

Active Hydrocarbon Seepages in the Offshore Part of the St. Lawrence Paleozoic Platform Pictured by Geophysical, Geochemical and Submarine Observations

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Summary

Over 1900 pockmarks have been identified on the St. Lawrence Estuary sea floor. The location of these pockmarks over a prospective hydrocarbon domain (Paleozoic St. Lawrence Platform), their spatial distribution with linear pockmark trains parallel to bedrock features, their geophysical signature including seismic chimneys that root into the Paleozoic bedrock, the strongly negative $\delta^{13}\text{C}_{\text{PDB}}$ ratios of cements found in carbonate crusts, as well as submarine observations documenting bubble plumes, all argue for the present release of thermogenic gas from the St. Lawrence Platform.

Introduction

The increasing use of high-resolution multibeam bathymetry techniques over the past decades has led to the worldwide recognition of crater-like depressions on the sea floor, called pockmarks (Judd and Hovland, 2007). Pockmarks are commonly associated with the past and/or present release of fluids from the subsurface and have been described in several prolific hydrocarbon provinces. However, pockmarks have also been documented in non productive regions where they are often associated with the release of biogenic gas from the degradation of recently accumulated organic matter.

From an exploration point of view, pockmarks may thus provide critical supportive evidence for a petroleum system only if the expelled fluids are of thermogenic origin and linked to a prospective basin. This abstract presents a synthesis on seep features recently documented in the St. Lawrence Estuary in eastern Québec and reviews the evidence suggesting a causal relationship between pockmarks and an active hydrocarbon system.

Geological setting

The St. Lawrence Estuary is a narrow basin filled predominantly by Quaternary sediments. It exhibits a clear downstream decrease of the Quaternary sediment thickness from more than 400 m to less than 20 m (Syvitski and Praeg, 1989; Duchesne et al., 2007).

The Quaternary sediment fill unconformably overlies Neoproterozoic Grenvillian metamorphic rocks, Lower Paleozoic autochthonous rocks (St. Lawrence Platform) and the allochthonous Appalachians units. The present-day basin geomorphology is partly controlled by the boundaries of these lithotectonic domains and the St. Lawrence Platform underlies most of the up to 350 m deep, relatively flat Laurentian channel seafloor (Pinet et al., 2008a).

