Geological and Hydrogeological Synthesis of the Utica Shale and the Overlying Strata in Southern Quebec Based on Public Data in a Context of a Moratorium on Exploration*

Stephan Séjourné[1], René Lefebvre[2], Denis Lavoie[3], and Xavier Malet[2]

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[1]Consultant, Montreal, QC, Canada (ssejourne.geo@gmail.com)
[2]Institut National de la Recherche Scientifique – Centre Eau Terre Environnement, Quebec City, QC, Canada
[3]Geological Survey of Canada – Quebec Division, Quebec City, QC, Canada

Abstract

In the context of an ongoing Strategic Environmental Assessment that addresses the issues related to potential shale gas development in the St. Lawrence Lowlands of southern Quebec, the authors carried out a comprehensive synthesis of the geological and hydrogeological information publicly available to support the ongoing and future efforts to assess the integrity of the geological seal between the Utica Shale and the shallow groundwater. Potable groundwater is mostly found in the St. Lawrence Lowlands in the first tens of meters below surface, at times in the surficial quaternary deposits but mostly in the underlying shallow, naturally fractured rock. However, little data exist to evaluate the possible occurrence of fresh water at greater depths. Therefore, part of this work was also aimed at documenting the existing industry data that could be used to characterize the natural fracture pattern and the hydrogeologic environment at greater depths. By highlighting geographic or thematic weaknesses in the datasets, this contribution also aimed at supporting ongoing research projects to develop a method to evaluate the vulnerability of aquifers related to activities carried out in the subsurface.

Introduction

Shale gas exploration focusing on the Late Ordovician Utica Shale began in 2006 in the St. Lawrence Lowlands of southern Quebec. Up to 2010, 19 vertical wells and 11 horizontal wells had been drilled and 18 hydraulic fracturing programs had been performed (Figure 1). Exploration efforts have virtually stopped since the fall of 2010, when the Quebec government initiated a series of public hearings on the exploration for, and the potential exploitation of shale gas in southern Quebec. Following those hearings, the Bureau des Audiences Publiques sur l'Environnement (BAPE) recommended a Strategic Environmental Assessment (SEA) to be completed by late 2013. In the absence of new well data, understanding the deep hydrogeological environment can only be achieved through the gathering and synthesis of publicly available data.

Range of Data Evaluated

Three main avenues of investigation were followed to synthesize the available geological and hydrogeological information:

- Synthesis of all relevant geological data for the Utica Shale and the overlying strata (Lorraine and Queenston groups and quaternary deposits). These data included stratigraphic and structural settings (Figure 2), depth, thickness, lithology and mineralogy of the strata, synthesis of the petrophysical logs and the cores available (Figure 3), and synthesis of the known physical properties (pressure, temperature, porosity, permeability and fluids saturation). Governmental reports, well data and publications have been used to achieve this task.
- Building of a series of conceptual structural models in selected areas representative of the general tectonostratigraphic setting of the domain prospective for shale gas (Figure 1). These models are aimed at assisting the future research focusing on developing a regional 3D hydrogeological model over the area of interest and led to the identification of medium-depth sandy intervals within the Lorraine Group (Figure 4). Geological maps, 2D seismic and well data were used to achieve this task.
- Synthesis of the main results of past and ongoing regional hydrogeological studies initiated by the Department of Environment of Quebec (Programmes d'acquisition de connaissances sur les eaux souterraines du Québec – PACES). This involved the history of the past and ongoing hydrogeological characterization projects, synthesis of the hydrogeological data available (Figure 5), synthesis of the gas shows (Figure 6) and gas, oil and water analyses. Governmental reports, university datasets and well data were used to achieve this task.

Conclusions

Overall, the synthesis indicates there is no significant geographical weakness in the data coverage: The PACES projects cover the entire area prospective for shale gas in the St. Lawrence Lowlands and the lack of subsurface geological data in the southeastern sector is not critical so far as this area will not likely be the focus of any significant shale gas exploration in the mid-term. However, several thematic weaknesses are highlighted, especially in the regional tectonostratigraphic framework, the physical and chemical properties of the deep hydrogeologic environment, and the seal integrity above the Utica Shale. Until new well data are gathered in the field, the most critical thematic uncertainties can be overcome only partially through the systematic integration of publicly available geological datasets, and recommendations are proposed in that regard (Séjourné et al., 2013).

