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Large-Scale Screening for Natural Hydrogen: a Quebec's Perspective

Stephan Séjourné [1,2], Félix-Antoine Comeau [2], Maria Luisa Moreira dos Santos [2], Geneviève Bordeleau [2], Maxime Claprood [3], Pascal Mouge [4], Valentin Mulliez [4], Michel Malo [2], Bernard Giroux [2], Erwan Gloaguen [2], Jasmin Raymond [2]

[1] *Enki GeoSolutions*

[2] *Institut national de la recherche scientifique, Centre Eau Terre Environnement (INRS-ETE)*

[3] *Centre d'études sur les ressources minérales, Université du Québec à Chicoutimi (UQAC)*

[4] *Novatem*

Summary

The Canadian Shield and Paleozoic sedimentary basins in Quebec host a diverse array of ultramafic rocks, iron formations, uranium-rich rocks, supramature shales and lithospheric fractures, making it a promising area for natural hydrogen. However, Quebec spans over 1.5 million km^2 and lacks obvious exploration leads, complicating exploration efforts.

To document Quebec's natural hydrogen potential, a geological review and geochemical data inventory was conducted to highlight the characteristics and distribution of potential hydrogen source rocks. Then, a rating system was developed, considering the quality of source rocks, the presence of reservoir rocks, and proximity to end-users. This analysis identified key areas for fieldwork, reducing exploratory risks and investment needs.

This talk will present: 1) the systematic rating method used; 2) key findings, addressing where to start for natural hydrogen; and 3) the study's impact on Quebec's natural hydrogen ecosystem (academic, regulatory and industrial).

Results and Observations

Seventeen areas of interest have been identified in the Quebec's part of the Canadian Shield, which were grouped into four categories according to their affinities. These areas have been selected and delineated in order to provide a representative overview of the nature and extent of the rocks that may be sources of hydrogen, but the potential for natural hydrogen in the Shield is not limited to these areas. Key areas of interest include: 1) several gold mines in Abitibi, some of which having hydrogen gas occurrences reported (Fritz et al., 1987; Sherwood Lollar et al., 1993; Li et al., 2021); 2) kimberlite fields, including one being associated with evidence of low temperature serpentinization across the border in Ontario (Sader et al., 2007; 2021); 3) alkaline intrusions, with one at least for which hydrogen is reported in fluid inclusions (Truche et al., 2021) and 4) Proterozoic basins, including one with reported hydrogen in fluid inclusions (Héroux et al., 2004).

Vegetation anomalies, generally referred to as "forest rings", have also been documented locally in the black spruce forests of the Abitibi region, mainly in Ontario but also in western Quebec (Veillette and Giroux, 1999; Hamilton et al., 2004; Brauneder et al., 2016). Although these features

are very different from the diffusive circles (or “fairy circles”), they could be indicative of a reducing environment in the ground and deserve further investigation (Malvoisin and Brunet, 2023).

Ten areas of interest have been identified in the sedimentary basins of southern Quebec, which were grouped into five categories according to their affinities. As for the Canadian Shield, these areas have been selected and delineated in order to provide a representative overview of the nature and extent of the rocks that may be sources of hydrogen, but the potential for natural hydrogen in southern Quebec is not necessarily limited to these areas. Key areas of interest include: 1) Ophiolite complexes, which are correlative with the Bay of Islands complex in Newfoundland where Szponar et al. (2013) sampled strongly alkaline and highly reducing water sources containing dissolved hydrogen; 2) Cretaceous “Monteregian intrusions”, made of mafic to ultramafic rocks that only very weakly serpentinized and could be present in large volumes at depth (Feininger and Goodacre, 1995); 3) crustal fractures which could possibly act as conduits for migration of deep-seated fluids (Thériault et al., 2004, 2005); 4) Supramature hydrocarbon source rocks (Thériault, 2012) that have locally reached the anchizone and epizone stages; and 5) shallow sedimentary cover overlying anorthosites and other iron-rich rocks. This later group lacks proper seals but is considered favorable to test direct detection methods such as soil gas sampling.

