GeoConvention 2014 FOCUS | adapt refine sustain

BASELINE GEOLOGICAL AND GEOCHEMICAL NEAR SURFACE DATA – THE CASE OF THE UTICA SHALE IN SOUTHERN QUEBEC

Denis Lavoie; Geological Survey of Canada –Quebec office
Christine Rivard, Geological Survey of Canada – Quebec office
Geneviève Bordeleau, Geological Survey of Canada – Quebec office
Andy Mort, Geological Survey of Canada – Calgary office
Jean-Christophe Aznar, Institut National de la Recherche Scientifique – Eau-Terre-Environnement
Michel Malo, Institut National de la Recherche Scientifique – Eau-Terre-Environnement

Summary

Shale gas and tight oil exploration and development in populated areas with little past experience with the hydrocarbon industry is usually met with some strong opposition most of which is based on the perception of risk for groundwater quality. The industry and the public geoscience organizations are responsible for evaluating and monitoring the environmental impacts of unconventional resources development. The Geological Survey of Canada has initiated a detailed evaluation of shallow sub-surface conditions (geology, hydrogeology, geochemistry) at a specific site southwest of Quebec City where one shale gas well targeting the Utica Shale has been drilled and fracked. Soil gas, dissolved hydrocarbons in groundwater and organic geochemistry of extracts from shallow cores have been analysed for the origin of the gas. Preliminary groundwater data suggest a mixed biogenic and thermogenic origin for the gas (C1 to C3), and GC and GC-MS of the extracts document up to C20 hydrocarbons in the shallow bedrock. The establishment of baseline geological and hydrogeological settings is a critical first step prior to large scale development of unconventional hydrocarbons.

Introduction

The history of conventional hydrocarbon exploration in southern Quebec is minimal and is largely unknown to the local population. In southern Quebec, the Utica Shale has been targeted as a potential shale gas producer and from 2007 to 2010, 29 wells (vertical and horizontal) have been drilled and 18 of them fracked (Fig. 1). Shale gas development outside the Western Canada Sedimentary Basin is met with locally significant opposition on the perceived risk of groundwater contamination from fracking. In 2010, the Utica Shale exploration phase has come to a halt pending a review of all environmental aspects related to shale gas development. As part of its Environmental Geoscience program, the Geological Survey of Canada and its provincial and academic research partners have initiated in 2012, a research project in the St-Edouard area (50 km southwest of Quebec City; Fig. 1) where the well with the best IP and 30-days testing of the Utica Shale was drilled in 2010. The ultimate goal of the research is to tie the deep and shallow geological domains and evaluate the presence of natural or hydraulically-enhanced pathways connecting the Utica Shale and the shallow groundwater aquifers. This will be done through integration of data from bedrock geology, deep and shallow geophysics, geomechanics, as well as hydrogeological and geochemical characterization of the near surface environments. This abstract presents the preliminary data and interpretation based on the first field campaign that included shallow well drilling and coring, and groundwater and soil sampling.

