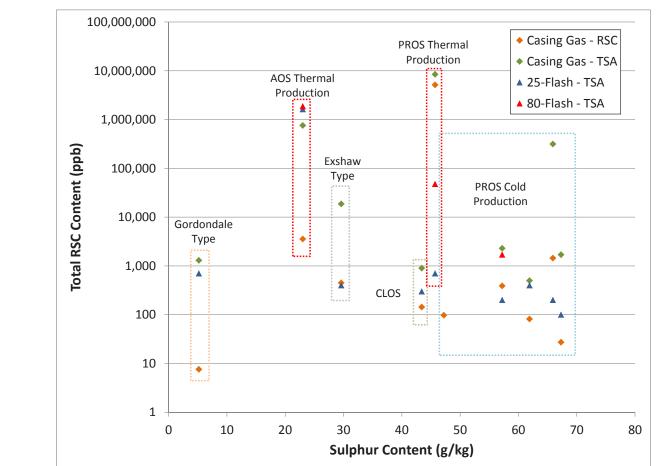


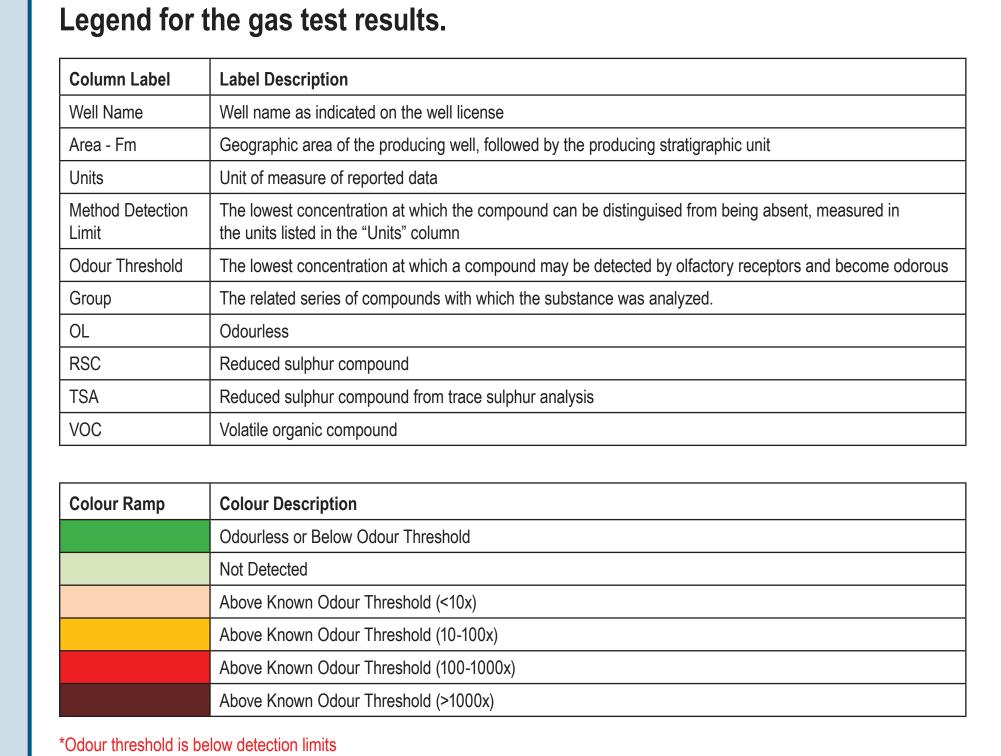
Figure 8. Total sulphur versus total RSCs.

