September 11, 2013

DRBC Public Hearing Comments

In Dec of 2012, The AP reported that a USGS team based in Menlo Park, CA found that a quake in Colorado and a damaging 5.6 magnitude earthquake in Oklahoma were induced by underground disposal of fracking waste. A detailed report by Young Kim of The Lamont-Doherty Laboratory (published in the Journal of Geophysical Research) in concert with USGS concluded that the occurrence of over 100 earthquakes within a 14 month period near Youngstown, Ohio were also the result of fracking waste injection wells. Scientists concluded that 95 quakes in the Raton Basin between 2001 and 2011 were also the result of deep injection of oil and gas drilling waste. USGS scientists concluded that most quakes this past decade were located within 3 miles of an active wastewater injection well. USGS scientist Justin Rubinstein, co-author of the report said that "This is a societal risk you need to be considering. At the moment we're the only people who have done this work and our evidence is pretty conclusive."

The same thing is happening elsewhere in the US including Arkansas, West Virginia, Texas and Wyoming where there are injection wells. ProPublica reported that "Records from disparate corners of the US show that wells drilled to bury this waste deep beneath the ground have repeatedly leaked, sending dangerous chemicals and waste gurgling to the surface or on occasion, seeping into shallow aquifers that store a significant portion of the nation's drinking water." The waste is comprised of millions of gallons of water mixed with toxic, carcinogenic chemicals combined with "produced water" that comes to the surface during fracking operations. "Produced water" has high levels of BTEX chemicals, and salts such as chloride and bromides and heavy metals and is also radioactive.

Migration of fluids from wells have been documented to travel faster and farther than researchers thought possible. In a 2000 case that wasn't caused by injection but brought important lessons about how fluids could move underground, hydrogeologists concluded that bacteria-polluted water migrated horizontally underground for several thousand feet in just 26 hours, contaminating a water supply in Walkerton, Ontario and sickening thousands of residents.

Deep well injection takes place in 32 states from PA to CA. The energy industry has its own injection well category, Class 2, which includes disposal wells and wells in which fluids are injected to force out trapped gas and oil. All hydrofracked gas wells are injection wells. Class 2 is very lightly regulated, a problem that allows unsupervised injection operations - one of the contributing factors of the fatal contamination of 38-mile long Dunkard Creek.

Tom Myers, a hydrologist, drew on research showing that natural faults and fractures are more prevalent than commonly understood to create a model that predicts how chemicals might move in the Marcellus Shale. Myers new model said that chemicals could leak through natural cracks into aquifers tapped for drinking water in about 100 years, far more quickly than had been thought. In areas where there is hydrofracking or drilling, man-made faults and natural ones could intersect and chemicals could migrate to the surface in as little as a few years - or less. "It's out of sight, out of mind. Simply put, they are not impermeable, it's not a matter of if fluid will move through rock layers, but when." he said referring to injected waste and the rock layers.

Until recently injection wells were not considered suitable in the PA geology and wastewater from fracking has been shipped to the injection wells in Ohio (which are the subject of earthquakes). But a recent change in policy - certainly not geology, has paved the way for the installation of fracking wastewater wells in PA. That means that if PA regulations were to be implemented in the DRB there would be fracking and injection wells here in the basin.

The DRB is within a seismically active region that has a documented history of earthquakes. Fracking induced earthquakes and migration of toxic fluids as a result, in addition to the risks that earthquakes pose to potentially hundreds or thousands of gas wells is much too dangerous a risk and should cause this commission to ban fracking in this basin.

Joe Levine,
Damascus Citizens

Reference attachments

Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio

Won-Young Kim[1]

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[1] Over 109 small earthquakes (M_w 0.4–3.9) were detected during January 2011 to February 2012 in the Youngstown, Ohio area, where there were no known earthquakes in the past. These shocks were close to a deep fluid injection well. The 14 month seismicity included six felt earthquakes and culminated with a M_w 3.9 shock on 31 December 2011. Among the 109 shocks, 12 events greater than M_w 1.8 were detected by regional network and accurately relocated, whereas 97 small earthquakes ($0.4 < M_w < 1.8$) were detected by the waveform correlation detector. Accurately located earthquakes were along a subsurface fault trending ENE-WSW—consistent with the focal mechanism of the main shock and occurred at depths 3.5–4.0 km in the Precambrian basement. We conclude that the recent earthquakes in Youngstown, Ohio were induced by the fluid injection at a deep injection well due to increased pore pressure along the preexisting subsurface faults located close to the wellbore. We found that the seismicity initiated at the eastern end of the subsurface fault—close to the injection point, and migrated toward the west—away from the wellbore, indicating that the expanding high fluid pressure front increased the pore pressure along its path and progressively triggered the earthquakes. We observe that several periods of quiescence of seismicity follow the minima in injection volumes and pressure, which may indicate that the earthquakes were directly caused by the pressure buildup and stopped when pressure dropped.

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1. Introduction

[2] Since the early 1960s, it has been known that waste disposal by fluid injection at high pressure into subsurface rock formations can cause earthquakes known as induced seismicity [e.g., *Nicholson and Wesson*, 1992; *McGarr et al.*, 2002]. There are well-documented cases of induced seismicity including Rocky Mountain Arsenal (RMA), Colorado, in the 1960s [*Healy et al.*, 1968]; Ashtabula, Ohio, in the 1980s [*Seeber et al.*, 2004]; Paradox Valley, Colorado, in the 1990s [*Ake et al.*, 2005]; and Guy, Arkansas, during 2011 [*Horton*, 2012], among others. The largest events at those induced seismicities range from M_w 3.9 at Ashtabula, Ohio, M_w 4.3 at Paradox Valley, M_w 4.7 at Guy, Arkansas, and M_w 4.85 at Rocky Mountain Arsenal [*Herrmann et al.*, 1981].

[3] Since early 2011, many significant earthquakes suspected to be induced events occurred in the United States midcontinent region [*Ellsworth et al.*, 2012]. They are M_w 5.7 earthquake on 06 November 2011 at Prague, Oklahoma [*Keranen et al.*, 2013]; M_w 5.3 event on 23 August 2011 at Trinidad, Colorado [*Rubinstein et al.*, 2012; *Viegas et al.*, 2012]; M_w 4.8 event on 20 October 2011 at Fashing, Texas [*Brunt et al.*, 2012]; M_w 4.8 earthquake on 17 May 2012 at Timpson, Texas [*Brown et al.*, 2012]; M_w 4.3 earthquake on 11 September 2011 at Cogdell oil field, Snyder, Texas [*Davis and Pennington*, 1989]; and M_w 3.3 event on 16 May 2009 at Dallas-Fort Worth, Texas [*Frohlich et al.*, 2011], and are listed in Table 1. These are broadly related to fluid injection into subsurface strata through disposal wells such as; for secondary recovery of oil (Cogdell, TX), waste fluid from coal bed methane production (Trinidad, CO), wastewater (Prague, OK) and brine from hydraulic fracturing of shale gas (Dallas-Fort Worth, TX).

[4] Over the last several years, hydraulic fracturing has become widely used in the northeastern United States to extract natural gas from the Marcellus Shale (tight Devonian black shale) [see, e.g., *National Academy of Sciences*, 2012]. Much of the hydraulic fracturing of shale gas has been carried out in Pennsylvania, but the wastewater (brine) from the hydraulic fracturing process is being transported to Ohio and disposed of by injecting into deep wells at a depth range of 2.2–3.0 km under high pressure of up to 17.2 MPa (2500 psi [pounds per square inch]). The target injection intervals are usually sandstone layers in the Knox Dolomite (Lower Ordovician to Upper Cambrian) to Mt. Simon sandstone (Middle Cambrian). Five deep injection wells were drilled in

Additional supporting information may be found in the online version of this article.

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Table 1. Recent Potentially Induced Earthquakes Occurring in the United States[a]

Date	Time	Lat.	Long.	Depth	Magnitude	Location
(year-mo-dy)	(hh:mm:ss)	(ºN)	(ºW)	(km)	(M_w)	(references)
2011-11-06	03:53:10	35.53	96.77	5	5.7	Prague, OK[b]
2011-08-23	05:46:18	37.06	104.70	4	5.3	Trinidad, CO[c]
2011-10-20	12:24:41	28.86	98.08	5	4.8	Fashing, TX[d]
2012-05-17	08:12:00	31.93	94.37	5	4.8	Timpson, TX[e]
2011-02-28	05:00:50	35.27	92.34	3	4.7	Guy, AR[f]
2011-09-11	12:27:44	32.85	100.77	5	4.3	Snyder, TX[g]
2011-12-31	20:05:01	41.12	80.68	5	3.9	Youngstown, OH[h]
2009-05-16	16:24:06	32.79	97.02	4	3.3	Dallas-Fort Worth, TX[i]

[a]Listed according to their magnitudes.
[b]*Keranen et al*. [2013].
[c]*Meremonte et al*. [2002], *Rubinstein et al*. [2012], and *Viegas et al*. [2012].
[d]*Brunt et al*. [2012].
[e]*Brown et al*. [2012].
[f]*Horton* [2012].
[g]*Davis and Pennington* [1989], http://www.eas.slu.edu/eqc/eqc_mt/MECH.NA/20110911122745.
[h]*ODNR* [2012].
[i]*Frohlich et al*. [2011].

the Youngstown, Ohio area since 2010, but only the Northstar 1 injection well was operational during 2011 (Figure 1). Since the Northstar 1 waste disposal well became operational in late December 2010, Youngstown, Ohio has experienced small earthquakes. On 17 March 2011, residents in Youngstown, Ohio felt a M_w 2.3 earthquake. By 25 November 2011, nine earthquakes (M_w ~1.8–2.8) occurred near Youngstown, Ohio. These shocks are reported by the Division of Geological Survey of the Ohio Department of Natural Resources (ODNR) [see *Ohio Department of Natural Resources (ODNR)*, 2012, Table 5] by using data from sparse seismic stations in the region [*Hansen and Ruff*, 2003]. Prior to 2011, no earthquakes were recorded around Youngstown [*Stover and Coffman*, 1993; *Hansen*, 2012]. Although these earthquakes could not be accurately located due to sparse coverage of seismic stations in the region, these shocks were occurring close to a deep waste injection well Northstar 1 (Figure 1). On 1 December 2011, Lamont Cooperative Seismographic Network deployed four portable seismographic stations around Youngstown at the request of and in collaboration with ODNR to monitor seismicity at close distances and to determine hypocenters of the small earthquakes accurately for assessing whether these shocks were induced by the deep waste disposal well injecting fluid since the end of 2010 in the area (see Figure 1).