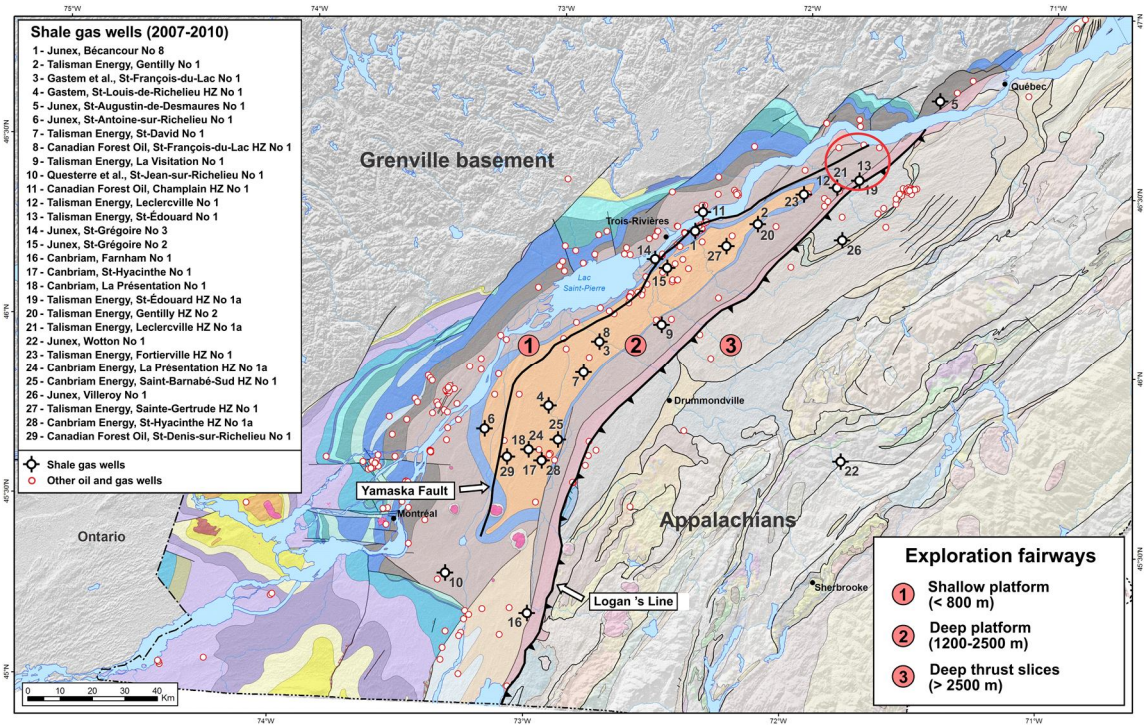

Fig. 1: Simplified geological map of southern Quebec with the location of the 29 shale gas wells. The location of the study is circled in red. Modified from Lavoie et al. (2014).

Rationale and method

The presence of naturally-occurring dissolved hydrocarbons in shallow aquifers is a well-known fact in many sedimentary basins; the St. Lawrence Platform in southern Quebec is no exception with the presence of hydrocarbons in groundwater being documented since the late 1800's. If such presence is fairly well established, the source of the hydrocarbons, being either biogenic or thermogenic, is equivocal. In order to evaluate the shallow sub-surface system, 25 private water wells have been sampled and 4 shallow (50 m) wells drilled, cored and sampled for water chemistry, rock organic geochemistry and thermal maturation. Water sampling of GSC wells is done bimonthly. Groundwater is analyzed for conventional chemistry, concentrations of dissolved hydrocarbons and isotopic characterization of methane. Moreover, a detailed soil survey (Radon, CO_2 and hydrocarbon gas) was conducted over the area.

Results

Most groundwater samples contain significant concentrations of dissolved hydrocarbons including methane and less abundant ethane and propane. Methane concentrations do not appear to be related to geology, but mainly to the water type: high methane concentrations being found in wells with Na-HCO_3 type groundwater, while lower methane concentrations are found in Ca-HCO_3 water type. Higher concentrations are mainly found in the northern part of the study area, 10 km north of the shut-in Utica Shale well. Methane concentrations in the region range from 0.006 (detection limit) to 40 mg/l, with a median value of 4 mg/l (Fig. 2).

The presence of dissolved ethane and propane in groundwater indicates that some of the hydrocarbons are thermogenic in origin. Gas wetness *versus* $\delta^{13}C$ of methane diagram suggests possible mixing of thermogenic and biogenic sources, a conclusion also supported by $\delta^{2}H$ and $\delta^{13}C$ values of methane.