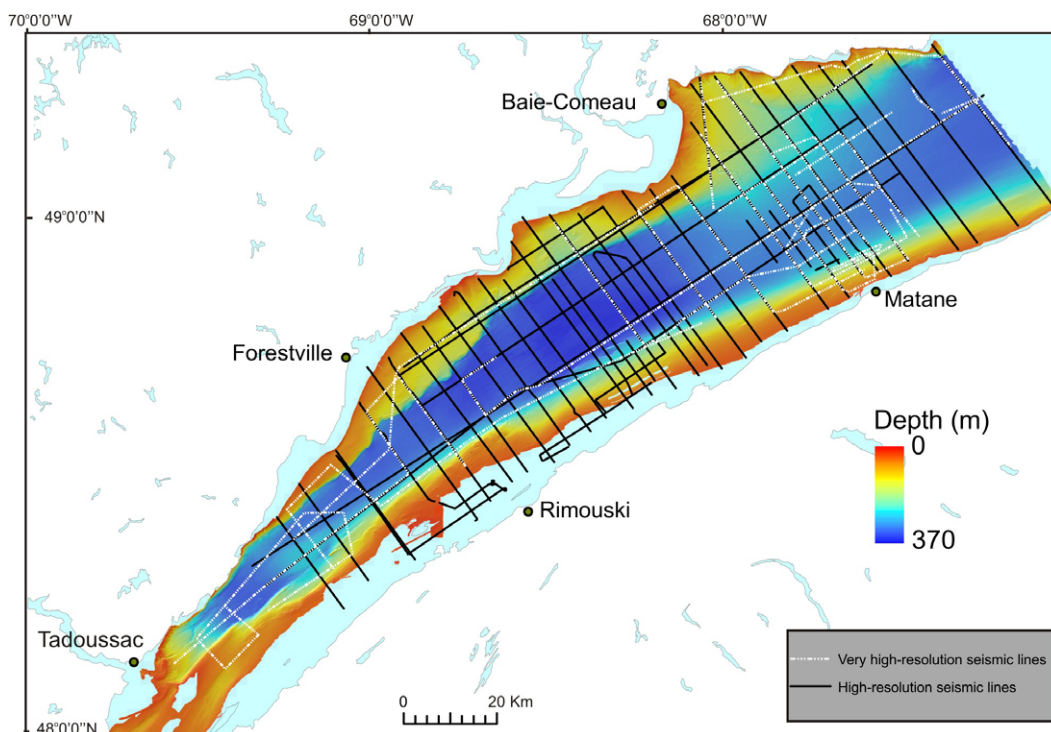


Figure 1: Multibeam bathymetry image of the Lower St. Lawrence Estuary with location of seismic lines

Datasets

Recent multibeam bathymetry data provides a complete coverage of the St. Lawrence Estuary north of Tadoussac (Fig. 1) for water depth greater than 30 m. Seismic data consists in 1) 55 high-resolution single channel seismic sections collected with a Sparker source, for a total length of >3300 km; 2) more than 1500 km of very-high resolution seismic reflection sections collected with a Hunttec single channel Deep-Tow-System. Video observation of the seafloor has been performed over 3 pockmarks, and short cores of unconsolidated sediments with carbonate concretions of various sizes and shapes have been collected.

General characteristics of pockmarks

In the St. Lawrence Estuary (eastern Québec, Canada) over 1900 pockmarks have been identified on multibeam bathymetry and high-resolution seismic profiles (Pinet et al., 2008b). In the study area, pockmarks occur in water depths ranging from 65 to 355 m. They range from less than 100 m to ~700 m in diameter and are up to 25 m deep (average < 10 m). Pockmarks are predominantly located within the central part of the Estuary (Laurentian Channel) and on its northwest shoulder.

Evidence for an active hydrocarbon system

Five lines of evidence support the interpretation that pockmarks formed through the recent and still active release of thermogenic gas.

1- Most pockmarks are located above the offshore part of the Paleozoic St. Lawrence Platform, a lithotectonic domain with an increasingly documented hydrocarbon potential (Pinet and Lavoie, 2007; Lavoie et al., 2009 a and b).

2- Pockmarks seen on the multibeam bathymetry images are associated in subsurface to a series of seismic features such as chimney, local enhancement and blanking. Of particular significance is the fact that vertical seismic chimneys root into the top of the Paleozoic succession, which suggest that the fluids emanate from the St. Lawrence Platform. Based on spectral decomposition of the seismic data, natural gas dominates the fluids.

3- Pockmarks exhibit a non-random distribution. Over 75 individual structures may occur in ‘pockmark trains’, up to 15 km long (Fig. 2). These linear pockmark trains systematically strike NNE (the trend of the main geological domains) and are controlled by the geology of the underlying Paleozoic bedrock. Such a relationship is substantiated by the parallelism of pockmark trains with bedrock features, including a bedrock ridge buried by Quaternary sediments (Fig. 2). This suggests that some unknown specific unit(s) or structural features within the Paleozoic succession act as pathway for the migration of thermogenic gas.

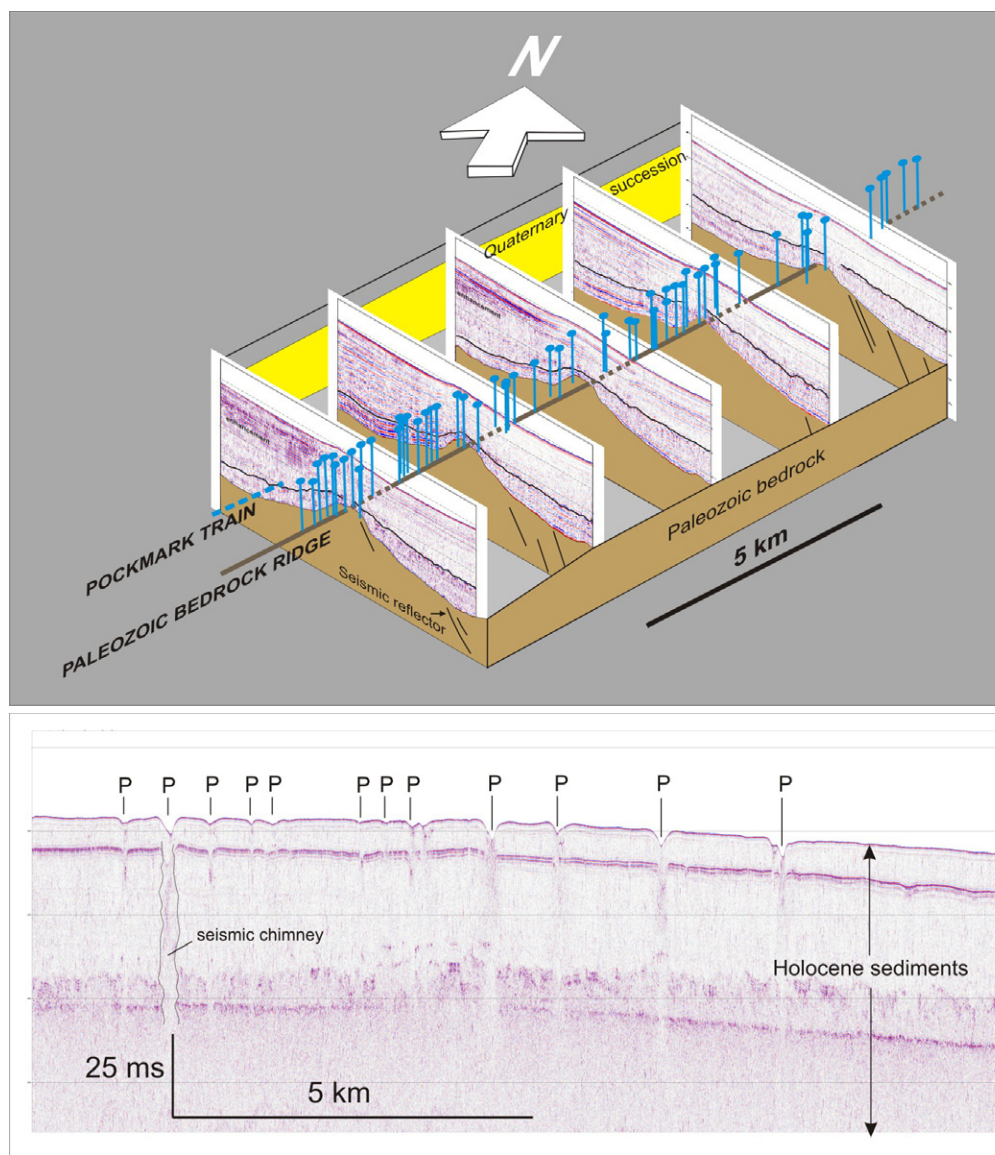


Figure 2: A- Linear pockmark trains parallel to a bedrock ridge. Blue dots correspond to individual pockmark. B- Very-high resolution Hunttec seismic profile parallel to the pockmark train image in A. P, pockmark.

4- Carbonate crusts of interpreted chemosynthetic origin have been sampled in two pockmarks associated with high backscatter values. These crusts exhibit strongly negative $\delta^{13}\text{C}_{\text{PDB}}$ ratios carbonate cements suggesting that they formed through the bacterial oxidation of methane (Lavoie et al., in preparation).

5- Seafloor video observations from three pockmarks document gas bubbles emission sites and extensive bacterial mats indicating that seepage is presently active. Gas plume (or flare) are also visible on echo sounder images and extend from the seabed to variable levels in the water column.

Conclusions

The occurrence of thermogenic gas seeps in the St. Lawrence Estuary indicates that a mature and quality source rock exists within the geological system. Moreover, the presence/lack of sealing units in the Paleozoic (or Quaternary) succession may be the main controlling factor on the regional variations in the abundance of seep features.

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