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Centre d'expertise
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Public Health Review on Shale Gas Activities: Water, Air Contamination and Technology Risk Management

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May 29th, 2014

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Presentation

The presentation is based on a report published by INSPQ in September 2013 : *État des connaissances sur la relation entre les activités liées au gaz de schiste et la santé publique, mise à jour.*

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INSPQ Report (2013) - Water

- Drinking water contamination risk related to the shale gas installation and fracking process remains, on the long term, the main source of concern for public health.
- Involved contaminants
  - Substances from shale formations: methane, drilling mud (brine), metals, radionuclides, etc.
  - Fracturation fluids.

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INSPQ Report (2013) - Water

Based on INSPQ analysis (2013), water contamination cannot be excluded.

- Hypotheses on contamination origin
  - Leaks are due to deteriorating or improperly formed casings around piping systems. Fissures occur at hundred metre depth. Methane and hydrocarbons light liquid pass laterally or vertically through fracture systems.(DiGiolio et al., 2011; ATSDR, 2011; Osborn et al., 2011; Jackson et al., 2013).
  - Hydraulic fracturing process generates new fractures or increases existing fractures above the fracturing zone. Gas infiltrates through these new fractures and migrate up to the water table . (Osborn et al., 2011; Jackson et al., 2013; Rozell et Reaven, 2012; Hunt et al., 2012; Warner et al., 2012; Mayer, 2012).

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Results

- Many investigations on underground drinking water were achieved following incidents or citizen complaints.
- In some cases, research confirmed a link between underground water and shale gas installations:
  - ATSDR, 2011 (residential water wells contamination: While the gas well was undergoing hydraulic fracturing by the Chesapeake Energy Corporation, a well head flange failure occurred, uncontrolled flowback fluid release occurred on April 19, 2011.
  - DiGiolio et al., 2011 (residential wells contamination by fracking fluids in Pavillon, WY): Conclusion: leaks due to deteriorating or improperly formed casings around piping systems of a gas well.
  - PDE Protection, Bureau of Oil and Gas Management (2010): Since 1859, in Pennsylvania, it is estimated that 300 000 oil and gas wells have been drilled in this state. Many wells were not properly plugged when abandoned and are the cause of water and air contamination.

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Results (continued)

- Studies demonstrate that methane and other alkane concentrations were substantially and systematically higher at proximity of natural gas wells and hydraulic fracturing in aquifers overlying the Marcellus and Utica shale formations.
  - Osborn et al., 2011; Jackson et al., 2013

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Determination of Underground Water Contamination Origin

Characteristics of hydrocarbons and gas from the thermogenic zone: shale and tight gas reservoirs

- Significant quantities of methane are trapped in the form of methane hydrate (2H-CH4).
- Because isotopic disintegration occurred over hundreds of thousands of years, the carbon of the methane is not only the fossil carbon 14 (^{14}C), but contains its isotopes, carbon 13 (^{13}C).

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Determination of Underground Water Contamination Origin

- Besides methane, the thermogenic zone includes a variable rate of heavier hydrocarbons ranging up to heptane (C_7H_{16}).
  - The $\delta^{13}C\text{-}CH_4$ and $\delta^{2}H\text{-}CH_4$ values and the ratio of methane to higher chain hydrocarbons (ethane, propane and butane) can typically be used to differentiate shallower biologically derived methane from deeper physically derived thermogenic methane and other alkanes. It is an isotopic signature of alkanes, a kind of fingerprint of their origin.
- The following elements can also be found:
  - CO_2, SO_2, H_2S, nitrogen (N_2), small amounts of helium (He) and radioactive elements (uranium, thorium and radium).

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Determination of Underground Water Contamination Origin

- Stephen G. Osborn et al. (2011). *Methane contamination of drinking water accompanying gas well drilling and hydraulic fracturing.* Published in the *Proceedings of the National Academy of Sciences,* USA www.pnas.org/cgi/doi/10.1073/pnas.1100682108.
- Robert B. Jackson et al. (2013*). Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction.* Published in the *Proceedings of the National Academy of Sciences,* USA www.pnas.org/cgi/doi/10.1073/pnas.1221635110.