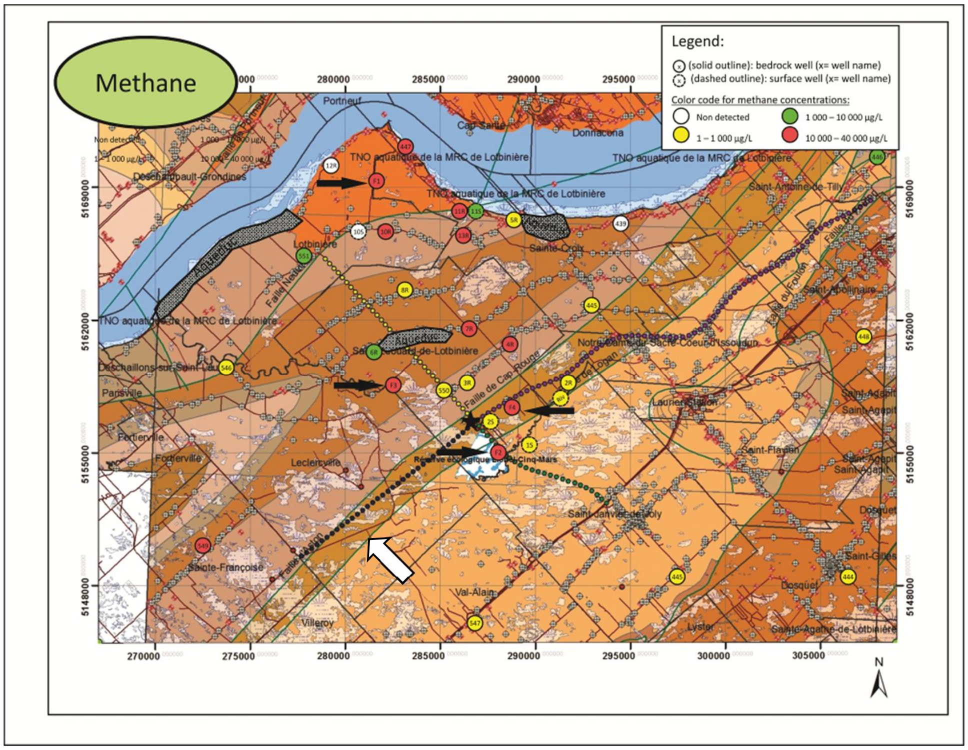

Fig. 2: Concentration of dissolved methane in shallow groundwater. Highest concentrations are in red. The dotted lines are industry seismic lines, the Utica Shale well (star) is at the interception of the 2 lines. GSC shallow wells pointed by black arrows. The Appalachian – Platform contact (Logan's Line) is shown by the white arrow.

The bedrock geology is dominated by a 1 to 2 km thick succession of Upper Ordovician shales and sandstones that overlie the Utica Shale. The study area straddles the little deformed St. Lawrence Platform and the Appalachians (Fig. 2). Results of Rock Eval and $Ro_{vit\text{-}equiv}$.from the shallow cores (Fig. 2) document oil window condition in the north and condensate zone to the south. GC and GC-MS results from extracts (Fig. 3) indicate the presence of C1 to C20 hydrocarbons in the cores.

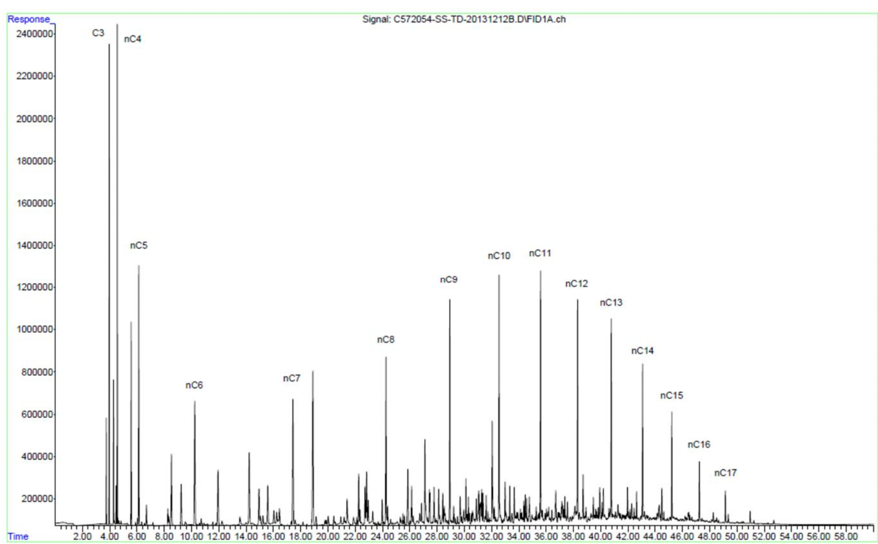

Fig. 3: GC-MS graph of extracts from the Lotbinière Formation from the northernmost well drilled by the GSC (Fig. 2 for location).