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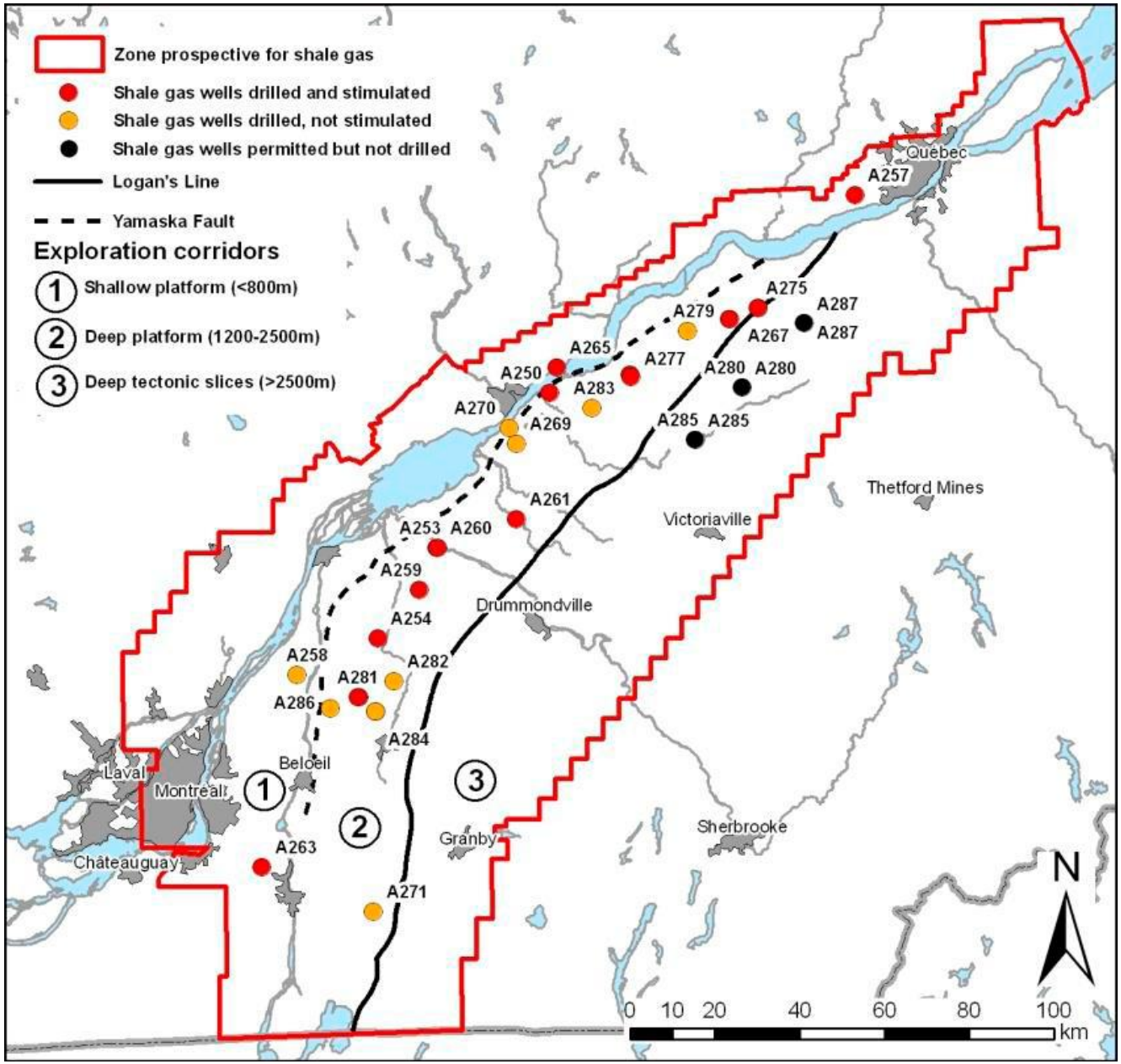

Figure 1. Prospective zone for the Utica Shale and location of the shale gas wells drilled between 2006 and 2010. Three exploration corridors have been delineated, the central one being deemed the most prospective for the moment (Thériault, 2012).