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Publications

Stephen G. Osborn et al., 2011 – Protocole Study

- In Northeastern Pennsylvania (Catskill and Lockhaven) and in New York State (Genessee), various contaminants found in 60 private wells at a depth of 36 to 190 m were analysed.
- Comparative contamination study
  - Of 26 drinking water wells located at less than 1 km from shale gas drilling (active wells).
  - With 34 drinking water wells located at more than 1 km from shale gas wells.
- Methane concentrations and light hydrocarbons (ethane, butane, propane), dissolved salt, isotopes (^{18}O and ^{2}H), carbon isotopes (^{13}C), boron and radium were measured.

Stephen G. Osborn et al., 2011. *Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing .* www.pnas.org/cgi/doi/10.1073/pnas.1100682108.

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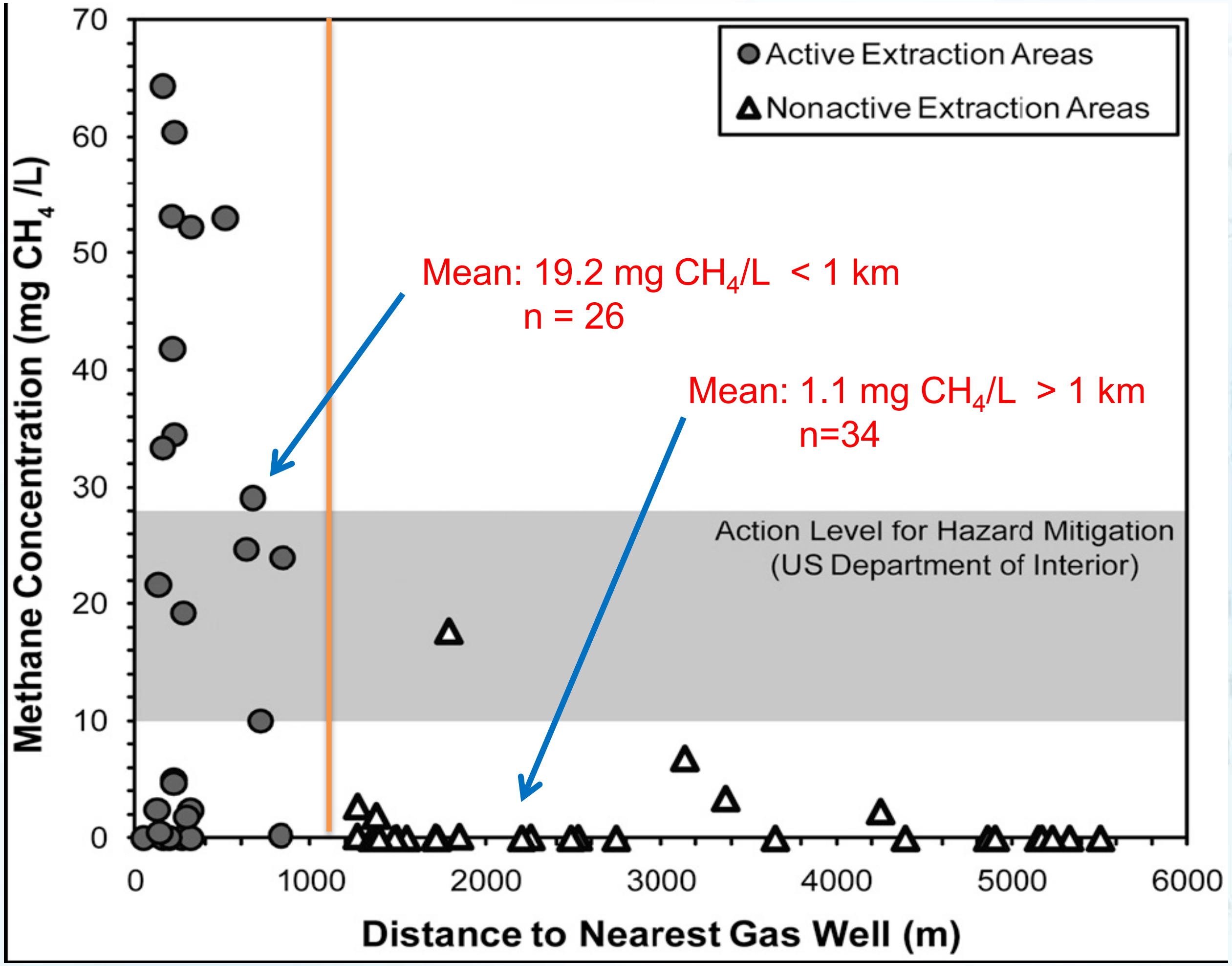
Methane Concentrations as a Function of Distance to the Nearest Gas Well Drilling Areas