[5] On 24 December 2011, a magnitude 2.7 shock occurred in the epicentral area, which was well recorded by the four-station local network in the distance range from 1.9 to 6.5 km from the epicenter. The hypocenter of the shock was very well determined by the local station data, which had adequate coverage with the station azimuthal gap of 119° and distance to the two closest stations less than the focal depth. The shock was located about 0.8 ± 0.4 km west of the Northstar 1 well at a focal depth of 3.6 ± 0.8 km (95% confidence level). On 30 December 2011, ODNR requested the operator to shut down the Northstar 1 well, because the 24 December 2011 event was located close to the injection well with high confidence. On 31 December 2011 at 20:05 (UTC), a magnitude M_w 3.9 earthquake occurred in the same epicentral area within 24 h from the shutdown of the injection operation.

[6] This is a rare case of likely induced seismicity in the northeastern United States where major events in a sequence have been well recorded by local portable seismographs in place (with a high sample rate of up to 500 samples/s), providing an opportunity to study the sequence of seismicity in detail. In this study, we analyzed the spatiotemporal distribution of seismicity in detail and compared it with available fluid injection parameters to determine if the seismicity in Youngstown area during January 2011 to February 2012 was triggered by the fluid injection into a deep well or not. We also analyzed seismic data in detail in an attempt to shed light on relations between the induced seismicity and physical injection parameters of the deep well injection in the Youngstown area. The *study area* or *Youngstown area* refers to an area about 15 km radius from the main shock on 31 December 2011 (41.118°N, 80.692°W) around Youngstown, Ohio (Figure 1) [see *ODNR*, 2012, Figures 20 and 22].

2. Geologic and Geohydrologic Setting

[7] The study area (northeast Ohio around Youngstown) is located in a stable continental region of North America. Subhorizontal Paleozoic sedimentary strata composed of carbonates, evaporates, shale, sandstone, and siltstone of approximately 2.7 km thickness overlies the Precambrian basement. The bedrock units of the study area dip gently (~1°) to the southeast into the Appalachian Basin [*ODNR*, 2012]. The Precambrian crystalline basement in northeast Ohio is composed of igneous and metamorphic rocks, extending the ~1.1 billion years old Grenville Province exposed to the north in Canada. Geologic structures, including faults, pervasive in the Grenville terrain, are considered as the origin of many faults and general structures within the overlying sedimentary strata [*Baranoski*, 2002].

[8] Most known fault systems in the study area trend ESE-WNW [*Baranoski*, 2002]. The Smith Township fault, located about 20 km southwest of the study area, is the closest known fault system, which is a northwest-southeast oriented fault with the upthrown side to the northeast [*Baranoski*, 2002, Map PG-23]. This fault can be mapped on multiple units from the Precambrian surface through the Berea Sandstone (Late Devonian) and above based on well logs and driller's reported formation tops, illustrating that it has had recurrent movement throughout geologic

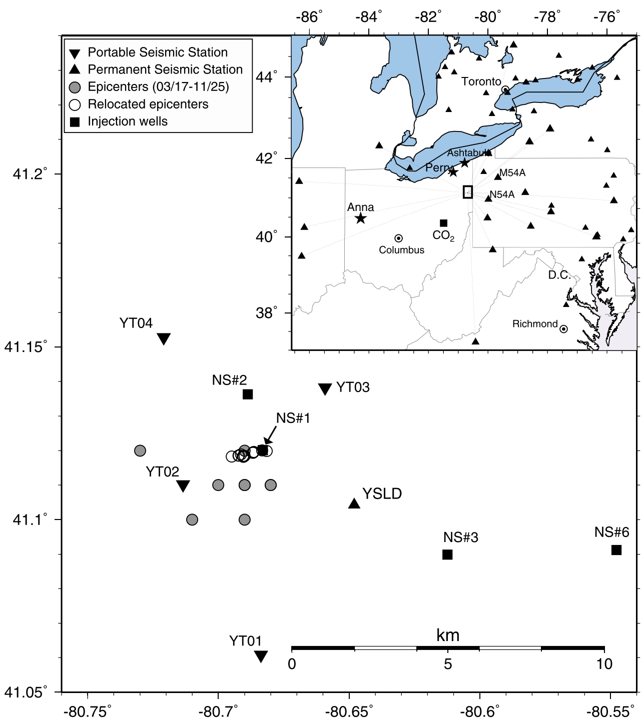

Figure 1. Nine earthquakes that occurred in Youngstown area during March–November 2011 are plotted by solid circles. These shocks were reported by ODNR and are scattered around the area. Twelve relocated earthquakes that have occurred in the area during March 2011 to January 2012 are plotted with open circles. The relocated earthquakes include M_w 2.7 shock on 24 December 2011, M_w 3.9 shock on 31 December 2011, and M_w 2.1 shock on 13 January 2012, which are recorded by local portable stations, and hence, located accurately by seismic data. Four portable seismographic stations deployed during 01 December 2011 to 30 April 2012 are plotted with inverted triangles, and a new seismographic station YSLD (Youngstown State University) an ANSS NetQuake strong motion instrument (solid triangle) are plotted for reference. Deep injection wells in the area are plotted with solid squares. Only Northstar 1 (NS#1) was operational during 2011. (inset) Permanent seismographic stations whose data were used to locate small earthquakes around Youngstown, Ohio are plotted with (solid triangles). Stations used for focal mechanism inversion are indicated by their source-receiver paths. Anna indicates Anna western Ohio seismic zone; Perry denotes 31 January 1986 M 5 earthquake; CO_2 denotes CO_2 No. 1 Well in Tuscawara County; Ashtabula denotes location of 1987 and 2001 earthquakes which occurred near the town.

time [*ODNR*, 2012]. Recent earthquakes that occurred in northeast Ohio with well-determined focal mechanisms indicate that left-lateral strike-slip faulting along E-W trending, steeply dipping faults are the predominant style of faulting due to broad-scale ENE-WSW trending horizontal compression, σ_{Hmax} [*Nicholson et al.*, 1988; *Zoback and Zoback*, 1991; *Du et al.*, 2003; *Seeber et al.*, 2004].

[9] The earthquakes in this study occurred exclusively in the Precambrian crystalline basement, whereas the potential reservoir strata in the injection interval are Paleozoic sedimentary rocks of alternating sandstone and dolomite layers. The Northstar 1 well was drilled into Precambrian granite for a total depth of 2802 m. The production casing was cemented in at a depth of 2504 m, and the well was completed open hole to depth 2802 m. Open hole electric logs indicate that the two largest porosity zones within the open hole section are the B zone Sandstone of the Knox Dolomite Group (Ordovician) with a total of 9.8 m net thickness averaging 9.4% porosity and the Mt. Simon Sandstone (Basal Sandstone) of Conasauga Group (Cambrian), which showed 15 m net thickness averaging 10.3% porosity [*ODNR*, 2012]. These two high-porosity zones are considered the reservoirs for brine injection at the site, although the target fluid injection zone is the entire open hole section of the well ~298 m (depth interval between 2504 and 2802 m).

[10] Within the Northstar 1 well, the Precambrian was encountered from a depth of 2741 m through total depth of 2802 m. Just above and at the Precambrian unconformity surface, porosity and permeability zones are indicated on the geophysical logs from 2736 to 2742 m depth. These porosity zones may be due to weathering of the Precambrian unconformity surface [*ODNR*, 2012]. The magnetic resonance log, which can detect higher and lower permeability zones of the rocks, showed a high-permeability zone with a high percentage of moveable fluid in the upper portion of the Precambrian strata (depth 2765–2769 m). Another high-permeability zone with a high percentage of moveable water is found from 2773 to 2776 m. At this same depth, high-angle natural fractures or fault zones have been identified from the well log and images. A clear ENE-WSW trending fracture zone has been identified from compass orientations of natural fractures plotted from fracture and breakout roseplots during geophysical logging at Northstar 1 well [*ODNR*, 2012].