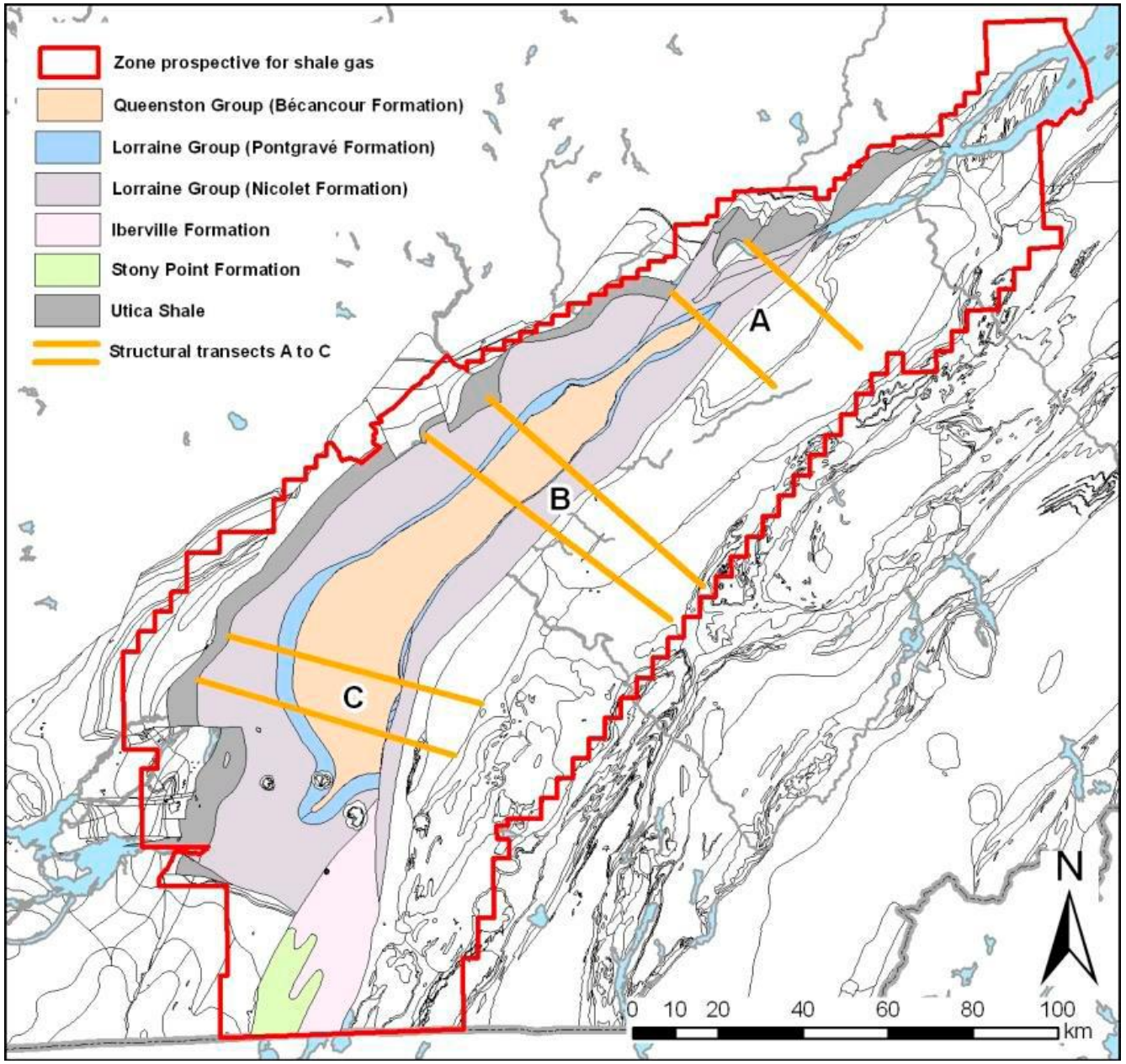

Figure 2. Regional geological map adapted from MRNF (2008), and location of the conceptual structural models prepared in the scope of the synthesis.