Water

60 drinking water wells analysed

Source: Osborn et al., 2011

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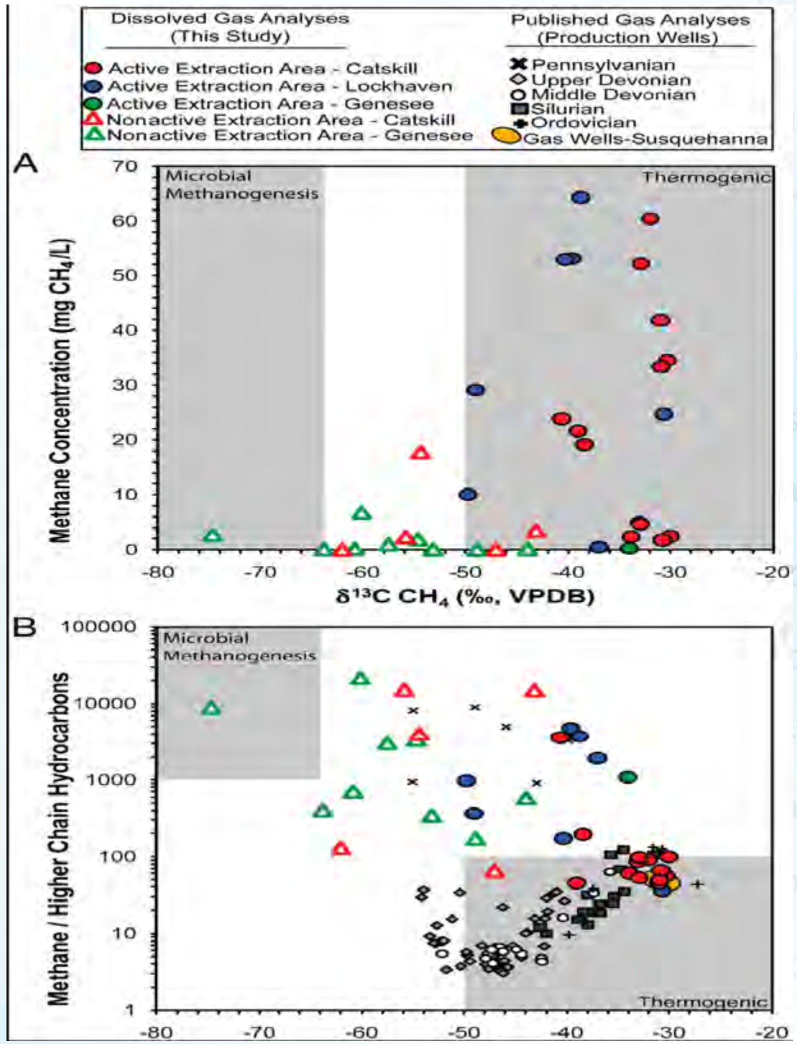
Methane Concentrations in Groundwater Versus the Carbon Isotope Values of Methane (from Osborn et al., 2011)