Oil and gas exploration data in the sedimentary basins of southern Quebec provide information on the nature of the fluids present in the subsurface, information that is rarely available in the Canadian Shield. The systematic inventory of publicly available information in the SIGPEG (2025) database identified 147 gas analyses from 63 wells, of which around half (34 wells) included at least one hydrogen analysis (100 analyses in total). For gas analyses with values above 0.1% H_2 (Figure 1), the analytical results, the history of activities carried out in the well prior to sample collection, and the local geological context were examined in detail to assess the significance of results. The aim was to assess the natural or anthropogenic origin of the hydrogen. It appears that the highest hydrogen values (between 6.7% and 71.75%) can be explained by the corrosion of steel casings or acidification operations. Hydrogen concentration values for which no artificial cause could be established or suspected range from 0.1% to 2.43%, and correspond to wells located in regions where potential geological sources of hydrogen are documented. In all cases, however, there is insufficient information to establish a direct link between the hydrogen detected in the wells and the possible hydrogen-source rocks present in the same region and, notably, these occurrences of non-anthropic hydrogen do not coincide geographically with the main plays previously identified.

Each of the twenty-seven plays identified above has been evaluated and rated according to three geological criteria and the proximity with possible end-users. The results are represented geographically in Figure 2 and summarized in Table 1. The rating of the areas of interest reveals three main groups based on the geological criteria. The first group stands out with scores of 89% or higher. The five areas included in this group all achieve the highest scores for the local geological criterion and the analogue criterion, with the only difference occurring at the level of the potential reservoir criterion. The second group comprises eight areas with geological scores ranging from 56% to 72%. The plays in this group almost all achieve an intermediate score for the local geological criterion and more variable scores for the other two criteria. Finally, a third group comprises the areas of interest that have obtained a geological score of 44% or less (for a minimum possible of 33%). Fourteen areas are included in this tail group, all of which are

characterized by a minimum score for the local geological criterion and low scores for the other two criteria. It is important to note that the areas of interest that scored highest on the criterion of proximity to end-users (mark A) are all included in the top group defined independently by the geological criteria.

Exploration for natural hydrogen is still in its infancy in Quebec, but several players are already active in this new field (both in the academic and private sectors) and a regulatory framework is needed to make sure that all stakeholders needs will be taken into account.

Conclusions

This study documents the presence and quality of potential source rocks for natural hydrogen in Quebec. The purpose of this study was not to demonstrate the presence of exploitable accumulations of hydrogen on the territory, but rather to develop a framework that allows prioritizing future exploration efforts, with a view to minimize the exploration risks and investments required to develop this carbon-free resource. Dedicated exploration work, starting with the detection of hydrogen emanations at the surface, remains to be carried out. Further details and references can be found in Séjourné et al. (2023), Comeau et al. (2023) and Séjourné et al. (2024).

