MONITORING EARTHQUAKES IN EASTERN CANADIAN AREAS WITH SHALE GAS EXPLORATION POTENTIAL

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Two eastern Canadian areas have had some shale gas exploration activities in recent years: southeastern New Brunswick (NB) and the St. Lawrence Lowlands of southern Quebec between Quebec City and Montreal (QC). In these two areas, the regional earthquake activity is routinely monitored by the Canadian National Seismograph Network (CNSN) providing earthquake location completeness slightly better than Nuttli magnitude (mN) 2.0. Earthquake epicentres have a location uncertainty of about 7 km estimated from confirmed quarry blast events. For some areas of QC where temporary portable seismographs are deployed, the completeness level is lowered to mN ~1.0 and focal depths can sometimes be calculated.

Both QC and NB have a low level of naturally occurring earthquakes. Normal crustal faults of the St. Lawrence Rift System are found in Southern QC. These normal faults are recognized as possibly seismogenic in the most recent editions of the seismic zoning exercises for the National Building Code of Canada. The NB seismicity is much more diffuse and of smaller magnitude.

For QC, we investigate the possibility that some earthquakes could be associated in time and in space with the shale gas exploration work conducted between 2006 and 2010. The challenge has been to distinguish between naturally-occurring (tectonic) earthquakes and those potentially induced (triggered) by hydraulic fracturing. For QC, the focal depths of earthquakes for the time period 1980-2014 were systematically calculated from crustal reflection phases for events larger than mN 2.8 or from direct P and S phases of smaller events when the density of stations was sufficient. The focal depth distribution shows that events occur mostly at mid-crustal depths (10-25 km) and those shallower than 5 km are extremely rare.

In our search for possible triggered events we examined a temporal connection (i.e., an event's origin time must be after the start of fluid injection) and relative proximity (i.e., within 10 km of well locations). For the very few earthquakes that satisfy the time and spatial conditions, seismic waveforms at stations within 10 km from the epicentres were systematically examined for a Rayleigh (Rg) phase indicative of a shallow source. Only three events showed such Rg phase (Figure 1). The times of occurrence of these earthquakes were hundred of days after the hydraulic fracturing had stopped, making the correlation extremely unlikely.

We present results for the St. Lawrence Lowlands region in addition to our study of a magnitude mN 4.1 tectonic earthquake that was proven to be mid-crustal and not related to any human activity (which specifically addresses the concern raised by the media and the public; Lamontagne et al., 2012).

In NB, only one seismic event in the hydraulic fracturing region was found but the long period between its occurrence and hydraulic fracturing (almost two years) makes a connection unlikely. The region is currently monitored by a dense six-station seismograph network that can provide us with the background seismicity level.

REFERENCES

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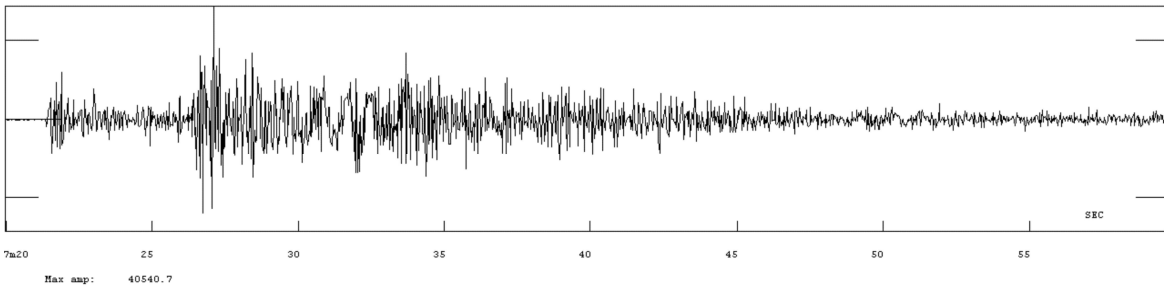

Figure 1. Velocity record of an earthquake that has a strong Rayleigh phase (Rg) indicative of a shallow source (magnitude mN 2.8; 20081011). Time marks of the X axis are five seconds apart.