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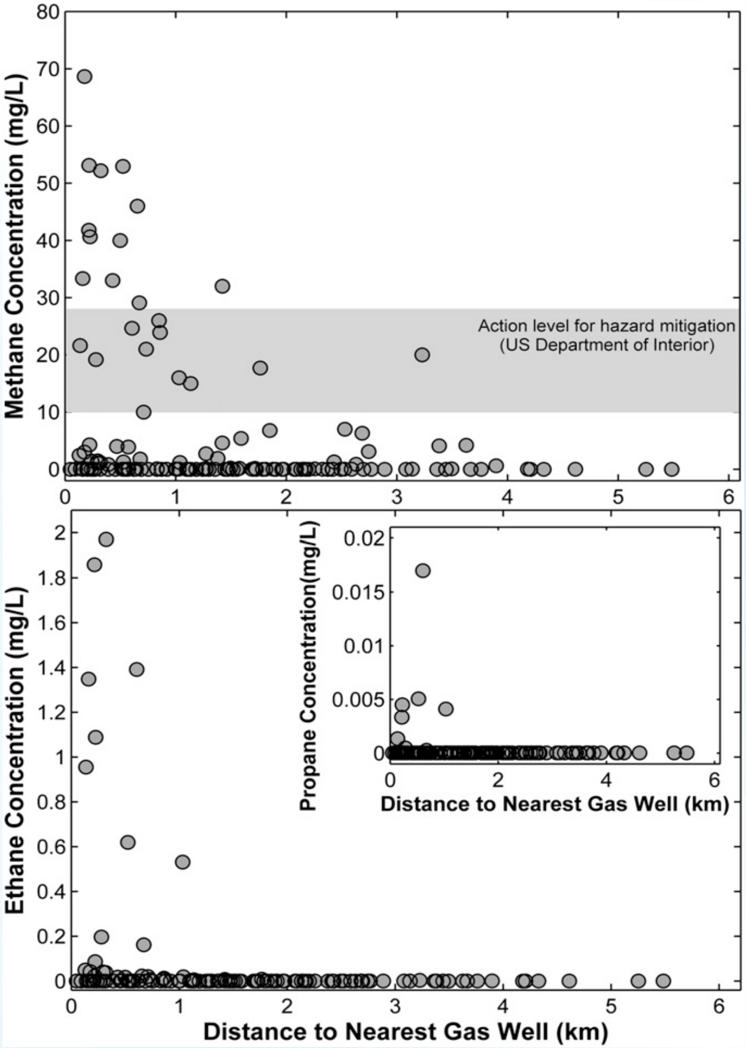
Jackson et al., 2013



- On 141 drinking water wells sampled, 82% detected methane.
- In residences located at < 1 km from gas wells, the mean concentrations (C_{mean}) were 6 times higher than the concentrations found at > 1 km (P = 0,0006).
- Ethane C_{mean} was 23 times higher in residences located at < 1 km from a gas well (P = 0,0013).
- Propane C_{mean} was detected in 10 drinking water wells, all at < 1 km from a gas well (P = 0,01).

Source: Jackson et al., 2013

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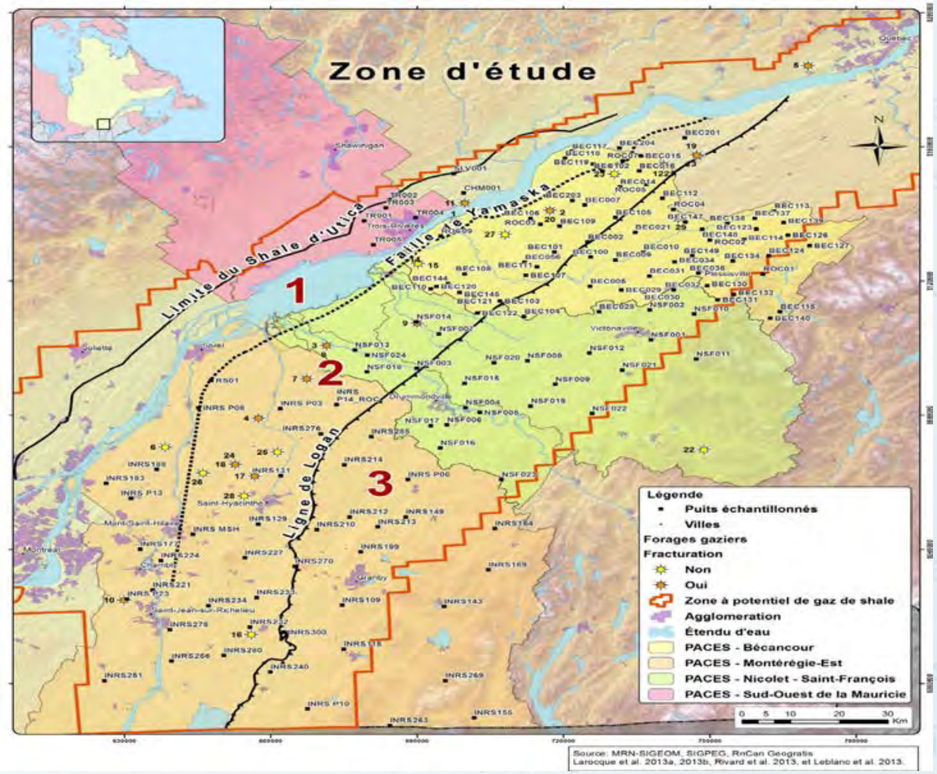
Pinti et al., 2013 - Quebec Background Level