3. Seismicity

[11] More than 200 felt earthquakes have been noted in Ohio since 1776, including at least 15 events that have caused minor to moderate damage [*Stover and Coffman*, 1993; *Hansen*, 2012]. The largest and most damaging earthquake occurred on 9 March 1937, in western Ohio, and the M 5.4 shock caused notable damage in the town of Anna, Shelby County, where nearly every chimney in town was toppled. The seismic activity in western Ohio around Anna is relatively frequent compared to other parts of Ohio, and hence, the area is referred to as the Anna seismic zone. A number of earthquakes have occurred in northeast Ohio; for example, M 5.0 event on 31 January 1986 near Perry [*Nicholson et al.*, 1988] (see Figure 1), and M 3.8 earthquake on 13 July 1987 and a M_w 3.9 earthquake on 26 January 2001 near Ashtabula [*Seeber and Armbruster*, 1993; *Seeber et al.*, 2004]. The 1987 and 2001 earthquakes in Ashtabula have been reported as induced events due to injection of waste fluid at a deep Class I well.

[12] There were no earthquakes reported within the study area (Youngstown, Mahoning County) prior to 2011 [*Stover and Coffman*, 1993]. During 17 March through 25 November 2011, nine small earthquakes (M_w 1.8–2.7) occurred around Youngstown, Ohio (Figure 1). Although, the locations of these shocks were not very accurate due to sparse seismic station coverage, the shocks occurred close to an operating deep waste injection well (Northstar 1 well)

Table 2. List of 12 Regional and 9 Local Events Relocated by Using Double-Difference Method[a]

Id	Date (year-mo-dy)	Time (hh:mm:sec)	Latitude (ºN)	Longitude (ºW)	Depth (km)	Mag (M_w)	Erh (km)	Erz (km)
			Twelve Regional Events Located by Regional Seismographic Network					
1	2011-03-17	10:42:20.49	41.12008	80.68321	3.76	1.78	2.02	4.10
2	2011-03-17[b]	10:53:09.69	41.11983	80.68148	3.84	2.28	1.61	-
3	2011-08-22	08:00:31.55	41.11846	80.68999	3.75	2.00	1.30	2.35
4	2011-08-25	19:44:21.36	41.11937	80.68675	3.86	2.15	2.06	3.46
5	2011-09-02[b]	21:03:26.06	41.11960	80.68639	3.98	2.16	2.86	6.79
6	2011-09-26[b]	01:06:09.83	41.11847	80.69048	3.77	2.33	1.22	2.57
7	2011-09-30[b]	00:52:37.57	41.11945	80.68675	3.89	2.77	1.10	2.28
8	2011-10-20	22:41:09.96	41.11821	80.69044	3.82	2.18	1.51	-
9	2011-11-25	06:47:27.03	41.11885	80.69138	3.67	2.02	1.44	3.07
10	2011-12-24[b]	06:24:57.98	41.11850	80.69235	3.56	2.66	0.38	0.84
11	2011-12-31[b]	20:05:00.04	41.11855	80.69215	3.67	3.88	0.41	0.86
12	2012-01-13	22:29:34.00	41.11828	80.69484	3.65	2.09	0.34	0.82
			Small Events Located by Local Portable Seismographic Network					
13	2012-01-11	21:29:28.06	41.12294	80.67929	3.50	0.39	0.41	1.08
14	2012-01-12	03:01:45.43	41.12304	80.68028	3.57	0.07	0.41	1.10
15	2012-01-13	01:47:29.55	41.12252	80.68132	3.47	−0.05	0.43	1.34
16	2012-01-14	12:53:36.94	41.1203	80.6837	3.90	0.09	0.46	0.84
17	2012-01-17	02:25:59.60	41.11901	80.69127	3.91	0.34	0.43	1.01
18	2012-01-17	07:09:08.73	41.12413	80.67020	3.61	−0.06	0.46	1.37
19	2012-01-18	12:12:01.21	41.11866	80.69570	3.59	0.41	0.41	0.86
20	2012-01-22	12:06:20.37	41.12316	80.67916	3.53	−0.11	0.41	1.10
21	2012-02-11	06:47:19.09	41.12459	80.67278	3.66	−0.40	0.53	1.49

[a]Event #16 was not relocated by double-difference method; Events 10, 11, and 12 are also relocated by using local seismographic network data; Mag = moment magnitude; Erh = horizontal location error; Erz = vertical location error; Location errors are from single event locations and correspond to 95% confidence error ellipse.

[b]Felt earthquakes.

located in Youngstown. The error ellipses of these shocks were up to 1.99 × 1.57 km at 68% confidence level as reported by ODNR (M. Hansen, personal communication, 2011). Hence, these shocks were suspected as induced earthquakes. The seismicity continued, and on 24 December 2011, a magnitude 2.7 shock occurred in the study area, which was followed by a M_w 3.9 event on 31 December 2011. The M_w 2.1 event on 13 January 2012 was the last $M_w > 2.0$ earthquake of the 2011–2012 sequence (Table 2).

3.1. Single Event Location and Location Accuracy

[13] Twelve regional events with $M_w \geq 1.8$ that occurred during 17 March 2011 to 13 January 2012 in Youngtown area were first located by using HYPOINVERSE [*Klein*, 2007]. The velocity model used for location is an average 1D model for northeastern Ohio that consists of the top layer with *P* wave velocity of 4.5 km/s and thickness of 2.7 km, and a 7.3 km thick crystalline basement with *P* wave velocity of 6.12 km/s [*Seeber et al.*, 2004]. The *S* wave velocities are considered to be $V_P/\sqrt{3}$ (Table 3). All events were located with *P* and *S* wave arrival times from at least a dozen seismographic stations around Youngstown, Ohio. For the nine earthquakes during March–November 2011, the nearest station is at about 60 km, but most stations were at distances 100 to 300 km with azimuthal gap of about 90° (Figure 1); hence, the location uncertainties are large—horizontal error is up to 2.8 km for 95% confidence level as listed in Table 2. The locations of 12 earthquakes with their horizontal error ellipse are plotted in Figure 2.

[14] The last three events among the 12 shocks were also recorded by a four-station local network deployed during 1 December 2011 to 30 April 2012 around the epicentral area (Figures 1 and 2). Hence, these shocks were accurately located by the local network data. Three shocks exceed the network criteria [e.g., *Gomberg et al.*, 1990], which are based on the geometry of stations, and can be used to assess the reliability of the location. For three shocks, the number of local *P* or *S* wave arrival times used for each event were greater than eight (nobs = 8–10) of which half are *S* wave arrivals; the greatest azimuthal gap without observation was less than 180° (gap = 90–120°); distance to the closest station was less than focal depth (dmin = 1.9 km); and at least one *S* wave arrival time was within a distance of about 1.4 times the focal depth for good depth constraint [*Gomberg et al.*, 1990]. Three earthquakes that were recorded both by regional and local networks provide data to assess the event location uncertainty and will be used in a later section to anchor relocation of earlier shocks with no local data coverage.

[15] To assess the effect of vertical velocity heterogeneities on focal depth and epicenter determination, we constructed 1D Earth models from the available acoustic well logs in the study area (NS#1 and CO_2 No. 1 Well, see Figure 1). We inferred crustal velocity structure for the top 2.74 km of Paleozoic sedimentary rocks in the region (see the supporting information). The Youngstown well log velocity model consists of 19 layers and is characterized by interbedded high-velocity carbonate rock layers and thick low-velocity shale strata. The prominent strata are the Salina Group of Upper Silurian formation with interbedded salt, anhydrite, dolomite, and shale, which show large velocity and density fluctuations, followed by Lockport Dolomite of Lower Silurian that exhibit very high *P* wave velocity (see Figure S1). At the injection target interval depth

Table 3. Youngstown, Ohio Layered Earth Models

Depth (km)	V_P (km/s)	V_S (km/s)	Depth (km)	V_P (km/s)	V_S (km/s)	Density (kg/m^3)	Depth (km)	V_P (km/s)	V_S (km/s)	Density (kg/m^3)	V_P/V_S
Northeastern Ohio[a]			*Youngstown well log A*[b]				*Youngstown well log B*[c]				
0.00	4.50	2.60	0.00	3.86	2.19	2630	0.00	3.86	2.26	2630	1.71
			0.93	4.98	2.83	2600	0.93	4.98	2.80	2600	1.78
			2.11	6.13	3.48	2710	2.11	6.13	3.50	2710	1.75
2.74	6.12	3.54	2.74	6.15	3.49	2710					
10.0	6.62	3.83	10.0	6.62	3.76	2710	10.0	6.62	3.83	2710	1.73

[a]Constant $V_P/V_S = 1.73$ and density = 2700 kg/m^3.
[b]Constant $V_P/V_S = 1.76$.
[c]Variable V_P/V_S. The Moho is at 41 km depth with $V_P = 8.1$ km/s, $V_S = 4.68$ km/s, and density = 2700 kg/m^3; at the top of the upper mantle.

range of 2.3–2.74 km, low-velocity sandstone and high-velocity dolomite strata are interbedded.