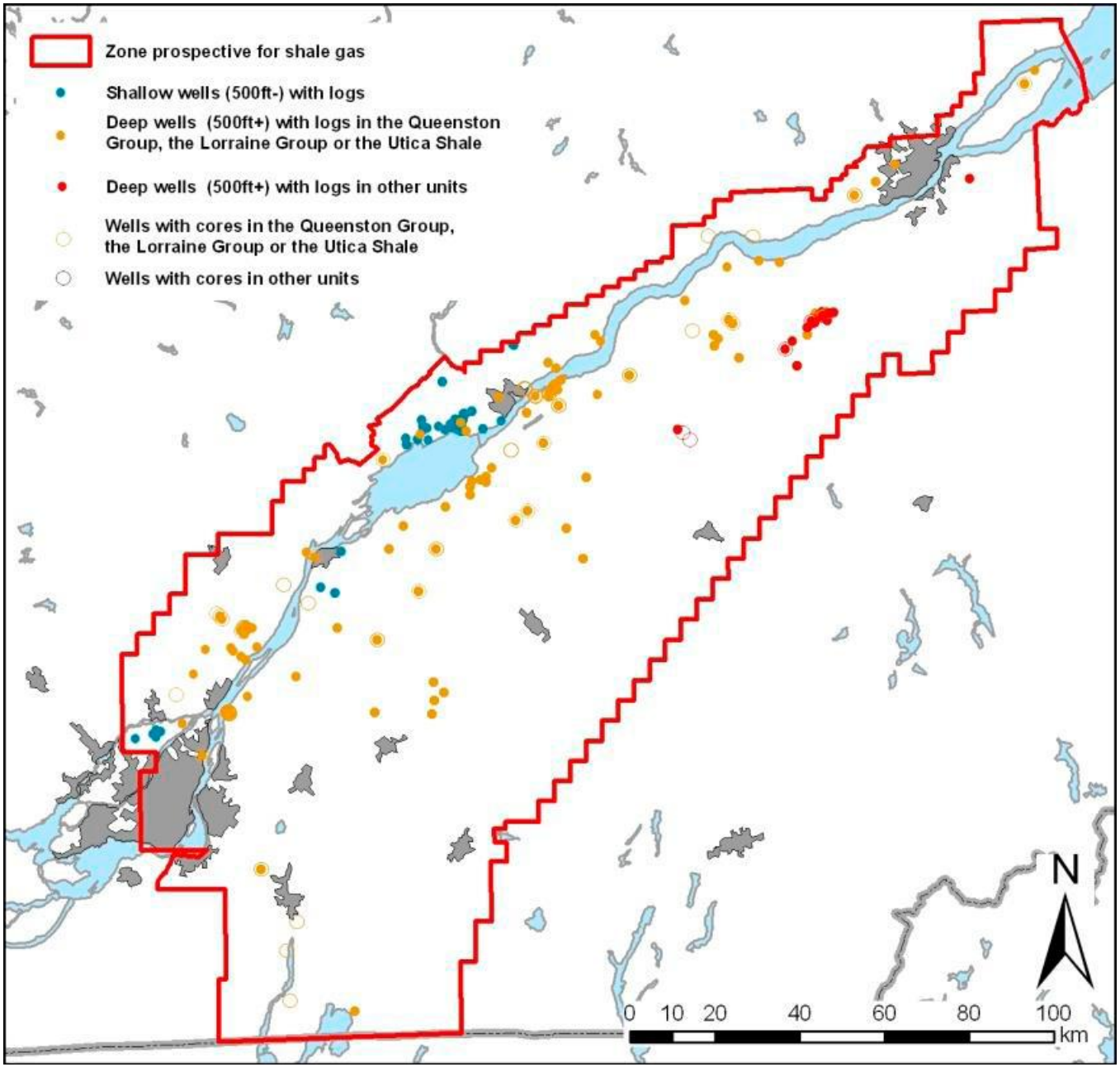

Figure 3. Location map of the wells with petrophysical logs and/or cores in the Utica Shale and overlying units.

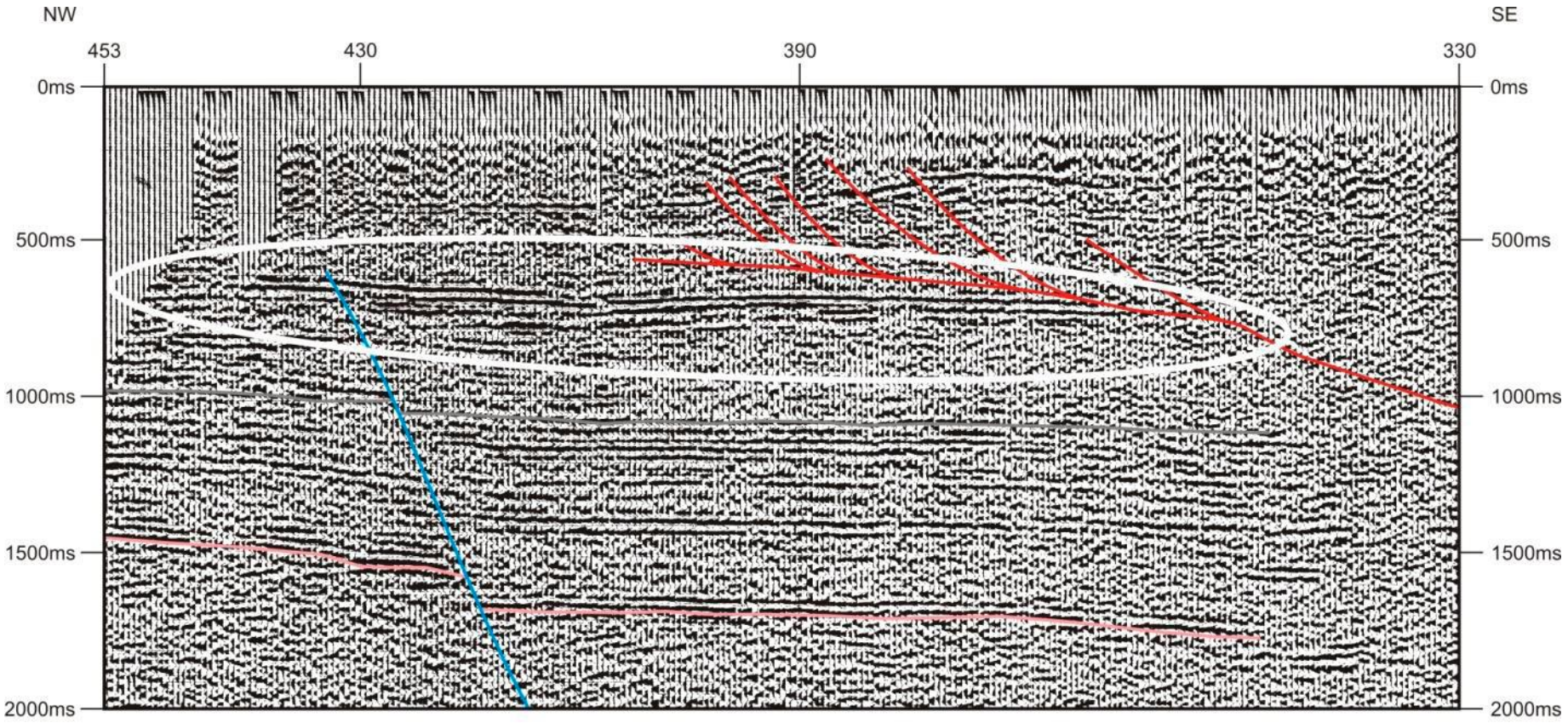

Figure 4. Stack seismic section illustrating medium-depth units characterized by strong acoustic impedance contrasts in the Lorraine Group (white ellipse), above the Utica Shale. These strata show a thickening in the footwall of a normal fault.

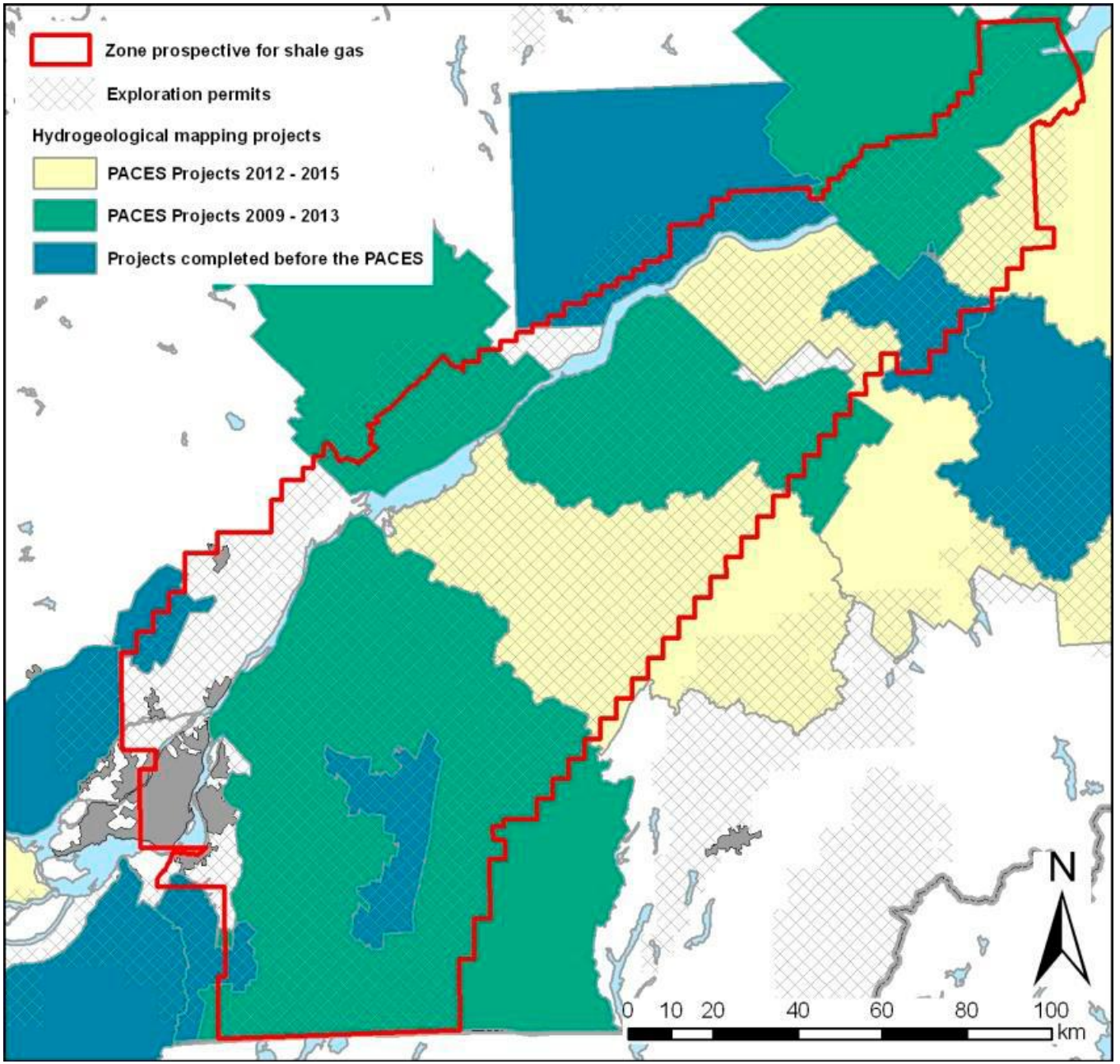

Figure 5. Map of the hydrogeological mapping PACES projects in the study area.

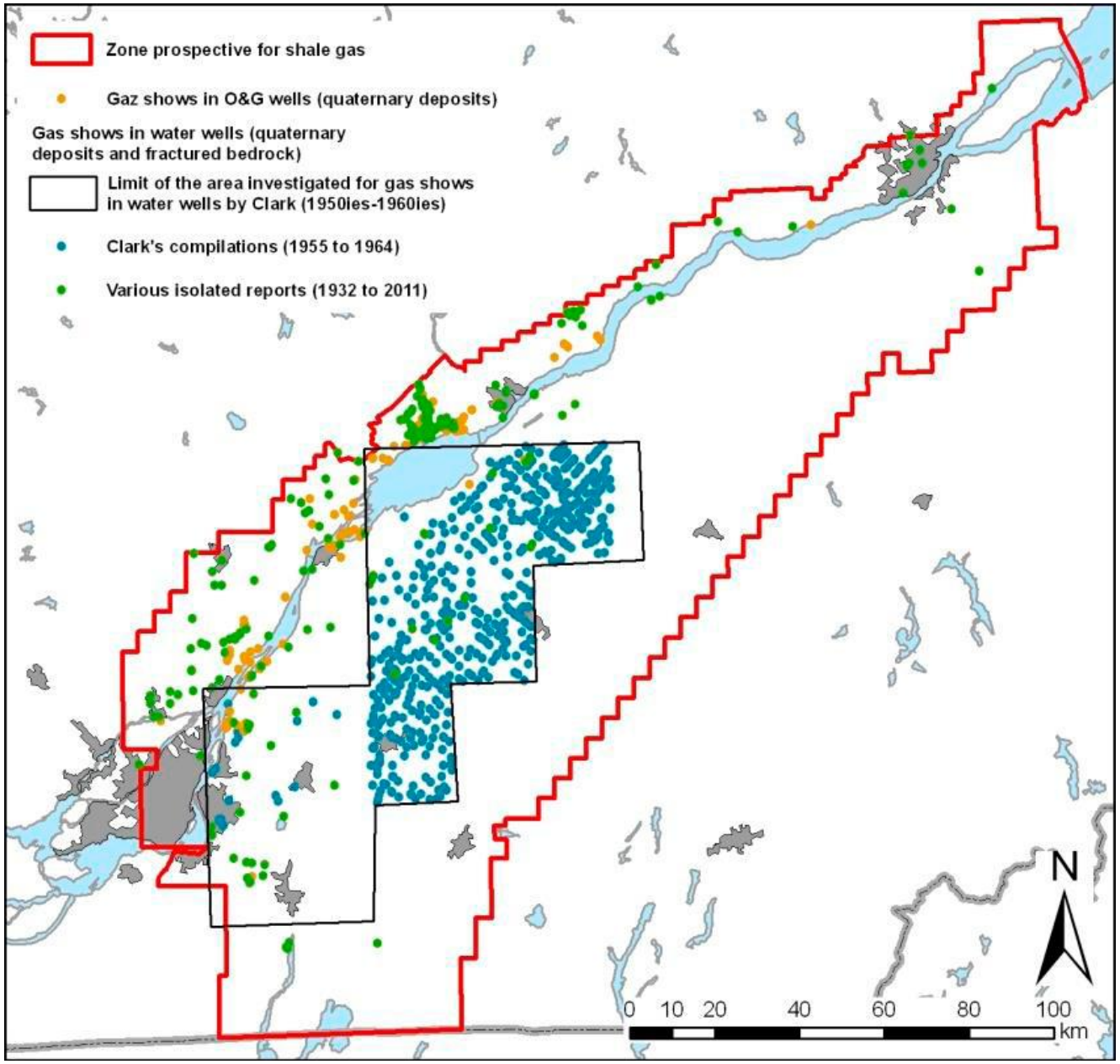

Figure 6. Location map of known gas shows in the surficial quaternary sediments and the underlying shallow, naturally fractured rock. Datasets correspond to both industry and water wells.