- 130 residential, municipal or monitoring water wells were sampled.
- Methane concentrations > 7 mg/L were obtained in 18 drinking water wells.
  (safety limit in Quebec)

Note: The data observed by Pinti et al. will be compared to the observed data in previous studies in order to verify the validity of the shale origin hypothesis of aquifers' contamination.



Carte 1. Localisation des puits d'alimentation en eau potable échantillonnés. En fond de carte sont représentées les régions des différents programmes PACES réalisés ou en cours de réalisation. Les trois couloirs d'exploration sont aussi représentés (Pinti et al., 2013)

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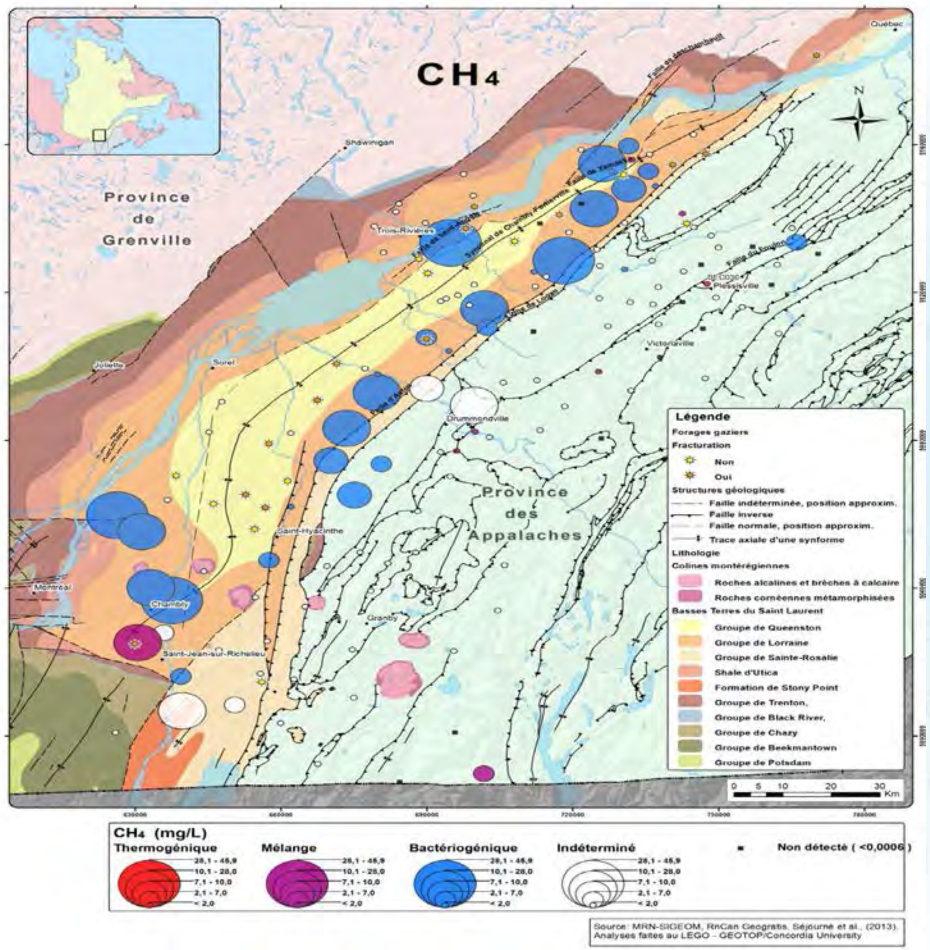
Pinti et al., 2013 – Results and Conclusions



Carte 7. Concentrations ponctuelles de méthane, sur fond de carte géologique. La taille des bulles représente la concentration en méthane et les couleurs sont basées sur l'interprétation de la figure 11 (Pinti et al., 2013, p. 49)

- Negative correlation between dissolved methane concentrations in water wells and their distance from the major geological regional faults has been observed.
- This relationship cannot be explained by the rise of gas from deeper formations, because the isotopic signature of the methane reflected biogenic and few mixed sources, thus methane is produced relatively close to the surface.
- The authors said that more intense fracturing of the rock near the large geologic fault could facilitate the remobilization of trapped gas from sediments and its transfer into the groundwater aquifers.

Source: Pinti et al., 2013, p. 50

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Publications

Baldasare et al., 2014 – Northeastern Pennsylvania Background Level

- 10 445 underground drinking water wells were sampled and analysed before gas wells drilling. (**Mean Concentration: 1,03 mg/L**).
- 3 006 underground drinking water wells (28,8%) had CH_4 concentrations > 0,026 mg/L. (**Mean Concentration: 3,53 mg/L**).

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Comparison of Methane Background Levels Observed in Pennsylvania and Quebec with Levels Measured in Osborn et al. (2011) Study

Methane			
Study	**Sampled of underground drinking water wells (total)**	**Mean concentration (mg/L)**	**Drinking water wells concentration > 7 mg/L/ total (%)**
Baldassare et al., 2014	10 445	1,03	3,9
Pinti et al., 2013	130	3,81	13
Osborn et al., 2011	60	8,34 19, 2 (< 1 km) 1,1 (> 1 km)	25 85(< 1 km)

Comparison of Ethane and Propane Background Levels Observed in Pennsylvania and Quebec with Levels Measured in Osborn et al. (2011) Study

Ethane			
Study	(n) Sampled of underground drinking water wells	Concentration (mg/L)	Drinking water wells ethane detected (%)
Baldassare et al., 2014	10 445	0,03-0,3	19
Pinti et al., 2013	130	< 0,086	32
Osborn et al., 2011	60	Up to 2 (< 1 km) < 0,2 (> 1 km)	-

Propane			
Study	(n) Sampled of underground drinkingwater wells	Concentration (mg/L)	Drinking water wells propane detected (%)
Pinti et al., 2013	130	< 0,0061	8
Osborn et al., 2011	60	Up to 0,017 (< 1 km)	17

Comparison Between Pinti et al. (2013) and Osborn et al. (2011) concerning the Distribution of Methane Concentration from Sample Drinking Water Wells as a Function of δ^{13}C-CH4

Fig 10: Pinti et al., (2013) , E3-9

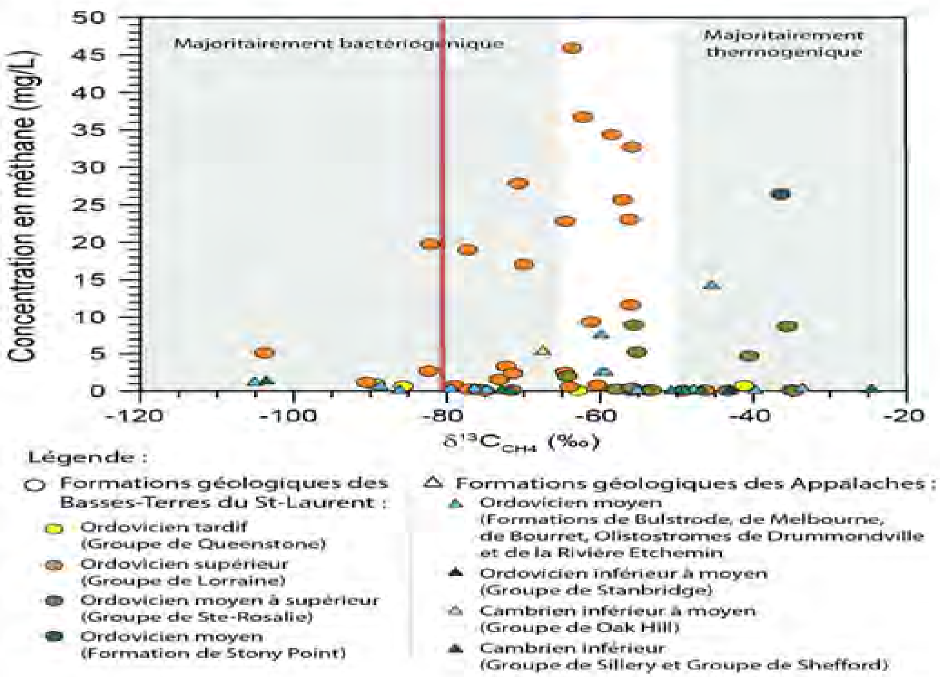
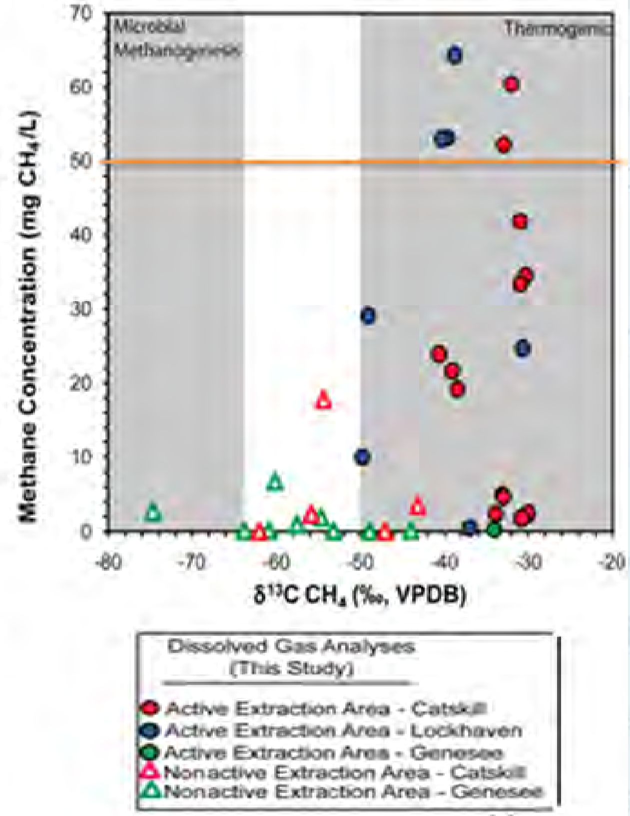


Fig 4: Osborn et al., (2011)



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Ratio Methane (C1)/ {Ethane (C2) +, Propane (C3)} Concentrations as a function of $\delta^{13}C_{CH4}$

Figure 11 modified: Pinti et al. (2013)

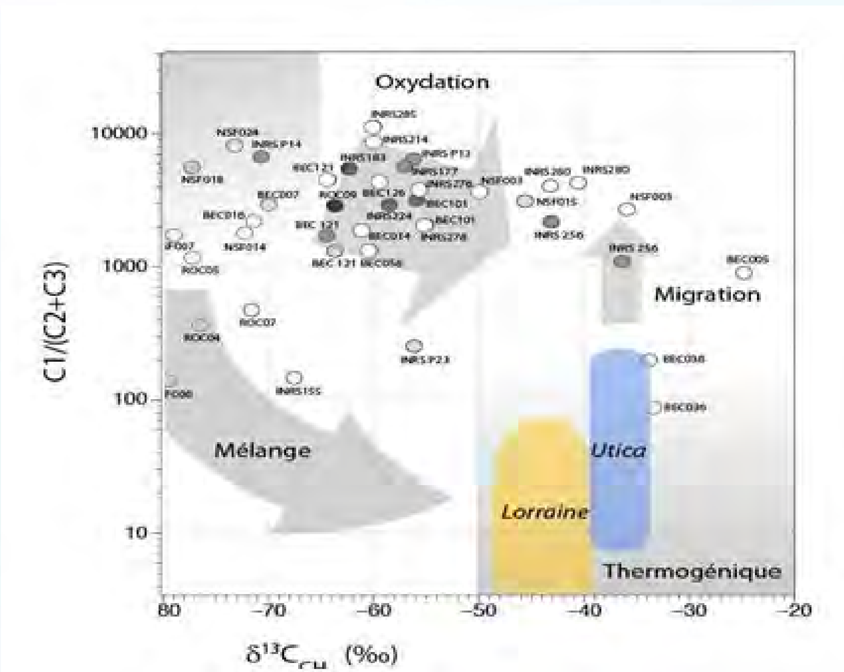
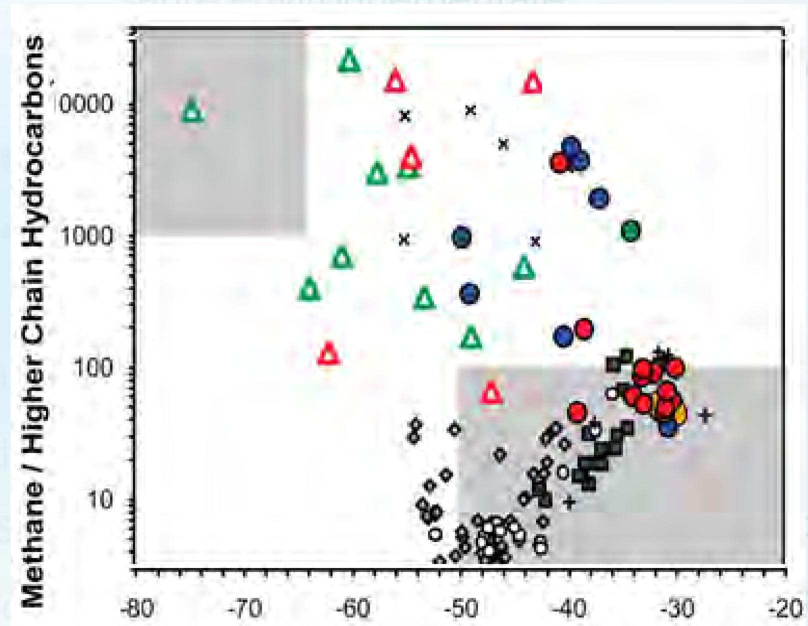
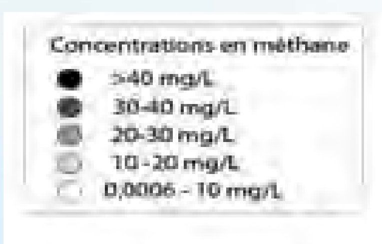


Figure 4B: Osborn et al. (2011)





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Health Effects

- In short term, confirmed risk of methane explosion.
- On the long term, no health risk studies have assessed the health effects associated with exposure to one or more contaminants found in drinking water in relation to shale gas activities.
- Suspected long-term health effects related to low doses of chemical contaminants may cause chronic diseases (ex.: cancer and neurologic, immune and reproductive diseases). These diseases take generally years to appear. The limited shale gas operating duration explains the absence of epidemiological studies.

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Conclusions

- In the USA, underground contaminated water was observed after a short operating duration and was noted, on average, in less than five years.
- No research has yet been able to invalidate the underground water risk contamination hypothesis from shale formation, but the origin of the contamination remains unclear (casing failure versus migration from shale formation) .
- Over time, the risk of default or alteration of the drilling well cement casing seems more plausible.
- Based on our own analysis, from a public health point of view, risk of underground water contamination remains of concern.

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Exposure Information (2010-2013) - Air

Air Pollutant Levels

- In proximity to a shale gas site, emissions of air pollutants (e.g. : COV, NO_X) could be more important during the production than during the digging[1,2]; compressors and flares would be among the main sources of pollutant air emissions[3].
- Measurements and estimates from models suggest that populations located close to shale gas wells would be more exposed to $PM_{2,5}$, O_3 et COV[4,5,6] than populations living far away from shale gas sites.
- Based on the projection of the future number and location of Quebec shale gas wells, SNCL estimated that the concentration of a number of pollutants (e.g. : COV, $PM_{2,5}$, NO_x) will exceed the air quality criteria of the Quebec Ministry of the Environment.

1. ALL Consulting, 2010; 2. Litovitz et al., 2013; 3. Olager, 2012;
4. NYSDEC, 2011; 5. Rich et al,. 2011; 6. Pa DEP, 2011

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Public Health Emergency and Technology Risk Management

- Risk of explosions, fires, leaks and spills.
- Accidents may happen throughout the exploration and exploitation processes on site and during transport.
- In Quebec, the shale gas exploitation would be located close to densely populated areas and in agricultural regions.
- The frequency of incidents is difficult to document, however it was shown that industry safety practices are not always in accordance with best practices.

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Public Health Emergency and Technology Risk Management

- Among the 26 % to 58 % of statements of offences issued, the probability of occurrence of major environmental events is about 0,7% (OCMOH, 2012; Staaf, 2012).
- The territory covered is subject to landslides devastating nature. Then, activities related to shale gas could act as as triggers of landslides.

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