[16] In order to assess uncertainties in earthquake location, we inferred a simple average 1D velocity model by averaging groups of strata with similar characteristics. Hence, the model Youngstown well log A has three layers with constant V_P/V_S ratio of 1.76, and a two-layer model Youngstown well log B has various V_P/V_S ratio for each layer (Table 3). Locations using these velocity models indicate that two layers over the basement Youngstown well log B model, with variable V_P/V_S ratios for each layer, yielded the location with the least root-mean-square (RMS) travel time residuals; however, the differences in location parameters are negligible. The northeastern Ohio velocity model that we used yields the focal depths of 3.52, 3.67, and 3.64 km for 24 December 2011, 31 December 2011, and 13 January 2012 events, respectively, with their 95% confidence error ellipsoids extending up to 0.86 km in the vertical direction. The horizontal error is up to 0.41 km at 95% confidence level (see Table 2).

[17] Three different velocity models yield very similar locations with negligible differences in their location errors. The differences in focal depths are less than 0.15 km depending upon the three models used. If we take the centroid of the source region to be at 3.5 km depth, then these location uncertainties in the vertical direction stretch between 2.7 and 4.3 km depths, which puts the earthquake sources firmly in the Precambrian basement. We consider the location accuracy given is well constrained by velocity structure from well log data, and the solution is reliable considering the network criteria discussed above.

3.2. Focal Mechanism of the Earthquake on 31 December 2011

[18] The shock on 31 December 2011 was large enough to allow us to determine its seismic moment, focal mechanism, and focal depth by modeling observed seismic records at permanent seismographic stations around the study area and inverting for these parameters (Figure 1). We employed a regional waveform inversion method described in *Kim and Chapman* [2005], which is essentially a grid search inversion technique over strike (θ), dip (δ), and rake (λ) developed by *Zhao and Helmberger* [1994]. The results of the waveform modeling and inversion indicate that the focal mechanism of the main shock on 31 December 2011 shock is predominantly strike-slip faulting along steeply dipping nodal planes (see Figure 3). The best fitting double-couple source mechanism parameters are $\theta = 265°$, $\delta = 72°$, $\lambda = 12°$ (second nodal plane; $\theta = 171°$, $\delta = 79°$, and $\lambda = 162°$), and seismic moment, $M_0 = 8.30 \pm 8.0 \times 10^{14}$ Nm (M_w 3.88). The subhorizontal *P* axis trends southwest-northeast (219°) with a plunge of 5° whereas the *T* axis trends SE-NW (127°) with a plunge of 20°. The *P* axis orientation is about 15° rotated counterclockwise from that of the 26 January 2001 earthquake in Ashtabula, Ohio, which is the nearest earthquake with known focal mechanism [*Du et al.*, 2003]. The waveform modeling indicates that the synthetics calculated for focal depth of 3 ± 1 km fit the observed data well.

3.3. Accurate Relocations of 12 Regional Earthquakes

[19] We relocated 12 regional earthquakes by using the double-difference earthquake relocation method to minimize the effect of velocity model errors [*Waldhauser and Ellsworth*,

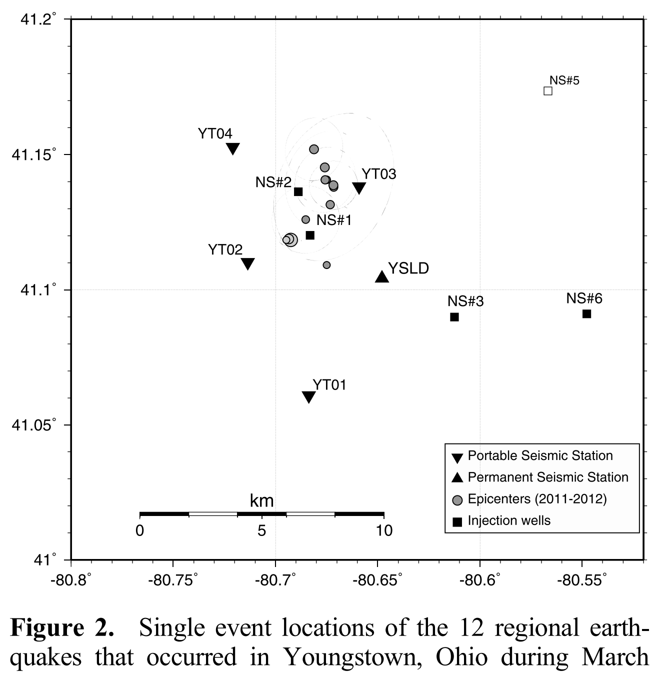

Figure 2. Single event locations of the 12 regional earthquakes that occurred in Youngstown, Ohio during March 2011 to January 2012 are plotted with shaded circles. The horizontal location errors are represented by 95% confidence error ellipses. Four portable seismographic stations around the region deployed during 01 December 2011 to 30 April 2012 and a new seismographic station YSLD (Youngstown State University) are plotted for reference. The last three events were located by using *P* and *S* wave readings from four portable seismographic stations located within 2–6.5 km from the earthquake source area.

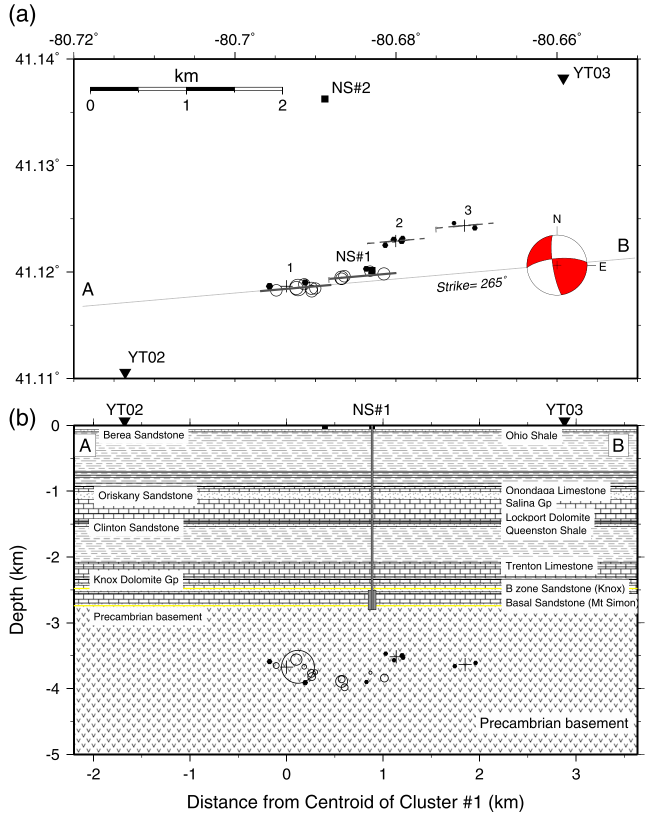

Figure 3. (a) Relocated 12 regional earthquakes (circles) and 9 local earthquakes (black hexagons) which occurred during 17 March 2011 to 18 February 2012. Earthquakes are relocated in three clusters. Focal mechanism of the M_w 3.9 shock on 31 December 2011 is represented by a beachball indicating predominantly a left-lateral strike-slip faulting mechanism. Line A-B is parallel to the trends of the earthquake distribution striking N85°. Deep injection wells in the area NS#1 and NS#2 are indicated (solid squares) and portable seismographs YT02 and YT03 are plotted with solid inverted triangles. Centroid of clusters is plotted with plus symbols. (b) Geologic section along A-B at NS#1. Most of the rocks above the crystalline Precambrian basement are Paleozoic strata that consist of sandstone, limestone, shale, and dolomite. The injection well, NS#1, is indicated with a vertical shaded bar down to a depth of 2802 m. Open section of the well between 2504 and 2802 m is indicated by shaded rectangle. Target injection zone is between B zone sandstone of the Knox Dolomite Group and Mt. Simon sandstone (basal sandstone). Hypocenters are plotted with open circles, whose size is proportional to source radius of each event determined by empirical Green's function analysis and circular source model of *Madariaga* [1976].

2000]. We employed the waveform cross-correlation technique to reduce arrival time picking errors of weak regional *P* and *S* wave arrivals. The relocated regional events show that the epicenters align along a trend striking ENE-WSW (N85°) and at focal depths from 3.5 to 4.0 km (see Table 2 and Figure 3). Hence, these regional events are within a 1.2 km long near-vertical en echelon fault just below the Northstar 1 wellbore (Figure 3). A geologic section along the line A-B below the Northstar 1 well shown in Figure 3 indicates that all the events occurred in the Precambrian basement. Distribution of the main shock and other shocks suggest that the nodal plane striking 265° and dipping 72° to North is the likely fault plane and that the mechanism is left-lateral strike-slip faulting along E-W trending subsurface faults.

3.4. Small Earthquakes Located by Portable Seismograph Data

[20] Nine small earthquakes with magnitude M_w −0.40 and 0.41 were detected and located by the four-station local network during 11 January to 11 February 2012 (Table 2). We relocated these nine events by using the double-difference earthquake relocation method with the waveform cross-correlation technique to reduce arrival time picking errors. The accurate relocation shows that the epicenters align into three distinct clusters (Figure 3). Three events are located in cluster #1 (events #16, #17, and #19), whereas four small events are in cluster #2 (events #13, #14, #15, and #20) and two small events are in cluster #3 (events #18 and #21; Figure 3). The cross sections of the clusters indicate that hypocenters of these shocks are at focal depth between 3.5 and 3.9 km and on near-vertical en echelon faults trending ENE-WSW (N85°; Figure 3), which is consistent with the locations of 12 regional events.