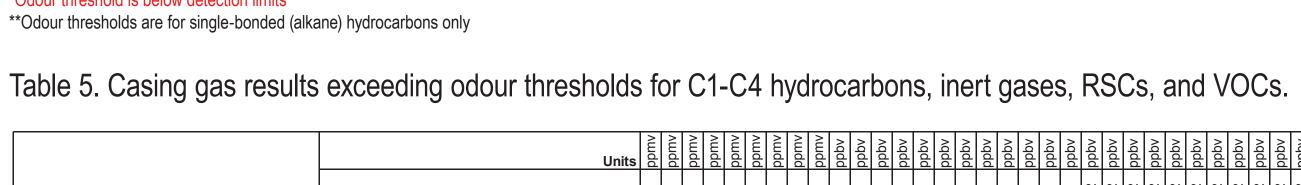
## Source-Rock Contribution

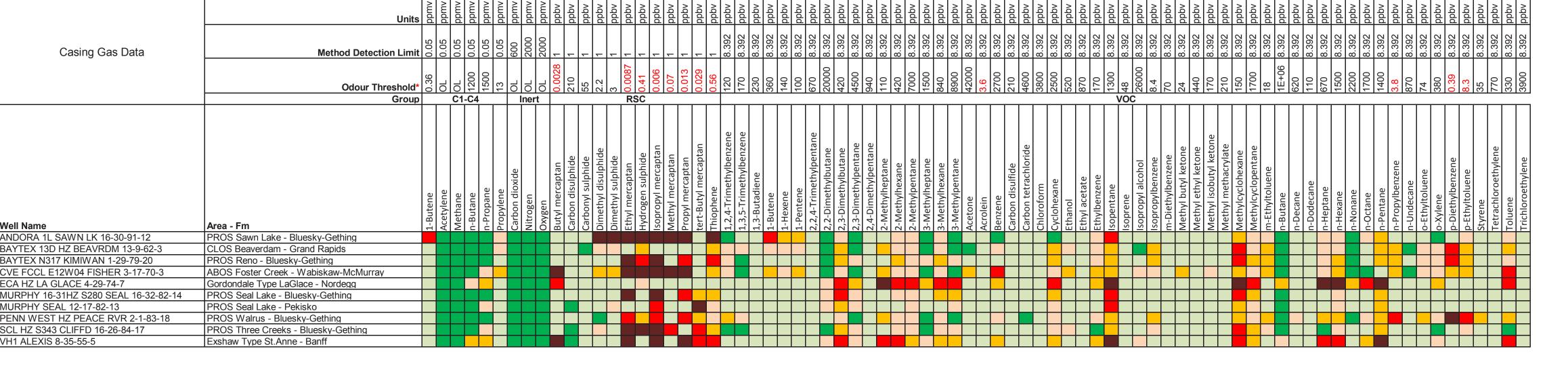
The trace metal and isotope data acquired during this study are consistent with those presented in Adams et al. (2013) and indicate mainly Gordondale and Exshaw sourcing in the PROS area and a lack of Gordondale source-rock contribution in the other OSAs (Figure 2). The Exshaw component increases as you move northeast through the PROS area (Figure 3). The exception to this is the sample from northeast of the Red Earth Highlands, which was taken from a well that had recently been converted to SAGD production. The water source for the steam may have changed the sulphur isotope ratios without affecting the vanadium to nickel ratio. Due to the mixing of these source oils and the complexity of the oil contribution based on depth, it would be extremely difficult to draw a line between where pure Gordondale-sourced oil and pure Exshaw-sourced oil exists within the Peace River recommendation areas. This area appears to be a mixture of both source rocks.

The Gordondale type oil analyzed for this study is likely of higher organic maturity than the type oils in Adams et al. (2013), which may account for the variation from the Adams et al. (2013) Gordondale source-oil box (Figure 2). Some samples could not be plotted in Figure 2 because isotopic data were not analyzed for or were unable to be determined by the laboratory. In Figure 3, the data shows an increasing Gordondale component from northeast to southwest across the PROS area. Some samples could not be plotted in Figure 3 because isotopic data were not analyzed for or because the nickel and vanadium contents were below detection limits.