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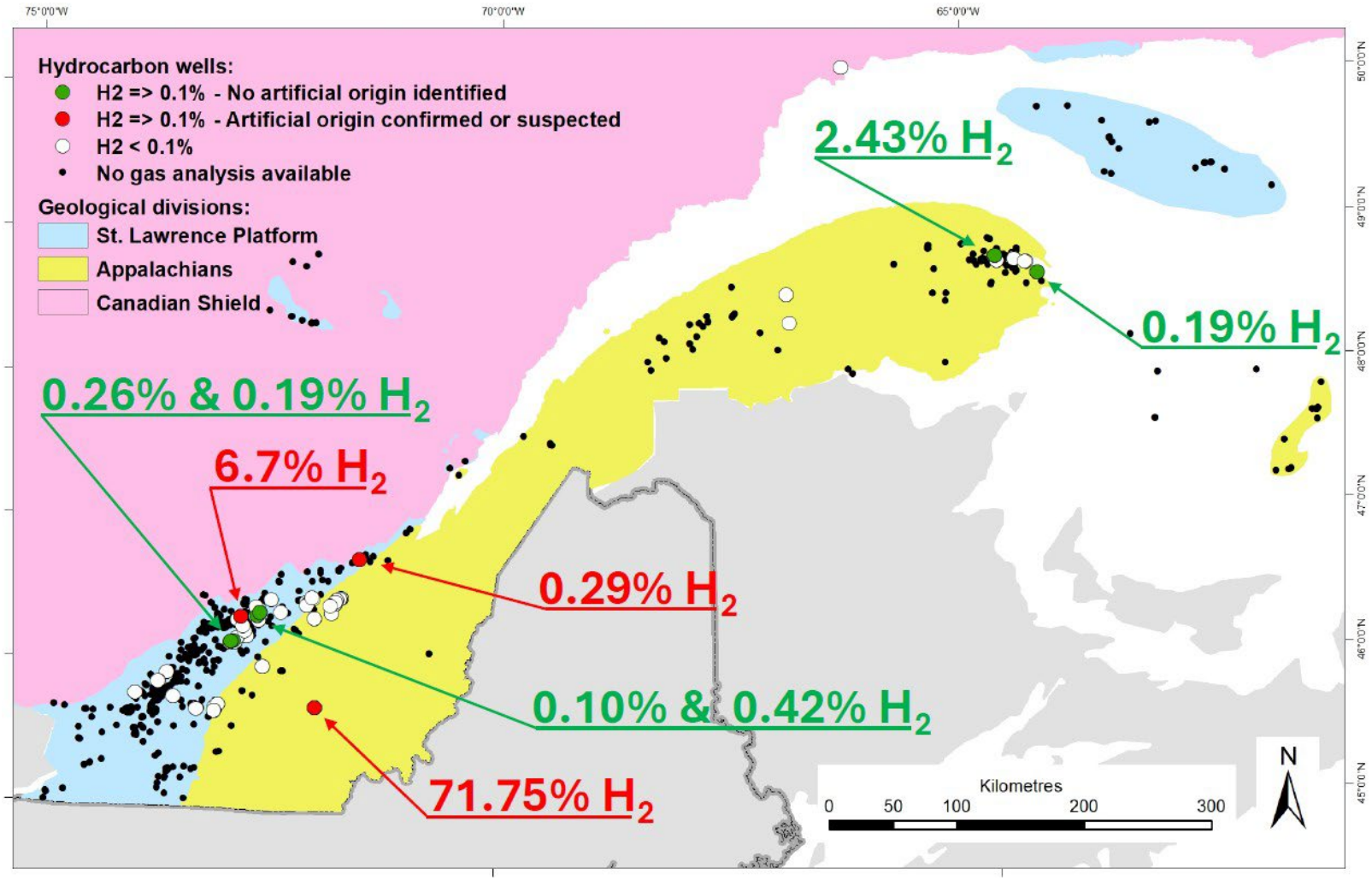

Figure 2: Gas analyses compiled for the hydrocarbon wells based on the SIGPEG (2023) database. Map background: SIGEOM (2023). Figure taken from Séjourné et al. (2024).