3.5. Regional Seismicity and Magnitude Distribution

[21] The distribution of felt earthquakes as well as small shocks detected and located by local network data in Youngstown suggests that there must have been a number of small shocks (less than $M \leq 2.0$) in the area that may have been undetected by the sparse regional seismic network. We applied a waveform correlation detector using the regional station data to detect those small shocks. The correlation detector is known to lower the seismic event detection threshold by about 1.0 magnitude unit beyond what standard processing detects [e.g., *Schaff*, 2008; *Schaff and Waldhauser*, 2010; *Gibbons and Ringdal*, 2012]. The method is well suited for this study, as we are dealing with small and repeating shocks with similar waveforms located within about a quarter wavelength from each other. We detected 97 additional small earthquakes ($0.4 < M_w < 1.8$) that occurred within about 1 km from the main shock during January 2011 to May 2012 by using the multichannel correlation detector. Hence, the method was able to find additional events by a factor of 10 increase in number of events such as those predicted by the Gutenberg-Richter magnitude-frequency relation. Three-component records from two USArray stations, M54A ($\Delta = 56$ km) and N54A ($\Delta = 107$ km) were the most useful (Figure 1). Three-component waveform records of 24 December and 31 December 2011 shocks were used as master templates.

[22] Figure 4 shows all detected seismic events plotted with their occurrence date against moment magnitude of the events, since commencement of the fluid injection on 29 December 2010 until the end of January 2012. A total of 109 earthquakes with magnitude between M_w ~0.4 and 3.9 detected by the correlation detector are plotted with solid bars, whereas 58 small earthquakes with magnitude $0.0 \leq M_w < 1.0$ detected by the local network are plotted with red bars. Among the 58 shocks, only four events were located by the local network data, as 54 events were only detected by a single station (YT01) which was the only station recording

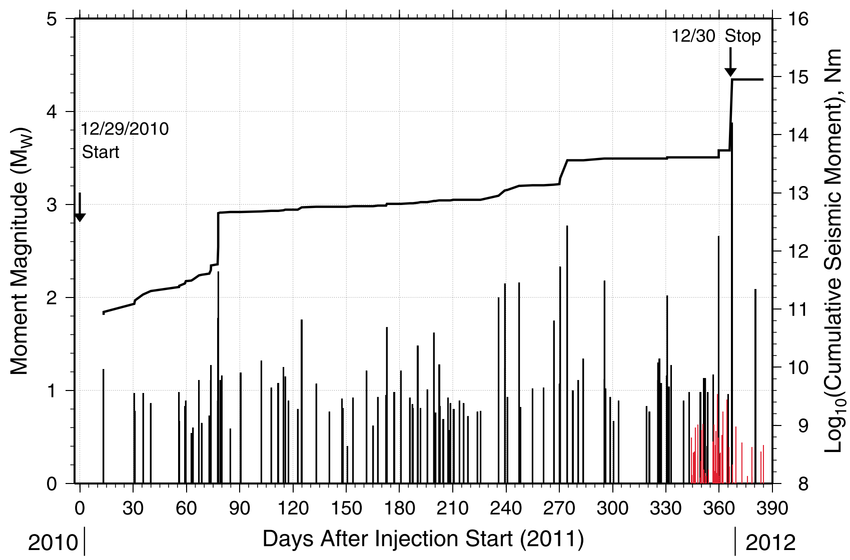

Figure 4. Earthquakes that occurred during 29 December 2010 to January 2012 in Youngstown area are plotted by vertical bars against their occurrence date, whose lengths are proportional to their moment magnitude, M_w (left vertical axis). Small earthquakes that occurred during December 2011 to January 2012 that are only recorded by local portable stations are plotted with red bars. Cumulative seismic moment is plotted by a continuous solid line (right vertical axis). The cumulative moment release is dominated by a few large ($M_w \geq 2.5$) events.

continuously during December 2011. Moment magnitudes (M_w) of earthquakes that occurred in the Youngstown area were determined from RMS (root-mean-square) amplitude of *S* or *Lg* waves and calibrated to that of the M_w 3.88 main shock on 31 December 2011 [*Shi et al.*, 2000]. For 58 small shocks, moment magnitudes were determined by using peak amplitude of *S* arrivals scaled to that of the main shock.

[23] These shocks might have been related to the fluid injection operation, and their spatiotemporal distribution can help us to understand the relationship between the injection parameters and induced seismicity in the area. Cumulative seismic moment of 167 earthquakes with M_w 0.0–3.9 is plotted against occurrence date as a thick continuous line in Figure 4. The seismic moment release is dominated by a few large ($M_w > 2.5$) earthquakes (Figure 4). We estimate that the detection threshold for the regional earthquakes using the correlation detector is about M_w 1.0 in the Youngstown, Ohio region, whereas the detection threshold for local earthquakes in the study area is about $M_w \geq -0.5$ by using local network data.

4. Waste Fluid Injection at Northstar 1 Deep Well, Youngstown, Ohio

[24] The Northstar 1 well was drilled to a total depth of 2802 m, and the waste fluid injection commenced on 29 December 2010. Daily injection volumes and start injection pressures are plotted in Figure 5 for the entire fluid injection operation [*ODNR*, 2012]. The maximum surface injection pressure was 13.0 MPa (=1890 psi) based upon the actual specific gravity of the injection fluid. The maximum injection pressure was permitted to increase up to 15.5 MPa on 16 March 2011 and increased to 17.2 MPa on 3 May 2011 [*ODNR*, 2012]. Three episodes of injection pressure changes are indicated in Figure 5. In the first 60 days, the fluid injection was carried out with a low level of injection pressure ~5 MPa, and the injection volume was less than 100 m^3/day. The injection parameters slowly increased with the injection pressure of about 10–12 MPa, and the daily injection volume of about 100–200 m^3/day during the days 60–110 (Figure 5). During days 110–140, the injection pressure increased sharply to 15.5 MPa and consistently held, and injection volume exceeded 300 m^3/day (Figure 5). The fluid injection at the well reached operational injection pressure of 17.2 MPa and injection volume of about 320 m^3/day around 19 May 2011 (day 141; Figure 5). These injection parameters are kept during June through December 2011 (see Figure 5).

[25] We can recognize several instances of gaps in surface injection pressure—a sudden drop in injection pressure followed by prolonged low pressure. These gaps are present in the daily injection volumes as well (Figure 5). The drops in injection pressure correspond to 2–4 days of no pumping at the wellhead followed by 8 to 20 days of gradual increase of injection pressure (Figure 5). Most of the short and sharp pressure drops correspond to no pump running for a day on national holidays—Memorial Day, 4 July, and among others. The longer gaps are due to injection tests, on Labor Day (246–250), pump maintenance (days 283–285), and Thanksgiving holidays (days 331–334), etc.

[26] The surface injection pressures shown in Figure 5 are listed as *average pressure* in the Northstar 1 injection log, which lists average wellhead pressure between start pressure at the beginning of injection each day and stop pressure at the end of injection each day. The wellhead pressure drops substantially after days of no injection operation as shown as minima in the pressure plot (Figure 5). Dissipation of injection pressure during the gaps is estimated to be about 0.069 MPa/h drop in the wellhead pressure. The average injection rate (number of hours the pump ran over a total daily injection volume) was about 15 m^3/h and remained nearly constant over the whole year

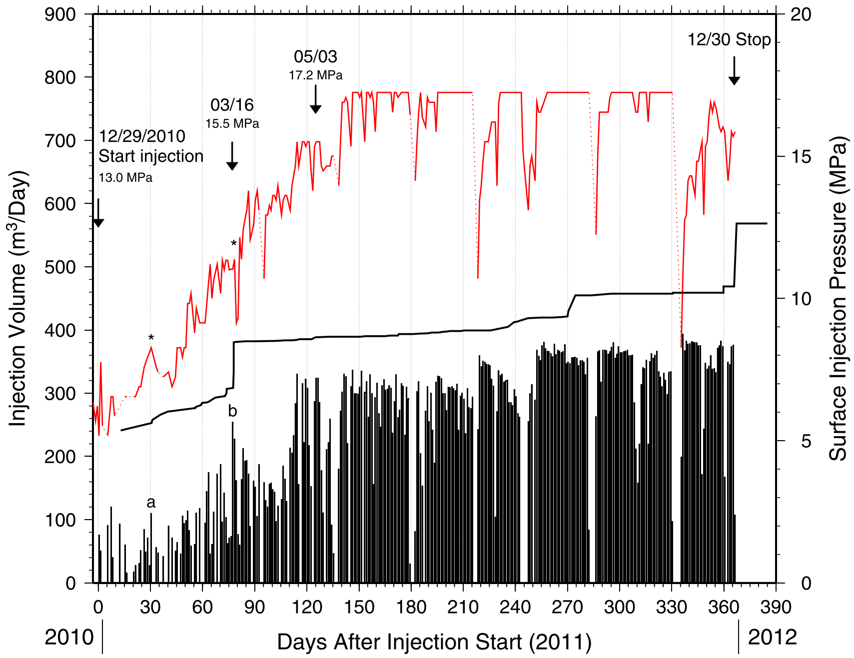

Figure 5. Average surface injection pressure in each day at Northstar 1 well during its operation 29 December 2010 to 30 December 2011 in MPa is plotted with red line (right vertical axis). Dotted portions indicate no entries in the injection log. Daily total injection volume in cubic meters, m^3, is plotted with solid bars (left vertical axis). Average injection volume is about 350 m^3/day when the well is running full time at the maximum surface injection pressure of 17.2 MPa. A total of 78,797.6 m^3 of fluid have been injected into the Northstar 1 well. Cumulative seismic moment of 167 earthquakes that occurred during the fluid injection period is plotted as continuous solid line for reference. Instances of sharp increase of daily injection volume are indicated **a** and **b**, which correspond to occurrence of earthquakes (see the text).

of injection operation at Northstar 1 well. During the summer months, June–August, the injection rate was somewhat low at 12.6 m^3/h.

[27] On 30 December 2011, ODNR requested the operator of the Northstar 1 cease injection at the well based upon the proximity of the 24 December 2011 hypocenter to the Northstar 1 injection wellbore. As of 31 December 2011, a total of 78,797.6 m^3 (495,622 barrels) of fluid had been injected into the Northstar 1 well. It is the only well out of 177 class II (brine disposal) waste disposal wells operating in the state of Ohio during 2011 that has been linked to potentially induced earthquakes. Daily total injection volume is proportional to the product of pump run time and injection pressure, and it may be an appropriate parameter to assess the effect of fluid injection on the subsurface hydraulic system (injection interval). The injection pressure alone is not sufficient to represent the injection; it needs sufficient fluid to exert the pressure on subsurface rocks.

4.1. Peaks and Minima of Injection Parameters and Seismicity at Youngstown, Ohio

[28] When the seismicity in the Youngstown area during 2011–2012 is compared with the fluid injection parameters at the deep injection well Northstar 1, there is some correlation between the injection parameters and occurrence of earthquakes. No felt earthquakes occurred prior to the injection operation on 29 December 2010. Once the injection at the well commenced, and the injection pressure was slowly applied, the first earthquake of M_w 1.2 occurred on 11 January 2011 at 11:16, about 13 days after the commencement. As the fluid injection progressed and injection parameters steadily increased, the seismicity in the area also increased as shown in the cumulative seismic moment release from days 13 to 76, 2011 (Figure 5). The seismicity shown in Figure 4, in particular, the cumulative moment closely follows the increased surface injection pressure as well as injection volume (Figure 5).

[29] There are a pair of peaks in injection volumes as marked **a** and **b** in Figure 5. These sharp peaks in the injection flow rate (m^3/day) appear to be correlated to the occurrence of earthquakes that followed such sharp increases closely. Such a short-term—several hours to a few days—response of the injection medium to the fluid injection may be an indication that the injection target strata are highly fractured, and the storage volume is hydraulically connected to the injection fluid dissipation pathways. The cross correlation between the earthquake series and the fluid pressure as well as injection flow rate series were calculated to determine whether there was a lag between peak fluid pressure and peak seismic activity. The cross correlation is not symmetrical and indicates that the peak of seismicity follows the peak pressure by approximately five days. The lack of symmetry in the cross correlation is due to delayed seismic activity at the beginning and continued seismic activity after the injection of fluid. About 10+ days of short-term response is also reported at RMA [*Healy et al.*, 1968] and is suggested that it was due to fractured Precambrian crystalline bedrock at the site. Although, the Precambrian basement in the Youngstown area was not the primary target interval, the fractured Precambrian rock directly below the wellbore shares similar fractured reservoir characteristics as the RMA site.

4.1.1. Quiescence of Seismicity and Minima of Fluid Injection Pressure

[30] There are quiescences in seismicity during certain time intervals such as days: 285–296 and 305–320 (see Figure 4), as marked with yellow bars in Figure 6. Those quiescent periods are defined as time intervals at least four consecutive days without earthquakes ($M_w \geq 0.9$), and they appear to follow the minima in the injection pressure as represented by vertical red lines in Figure 6. Although not all the injection pressure minima correlate with the quiescence in seismicity, 75% of the pressure minima (18 out of 24 minima) fall within the quiescent intervals (Figure 6), whereas about 62% of the quiescent intervals (18 out of 29 intervals) are associated with the pressure minima (Figure 6). We suggest that the cessation of fluid injection may have caused quiescences of earthquakes as illustrated in Figure 6. We are unable to model such behavior with reservoir analysis due to lack of detailed knowledge on the ambient pore pressure at the Northstar 1 well [e.g., *Hsieh and Bredehoeft*, 1981].

4.2. Physical Basis of the Induced Seismicity in Youngstown, Ohio

[31] The basic mechanism for initiation of induced earthquakes during fluid injection into deep wells is well understood [e.g., *Hubbert and Rubey*, 1959; *Healy et al.*, 1968; *Raleigh et al.*, 1976]: tectonic strain stored in the basement rock is released via earthquakes that are triggered by the injection of fluid into the basement rock. The Mohr-Coulomb fracture criterion may be written as [*Healy et al.*, 1968; *Yeats et al.*, 1997]:

$$\tau = \tau_0 + \mu \sigma_n, \tag{1}$$

where τ is the shear stress on the fault plane at failure, τ_0 is the fracture cohesion, μ is the coefficient of friction, and σ_n is the effective normal stress. Under the presence of pore pressure, the effective normal stress consists of two parts, a pore pressure P and the total stress S; hence, $\sigma_n = (S_n - P)$, in which S_n is the total normal stress acting on the fault plane, and P is the pressure of the ambient fluid [*Healy et al.*, 1968]. For fault slip on preexisting faults, the cohesive strength (τ_0) is taken to be close to zero [*Zoback and Healy*, 1984; *Zoback*, 1992]. μ ranges from 0.6 to 1.0 [*Zoback and Townend*, 2001], and *Byerlee* [1978] reports μ = 0.85 for a variety of rock types at normal stress up to 200 MPa. The right side of the equation consists of a frictional term μ ($S_n - P$), plus the cohesive strength, τ_0 and, hence as long as the right side is greater than the shear stress (τ), fault slip will not occur. This empirical relation indicates that the effect of increasing pore pressure is to reduce the friction resistance to fault slip by decreasing the effective normal stress (σ_n) acting on the fault plane.

[32] If the area has preexisting weak zones (fractures and faults), and the area is already close to failure, then a small increase in pore pressure would trigger earthquakes. Therefore, the gaps in injection parameters at the Northstar 1 well reduced the pore pressure (P) in the above equation and effectively strengthened the friction resistance on the subsurface fault. This leads to reduced size and number of triggered earthquakes and the quiescence in seismicity as shown in Figure 6.

[33] The parameters in the above equation can be evaluated for the Youngstown area on the basis of the following assumptions and relations between τ, σ_n, and the principal stresses. For strike-slip faulting in Youngstown area, the least (S_3) and greatest (S_1) principal stresses are horizontal [*Yeats et al.*, 1997]. We take the least principal stress (S_3) to be the bottom hole pressure (BHP) of 27.5 MPa (=1000 kg/m^3 × 9.8 m/s^2 × 2802 m); the intermediate principal stress S_2 is vertical and equal to the lithostatic pressure (mainly overburden) [*Healy et al.*, 1968]. S_2 at the bottom of injection well at 2802 m is 74.1 MPa (=2700 kg/m^3 × 9.8 m/s^2 × 2802 m). The greatest principal stress S_1 must be at least 74.1 MPa. Estimates of the pore pressure before the fluid injection (P) at the Northstar 1 well is unknown. If we take a similar value to that of RMA well, which was about 75% of the BHP, P is 20.6 MPa (=27.5 MPa x 0.75) which corresponds to the static fluid level of 700 m below the wellhead after injection stopped [*Hsieh and Bredehoeft*, 1981]. From the Mohr failure envelope, the shear and effective normal stresses are given as [*Healy et al.*, 1968; *Yeats et al.*, 1997]:

$$\tau = \frac{(S_1 - S_3)}{2} \sin 2\alpha \tag{2}$$

$$\sigma_n = \frac{(S_1 + S_3 - 2P)}{2} + \frac{(S_1 - S_3)}{2} \cos 2\alpha \tag{3}$$

where α is the angle between the fault plane and the plane normal to σ_1. $\alpha \sim 45°$ for the strike-slip focal mechanism with P axis trending 219° and fault plane striking 265° given in the previous section for Youngstown area. Given $S_1 = 74.1$ MPa, $S_3 = 27.5$ MPa, $P = 20.6$ MPa, and $\alpha = 45°$, the shear and effective normal stresses on a potential fault plane are τ = 28.3 MPa and $\sigma_n = 30.2$ MPa. Therefore, according to the Mohr-Coulomb failure criterion, the cohesive strength, τ_0 would have to be at least 2.6 MPa to prevent fault slip in the reservoir rocks in Youngstown area prior to fluid injection. If the cohesive strength is taken to be $\tau_0 = 0$ on the fault plane, then pore pressure (P) must be less than ~17.5 MPa to prevent failure.

[34] Average injection pressure of 7.5 MPa for two days and a daily total injection volume of 102 m^3/day may have triggered an M_w 1.0 shock on 3 February 2011 (day 35, Figure 6). If we use this injection pressure, the pore pressure is raised to 35.5 MPa (27.5 MPa + 7.5 MPa; BHP plus surface injection pressure), and it yields; $\tau = 28.3$ MPa, $\sigma_n = 15.3$ MPa, and $\tau_0 = 15.3$ MPa. The occurrence of faulting upon reduction of the frictional term due to increased pore pressure indicates a value for τ_0 of 15.3 MPa or less. This is comparable to $\tau_0 = 15.1$ MPa estimated for the RMA [*Healy et al.*, 1968]. The cohesive strength for crystalline basement rocks is about 50 MPa [*Healy et al.*, 1968]. The cohesive strength of 15.3 MPa may be reasonable for the fractured injection media at the Youngtown area, which appears to be fractured Precambrian rocks with preexisting fault or fracture zones, to hold the fault together.

5. Discussion

[35] The earthquakes did not stop immediately after the shutdown of the injection operation at Northstar 1, although the rate and size of earthquakes steadily dropped within a

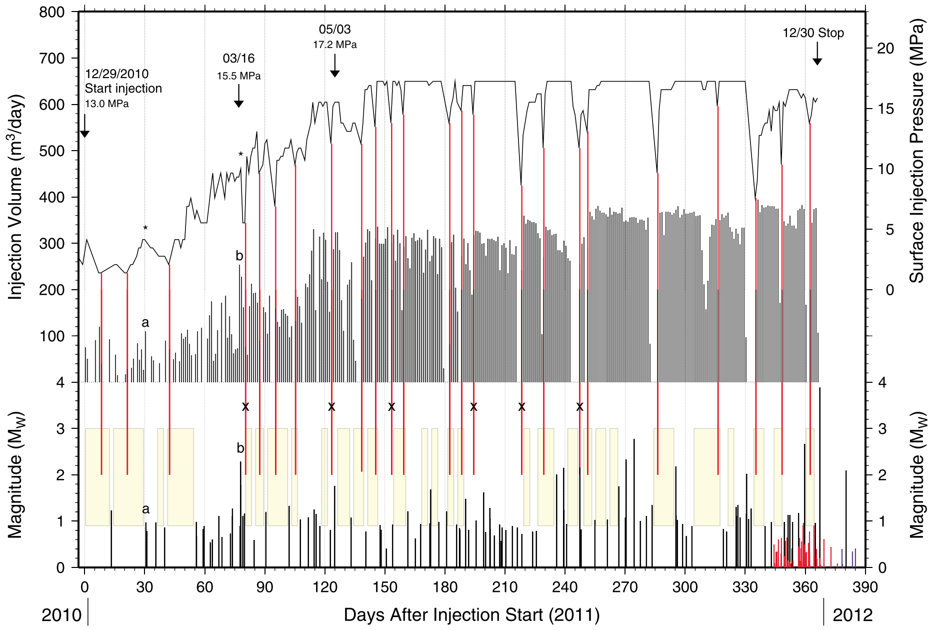

Figure 6. Surface injection pressure in MPa in each day during the whole operation of the Northstar 1 well 29 December 2010 to 30 December 2011 is plotted with black line (right vertical axis). Daily total injection volume in cubic meters (m^3) is plotted with solid bars (left vertical axis) and the earthquakes that occurred during December 2010 to January 2012 are plotted with vertical bars whose lengths are proportional to their moment magnitude, M_w. The minima in the injection pressure are represented by vertical red lines, and quiescent intervals of seismicity are indicated by yellow bars. These injection pressure minima are due to no pumping at the wellhead during equipment services and holidays, and 75% of the minima appear to be correlated to quiescent intervals of seismicity. The minima that are not related to the quiescent intervals are marked by x.

month following shutdown. The largest shock on 31 December 2011 occurred about 24 h after the end of injection on 30 December 2011 at Northstar 1. The largest earthquakes postdated the end of injection at other sites such as, Ashtabula, Ohio, and RMA near Denver, Colorado. At RMA, the largest earthquake (M_w 5.2) occurred on 10 April 1967 more than a year after injection ceased on February 1966 [*Healy et al.*, 1968]. Usually, pore pressure buildup from several months of fluid injection would require time to return to the preinjection level.

5.1. Migration of Seismicity From East to West

[36] Twelve relocated regional earthquakes cluster along ENE-WSW (Figure 7a), and their vertical distribution suggests that the rupture area can be represented by a pair of rectangular planes aligned en echelon with overall length of about 1.2 km and width of about 0.5 km (Figure 7b). The linear trend is consistent with a nodal plane striking 265° of the focal mechanism for the main shock on 31 December 2011 (Figure 7a). A pair of earthquakes on 17 March 2011 (events #1 and #2) occurred at the eastern end of a 1.2 km long rupture area close to the wellbore (Figure 7a), then the subsequent shocks in August and September 2011 occurred in the further western part of the rupture area (events #3 through #7; Figure 7). The shocks on December 2011 and January 2012 including the main shock on 31 December 2011 occurred at the western end of the rupture area (events #10–#12; Figure 7). Hence, the seismicity migrated gradually from the eastern end of the fault area close to the injection wellbore toward the western end, away from the injection point (Figure 7).

[37] The west-south-west (WSW) migration of the seismicity from the injection point can be explained by the outward expansion of the high fluid pressure front which increases pore pressure along its path on the fault zone and triggers earthquakes, and the progressive westward migration of seismicity continues until injection stops. The effect of increased pore pressure is to reduce the frictional resistance to faulting by decreasing the effective normal stress across the fracture plane [*Healy et al.*, 1968]. A predominantly WSW-ENE trending seismicity with narrow depth ranges of 3.5–4.0 km indicates the existence of a fractured Precambrian rock in the form of en echelon rectangular faults as conduits of fluid migration. A migration of seismicity was also observed at RMA [*Healy et al.*, 1968; *Hsieh and Bredehoeft*, 1981]. There is minor seismic activity in the northeast from the injection well within the ENE-WSW trending fractured Precambrian basement, suggesting the existence of step-like en echelon rupture planes (see Figure 3a). Deep basement fault(s) in the study area may act as vertical fluid conduits and provides a hydraulic connection between the fluid disposal well injection depths and the earthquake source depths (Figure 7).

5.2. Speed of the Earthquake Migration

[38] The seismicity migrated from East to West for about 1.2 km during 17 March 2011 to 13 January 2012. Although the migration rate is not homogeneous in time, an average speed is about 4.0 m per day (= 1.2 km/300 days) or ~120 m per month. Somewhat higher migration speed of 2 to 40 m/h was observed in a water injection experiment at the Nojima

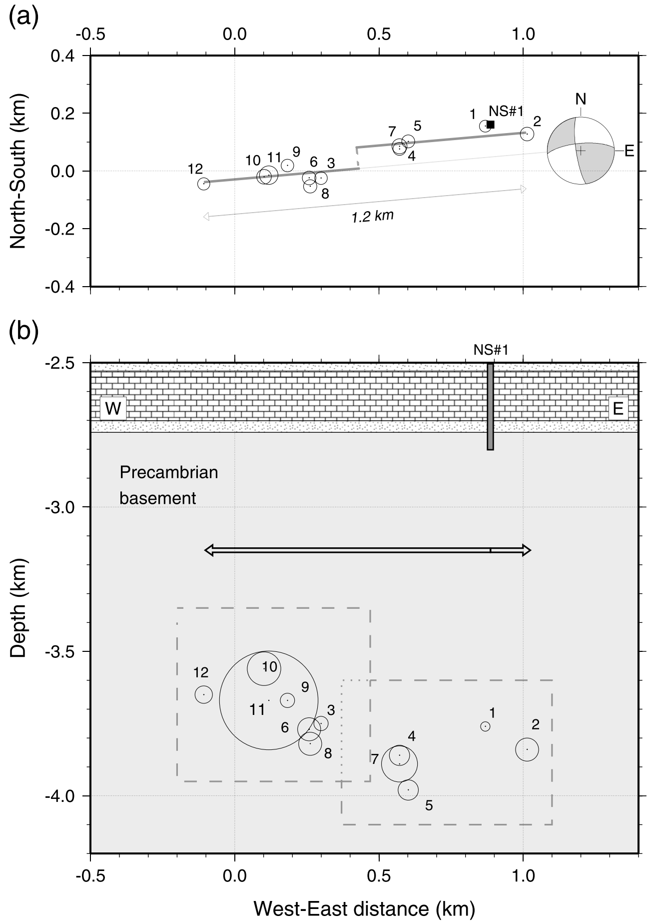

Figure 7. (a) Accurately relocated regional earthquakes that have occurred during 17 March 2011 to 13 January 2012 in Youngstown area are plotted by circles and denoted by event ids. The deep injection well Northstar 1 (NS#1) is plotted for reference. Events on 17 March 2011 (#1 and #2) are located close to the injection well. Subsequent later events have occurred further away from the injection well and the events on December 2011 to January 2012 are located at the western end of the rupture zone; (b) Cross-section view of the hypocenters. Injection interval of the well between 2504 and 2802 m is indicated by shaded rectangle. Events are clustered in depth ranges 3.5 to 4.0 km, and the seismicity shows gradual migration from the eastern end close to the injection wellbore to the western end of the fault zone. Circle sizes are proportional to the source radius of each event determined by empirical Green's function analysis and circular source model of *Madariaga* [1976]. Dashed lines suggest possible maximum rupture planes based on source model of *Brune* [1970].

fault zone in Japan [*Tadokoro et al.*, 2000, 2005]. *Seeber et al.* [2004] reported a somewhat similar observation in Ashtabula, Ohio where seismicity shifted ~1 km from the point of injection during May 1986 to June 1994.

[39] The seismicity waned after the main shock on 31 December 2011 (which also coincides with the stopping of the injection operation), which is somewhat different from the naturally occurring earthquakes in which most of the aftershocks occur immediately following the main shock. The seismicity plotted in Figure 4 is similar to an earthquake swarm, but in this case, seismicity is spread in time and space due to migrating high fluid pressure front. As such, most events may have occurred as doublets and multiplets.

5.3. Total Injected Volume and Maximum Seismic Moment of the Induced Earthquakes

[40] *McGarr* [1976] reported that annual sums of seismic moments for the Denver earthquakes from 1962 to 1965 agree with the yearly total moment estimated from the volume of fluid injected at the RMA well. He postulated that the seismicity that results from a change in volume ΔV is related to the sum of the seismic moments of the earthquake population, ΣM_0, that is, $\Sigma M_0 \sim \nu |\Delta V|$, where ν is the rigidity, and a necessary condition is that the change in volume is accommodated only by seismic failure. *Gibbs et al.* [1973] reported that the number of earthquakes per year appeared to correlate with changes in the quantity of fluid injected per year during 1962–1970 in Rangely, Colorado.

[41] *McGarr* [2012] proposed that the maximum induced earthquake size (moment) scales with total volume of injected fluid. The pore fluid pressure from injection is needed to trigger the earthquakes [*Raleigh et al.*, 1976; *Zoback and Harjes*, 1997], but additionally the total injected volume must be large enough to exert fluid pressure over a sufficiently large area of the preexisting faults, thereby triggering large-sized earthquakes. However, even if this volume is large, it may not be necessary that earthquakes will occur. For example, if a large volume is injected over a long period of time, sufficient to achieve fluid migration, earthquakes may not be triggered. We conclude that although total injected volume is a readily available parameter that may be useful for assessing the propensity for earthquakes to occur, it may need to be interpreted in association with knowledge of the injection rate, and/or an assessment of pressure levels. As in the progressive migration of seismicity, more injected volume would have a better chance to exert pressure to a wider rupture area, thereby increasing the maximum size of the induced earthquakes. Although we do not know the WSW-ENE extent of the fault(s) in the Youngstown area, it is possible that continued injection of fluid at Northstar 1 well could have triggered potentially large and damaging earthquakes.

6. Summary and Conclusions

[42] A total of 167 small earthquakes (M_w 0.0–3.9) were detected during January 2011 to February 2012 in Youngstown, Ohio. These shocks were located close to a deep fluid injection well Northstar 1. Twenty-one accurately located earthquakes are distributed along the pair of en echelon faults striking 265° (ENE-WSW) and dipping steeply to the north (dip = 72°N), consistent with the main shock focal mechanism.

[43] All the well-located earthquakes have occurred at depths ranging from 3.5 to 4.0 km in the Precambrian crystalline basement. Most of the previously known earthquakes associated with the fluid injections in the eastern United States have occurred in Precambrian basement indicating that tectonic strain stored in the crystalline basement is released through the triggered events (e.g., Ashtabula, Ohio [*Seeber et al.*, 2004], and Guy, Arkansas [*Horton*, 2012]). The *P* axis of the main shock mechanism trends

NE-SW and corresponds to horizontal compression (σ_{Hmax}) which is slightly rotated from the ENE-WSW trending broad-scale regional stress field in the northeastern United States [*Du et al.*, 2003; *Zoback and Zoback*, 1991].

[44] The first detected earthquake (M_w 1.2) occurred on 11 January 2011, 13 days after the commencement of injection at Northstar 1 well. At that time, a total of ~700 m^3 of fluid had been injected at a rate of up to 5 m^3/h, and the surface injection pressure was up to 13.5 MPa. Total injection volume was a very small quantity when it started to trigger an earthquake, and the injection pressure was relatively low, and hence, there must have been nearly direct fluid conduits to the ENE-WSW trending fault very close to the injection wellbore, and the subsurface condition at the Precambrian basement may have been near critical for the earthquakes to occur. The cross correlation between the earthquake series and the injection flow rate series indicates that the peak of seismicity follows the peak pressure with approximately five days lag. This short-term response of the injection media at Youngstown is similar to an observation at RMA where about 10 days of time lag in earthquake occurrences was observed following fluid injection [*Healy et al.*, 1968].

[45] We conclude that the recent, 2011–2012, earthquakes in Youngstown, Ohio were induced by the fluid injection at Northstar 1 deep injection well due to increased pore pressure along the preexisting (ENE-WSW trending) faults located close to the wellbore in the Precambrian basement. This is based on the facts that: (1) well-located earthquakes clustered in a narrow zone along the fault trace striking ENE-WSW in the Precambrian basement (Figures 3 and 6); (2) migration of seismicity from the east—close to the injection point, toward the west—away from the wellbore, indicating that the expanding high fluid pressure front increased the pore pressure along its ENE-WSW trending path and progressively triggered the earthquakes; (3) occurrence of earthquakes was generally correlated with the total daily injection volume and injection pressure, and a pair of peaks in the injection parameters appears to be correlated with the occurrence of earthquakes at the early stage of fluid injection when the subsurface hydraulic system started to build up pore pressure; (4) 75% of the minima in surface injection pressure (no pumping operations) appeared to correlate with quiescent intervals of seismicity, which may indicate that the earthquakes were caused by the pressure buildup in the fractured Precambrian basement and stopped when pressure dropped; and (5) a short-term response of the injection media to the fluid injection parameters on the time scale of hours to few days (5+) suggests that the site behaved as a fractured Precambrian reservoir as in the Rocky Mountain Arsenal, Colorado.

[46] **Acknowledgments.** John Armbruster at Lamont-Doherty Earth Observatory of Columbia University (LDEO) led fieldwork in Youngstown, Ohio and processed raw data during January–March 2012. Chris Grope at Youngstown State University participated in the fieldwork and helped in portable station service and data retrieval. Mike Hansen and Tim Leftwitch of the Ohio Division of Geological Survey, Ohio Department of Natural Resources, helped to carry out the fieldwork and supported this study, as well as provided well log data and other material for the study. Jeffrey Dick of Youngstown State University helped us to deploy a NetQuake station, YSLD, at the campus. Larry Smyers of D&L Energy Inc. provided a spreadsheet of injection parameters at Northstar 1 well. Paul Richards and Heather Savage at LDEO provided critical comments that improved the paper. Alberto Malinverno helped to interpret well logging data. I thank Bill Menke for helping me with Poisson distribution. Stephen Holtkamp and Michael Brudzinski of Miami University of Ohio shared their result of regional event detection which helped us to solidify detection of regional events down to M_w ~0.5. Mitchell Gold of LDEO read the manuscript and provided editorial help. Bill Leith of U.S. Geological Survey supported the field work, and Bill Ellsworth and Art McGarr of USGS provided useful comments. The U.S. Geological Survey has provided partial support for this study under contract G10AC00094. This is Lamont-Doherty Earth Observatory contribution 7681.

References

Ake, J., K. Mahrer, D. O'Connell, and L. Block (2005), Deep-injection and closely monitored induced seismicity at Paradox Valley, Colorado, *Bull. Seismol. Soc. Am.*, *95*, 664–683.

Baranoski, M. T. (2002), Structure contour map on the Precambrian unconformity surface in Ohio and related basement features, report, *Div. Geol. Surv. Map PG-23,* scale 1:500,000, Ohio Dep. of Nat.l Resour., Columbus. [Available at http://www.dnr.state.oh.us/Portals/10/pdf/mappg23.pdf.]

Brown, W. A., C. A. Frohlich, W. L. Ellsworth, J. H. Luetgert, and M. R. Brunt (2012), The May 17th, 2012 M4.8 earthquake near Timpson, east Texas: Was it natural or was it induced?, Abstract S53I-06 presented at 2012 Fall Meeting, AGU, San Francisco, Calif., 3–7 Dec.

Brune, J. N. (1970), Tectonic stress and the spectra of seismic shear waves from earthquakes, *J. Geophys. Res.*, *75*, 4997–5009.

Brunt, M. R., W. A. Brown, and C. A. Frohlich (2012), Felt reports and intensity maps for two M4.8 Texas earthquakes: 17 May 2012 near Timpson and 20 October 2011 near Fashing, Abstract S51E-2454 presented at 2012 Fall Meeting, AGU, San Francisco, Calif., 3–7 Dec.

Byerlee, J. D. (1978), Friction of rocks, *Pure Appl. Geophys.*, *116*, 615–626.

Davis, S. D., and W. D. Pennington (1989), Induced seismic deformation in the Cogdell oil field of west Texas, *Bull. Seismol. Soc. Am.*, *79*, 1477–1495.

Du, W.-X., W.-Y. Kim, and L. R. Sykes (2003), Earthquake source parameters and state of stress for northeastern United States and southeastern Canada from analysis of regional seismograms, *Bull. Seismol. Soc. Am.*, *93*, 1633–1648.

Ellsworth, W. L., S. H. Hickman, A. L. Llenos, A. McGarr, A. J. Michael, and J. L. Rubinstein (2012), