

# Hydraulic Fracturing and Earthquakes in Quebec



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- Hydraulic fracturing is designed to fracture rock deep underground and so actually is an earthquake or an induced seismic event
- Induced seismic events are common and is any seismic activity (earthquake) caused by man-made activities from driving heavy equipment to loading a hydro dam
- Risks associated with induced seismic are greater in areas with unstable geology
- Several studies show the fault systems in the St. Lawrence Lowlands are relatively stable and not likely prone to significant natural or induced seismic activity
- The largest recorded induced seismic events were associated with mining, hydro dams and geothermal energy projects

## OVERVIEW

Earthquakes are often triggered naturally by movements in the subsurface of the earth. They can also be induced or created by human activities including hydraulic fracturing, filling hydroelectric dams, waste water disposal and carbon dioxide capture and sequestration. The majority of these events produce very small earthquakes that cannot be felt at surface<sup>12</sup>. There are, however, rare instances where these induced seismic events have set off earthquakes that have been felt at surface.

Other than the change in fluid pressure within the rocks, the scale of the seismic activity often depends on the presence of faults with certain properties and orientations and a critical state of stress in the rocks<sup>3</sup>. In Quebec, detailed mapping of the faults, in-situ stresses and other geological features have confirmed that the Lowlands are in a stable state and it is highly unlikely that hydraulic fracturing in this area will cause significant earthquakes<sup>4</sup>.

## INDUCED SEISMIC ACTIVITY

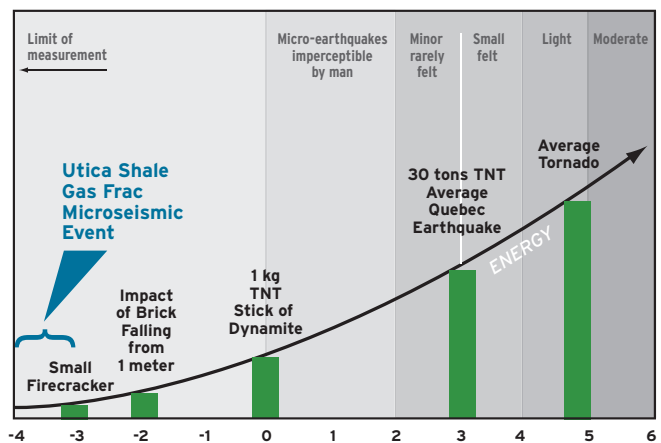
Seismic activity or earthquakes caused by human activity are known as induced seismicity or induced earthquakes.



Filling LG 3 reservoir at James Bay induced an earthquake with a magnitude of 3.7

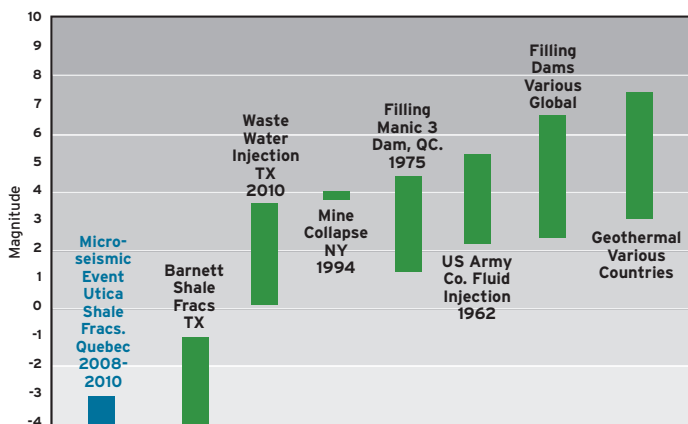
This phenomenon of human activity creating earthquakes has been well established for over a century and these seismic events are generally benign. These include activities as common as driving a heavy truck on a gravel road as well as more complex operations such as geothermal energy, mining, underground waste fluid disposal, hydroelectric dams and hydraulic fracturing. Occasionally, these induced earthquakes can be significant. As an example, in 1975, the filling of the Manic 3 reservoir near Baie-Comeau, Quebec resulted in an induced earthquake with a magnitude of 4.1<sup>5</sup>. The filling of the second reservoir in the James Bay resulted in a number of small induced earthquakes up to 3.7 in magnitude<sup>6</sup>.