Casing Gas Data

## Table 3. 25-flash gas results exceeding odour thresholds for C1-C7 hydrocarbons, inert gases,

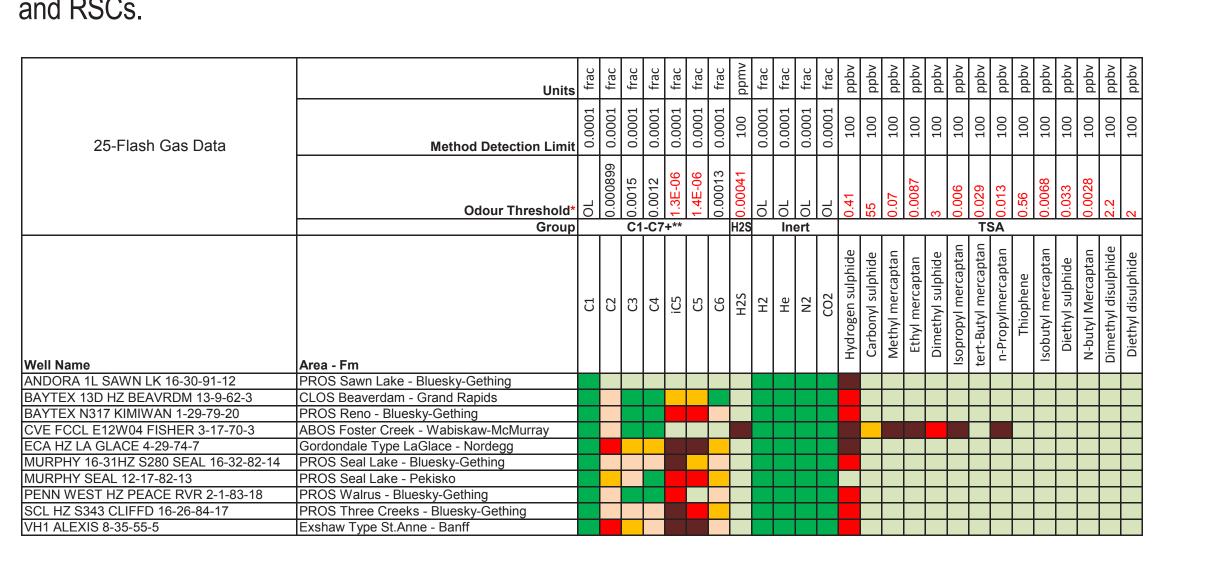
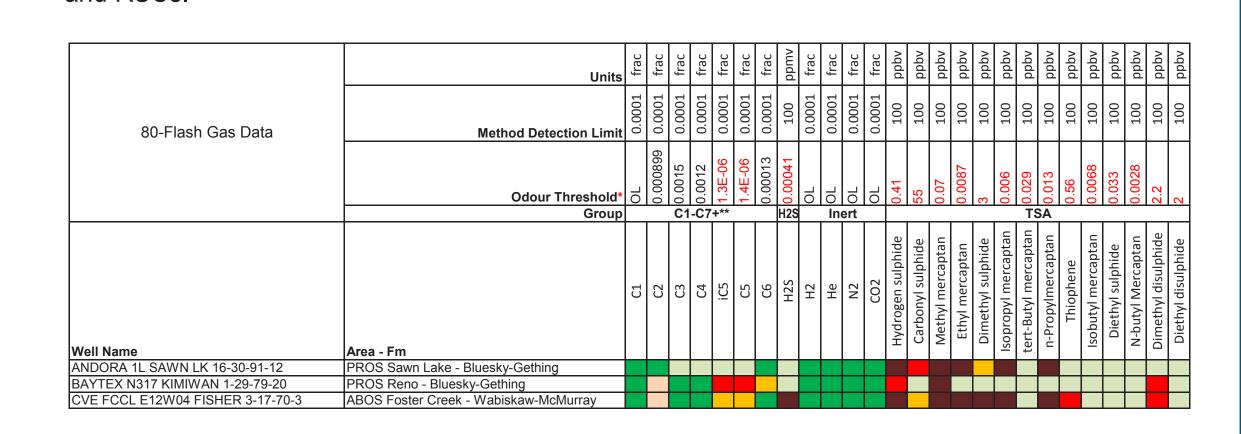


Table 4. 80-flash gas results exceeding odour thresholds for C1-C7 hydrocarbons, inert gases,



#### Table 6. 25-flash gas results exceeding odour thresholds for VOCs.



## Conclusions

- There are currently four geological plays in the PROS area with heavy oil and bitumen deposits: the Bluesky-Gething play, the Belloy play, the Debolt play, and the Pekisko play. The amalgamation of the heavy oil and bitumen deposits identified in each play was used to create a 3-D geobody representing the area currently prospective for oil sands designated heavy oil and bitumen.
- There is more Gordondale Member-sourced oil in these plays in the western part of the PROS area, and more Exshaw Formation—sourced oil in the eastern part of the PROS area as well as in deeper geological plays. However, stratigraphic architecture, the extensive faulting, and degree of homogenization of the oils through processes such as biodegradation make it impossible to draw a boundary separating their occurrence.
- The process and degree of biodegradation, not only the source rock, leads to increased sulphur content, and increased sulphur content does not appear to correlate to increased RSCs and VOCs in the samples.
- In the PROS area, the 3-D zone in the subsurface where the heavy oil and bitumen appears to have the highest probability for increased odours and emissions is related to depth, oil properties, and heat treatment during production, regardless of the geological play or source rock. This zone is called the 'PROS Heavy Oil / Bitumen Zone' and is defined as any zone above the depth where heavy oil and bitumen have densities ≥950 kg/m, viscosities ≥1000 cP, and below the base of the Fort St. John Group. This is the zone in each play where heavy oil and bitumen will need to be heated to temperatures significantly higher than initial reservoir temperature (high temperature differential), either in the reservoir or at surface, to allow it to flow.
- While both RSCs and VOCs are present in the produced oil sands designated heavy oil and bitumen, there is no correlation between their concentrations and the oil's source rock.
- There is a trend of increasing RSC concentrations released from the oil sands designated heavy oil and bitumen as the temperature difference between original reservoir temperatures and production temperatures increases.

#### References

Adams, J., Larter, S., Bennett, B., Huang, H., Westrich, J. and van Kruisdijk, C. (2013): The dynamic interplay of oil mixing, charge timing, and biodegradation in forming the Alberta oil sands: insights from geologic modeling and biogeochemistry; in AAPG studies in geology #64: heavy-oil and oil-sand petroleum systems in Alberta and beyond, F. J. Hein, D. Leckie, S. Larter, and J. R. Suter (ed.), American Association of Petroleum Geologists, p. 23–102.

Nagata, Y. (2003): Measurement of odor threshold by triangle odor bag method; Journal of Japan Air Cleaning Association, v. 41, no. 2, p. 17–25.

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