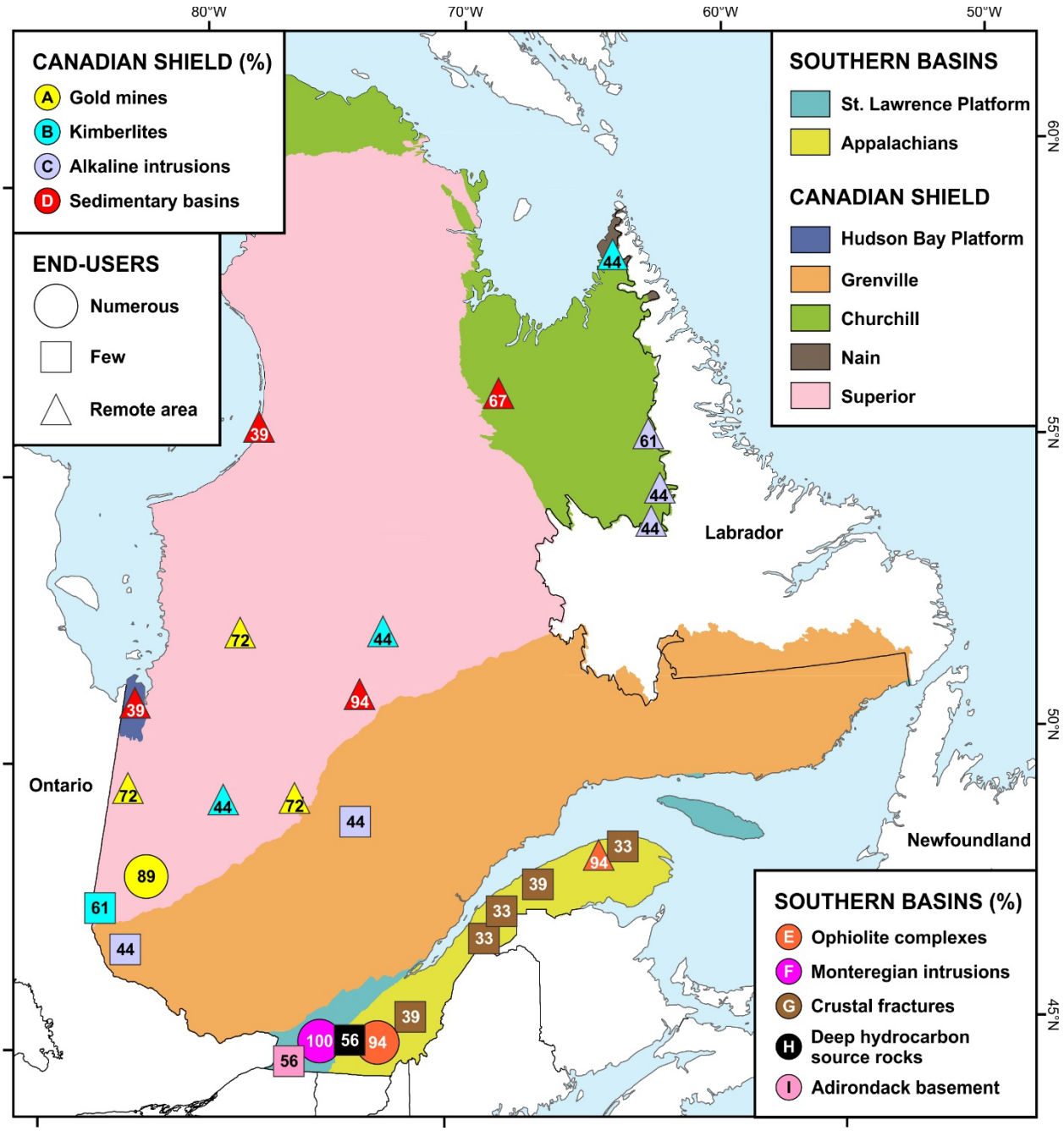

Figure 1: Rating of the potential hydrogen source rock areas considered in Quebec. The values shown correspond to the percentage rating assigned to each of the areas considered. Map background: SIGEOM (2023). Figure taken from Séjourné et al. (2024).

Table 1: Rating score of different areas of interest for natural hydrogen source rocks in the Canadian Shield and southern Quebec. Table taken from Séjourné et al. (2024).

HYDROGEN SOURCE ROCK PLAY		SCORE
F	Monteregian intrusions	100% (A)
E1	Ophiolite complex (southwest)	94% (A)
E2	Ophiolite complex (Gaspé)	94% (C)
D3	Mistassini and Otish basins	94% (C)
A1	Cadillac Fault gold mines	89% (A)
A2, A3, A4	Éléonore Casa Berardi and Chibougamau mines	72% (C)
D4	Labrador trough	67% (C)
B4	Témiscamingue kimberlite	61% (B)
C1	Lac Brisson Pluton	61% (C)
H	Utica shale (overmature)	56% (B)
I	Adirondacks overburden	56% (B)
C4, C5	Crevier and Kipawa intrusions	44% (B)
B1, B2, B3	Torngat, Otish and Desmaraisville kimberlites	44% (C)
C2, C3	Misery and Juillet syenites	44% (C)
G1, G4	Crustal fractures	39% (B)
D1, D2	Richmond Gulf Graben and Hudson platform	39% (C)
G2, G3, G5	Crustal fractures	33% (B)