Soil gaz were sampled for pore-space CO_2 (concentrations and $\delta^{13}C$), radon, methane and hydrocarbons (C2-C4) at 250 sites located along transects. Anomalous concentrations of CO_2, methane, ethane, butane and radon are associated with the tectonized Appalachian deformation front (Fig. 4) where they superimpose on higher concentrations of dissolved hydrocarbons in groundwater.

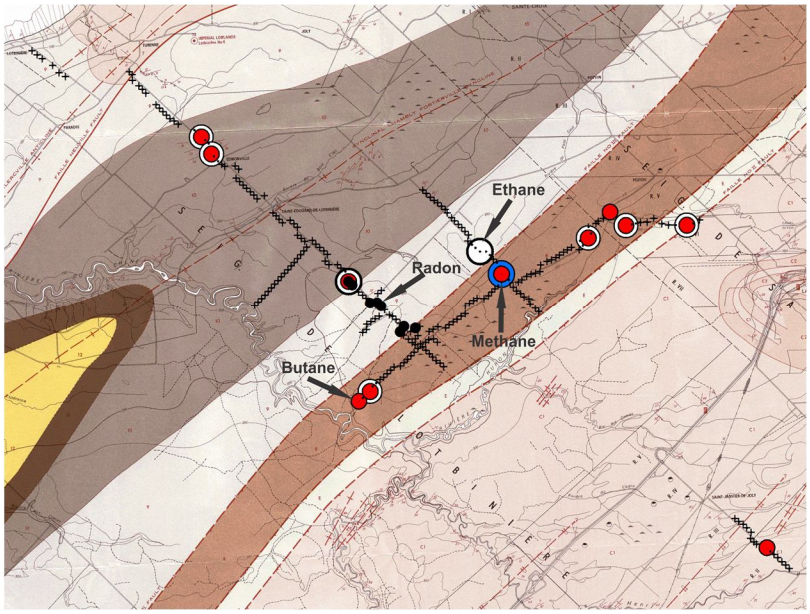

Fig. 4: Geological map with soil gas anomalies (values 2.5σ above average). Color codes: Black: Radon, Red: Butane, White: Ethane, Blue; Methane.

Conclusions

The perceived risk of groundwater contamination from unconventional resources development is a major societal concern in populated areas. It is critical that baseline geological, hydrogeological and geochemical data be acquired and the natural state of the shallow sub-surface environment be characterized prior to significant exploration activities. A detailed study of groundwater and shallow subsurface geological framework has been initiated in a *circa* 600 km^2 of southern Quebec. One shale gas well was drilled (2009) and fracked (2010) in this area. From Rock Eval and $Ro_{vit\text{-}equiv.}$, the near surface bedrock is within the oil window to condensate thermal domains. Extracts from shallow coring program are characterized by C1 to C20 hydrocarbons. The results of the first field season of the project document the presence of locally, naturally-occurring, significant concentrations of dissolved hydrocarbons in groundwater as well as radon and hydrocarbon anomalies in soils. The presence of C3+ hydrocarbons in groundwater and soil gas indicates a thermogenic component, an interpretation also supported by stable isotope values of methane and gas wetness values, although mixing with an oxidized biogenic-derived component is also likely. Additional fieldwork and further analyses and interpretation should help us determine unequivocally the origin of the methane frequently found in groundwater of this area.

References

Lavoie, D., Rivard, C., Lefebvre, R., Séjourné, S., Thériault, R., Duchesne, M.J., Ahad, J., Wang, B., Benoit, N. and Lamontagne, C. (2014) The Utica Shale and gas play in southern Quebec, Geological and hydrogeological synthesis and methodological approaches to groundwater risk evaluation. International Journal of Coal Geology. Special issue on potential environmental impacts of unconventional fossil energy development (in press).