Earthquakes are measured on a scale such as the Richter scale which is based on the magnitude of the energy released. The scale is logarithmic meaning that an earthquake with a magnitude of 4 is 10 times larger than magnitude 3 and 100 times larger than magnitude 2. Earthquakes with a magnitude of 2 are not felt at surface and those between 2 and 4 maybe felt depending on the depth at which the seismic event occurred and regional geology. It is usually at a magnitude of 6 before damage becomes a concern. The chart below compares the energy released by various events.



Comparison of earthquake magnitude

Hydraulic fracturing for natural gas development conducted in Quebec by Questerre and its partners between 2008 and 2010 have created earthquakes with magnitudes of -3.0 or less on this scale. These are negative because when the Richter scale was established in the 1930s, events of 2.5 magnitude were the smallest possible magnitude that could be measured. These earthquakes cannot be felt at surface and require very sensitive down hole equipment in close proximity to the operation to be detected and measured. By comparison, a brick dropped one meter above the ground releases more energy than these hydraulic fracturing events in Quebec. This is due to the limited energy released by these fracturing operations and the geology of the Lowlands.



Magnitude of various induced seismic events

There are two known examples of hydraulic fracturing being associated with induced seismic events. One is in the United Kingdom in 2011 and the results have been studied by the Royal Society, the UK's Academy of Sciences<sup>7</sup>. The study found that all the events were under magnitude 2.5 and not significant. The head of seismology of the British Geological Survey noted that there is only a very small risk of damage from earthquakes caused by hydraulic fracturing<sup>8</sup>. The other is in British Columbia and was measured with a magnitude of 3.8 that is also not typically felt at surface. Other reports of hydraulic fracturing triggering seismic events in Ohio and Texas were found to have actually been caused by water disposal wells.

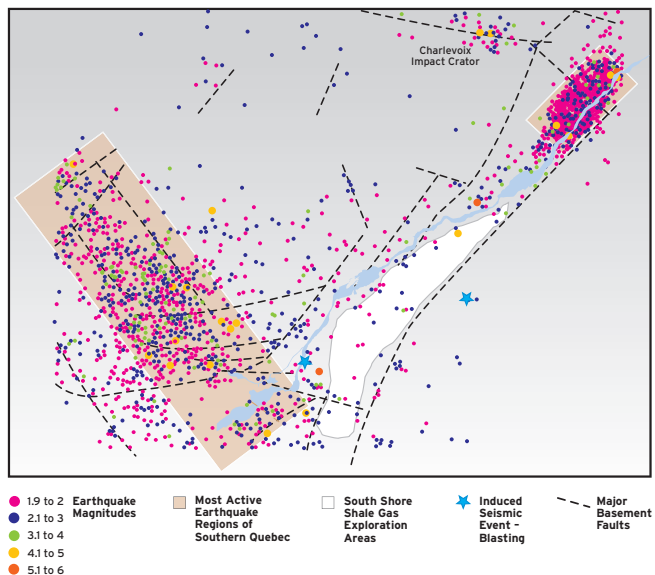
### QUEBEC GEOLOGY

Natural Resources Canada ("NRCAN") notes that the probability of earthquake-related surface ruptures in Quebec is small because most earthquakes are too small or too deep<sup>9</sup>.

In 2010, a 4.1 magnitude event was recorded in Laurier Station, a rare event for the area. Experts agreed that the earthquake was not related to hydraulic fracturing or gas storage at St. Flavian<sup>1</sup>.

To determine if hydraulic fracturing could induce significant earthquakes in the Lowlands, a detailed study mapped the natural and induced earthquake activity in southern Quebec. It also conducted a detailed analysis of the faults in the basin and the in-situ stresses. A study of faults was essential as earthquakes occur when rocks break or slip along a fault releasing energy in the form of heat and seismic waves.

The map below illustrates the earthquakes in southern Quebec utilizing historical data from as early as the 1600s from the Geological Survey of Canada and NRCAN. The vast majority of these earthquakes were too small to be felt at surface.



Earthquakes in southern Quebec including the St. Lawrence Lowlands

The St. Lawrence Lowlands have been identified as a very seismically quiet area that has seen 14 earthquakes between magnitude 2.5 and 4.1 at depths of 18 km over the last 400 hundred years. With respect to induced earthquakes, only two were identified that appear to relate to either mining or construction blasting.

### REFERENCES

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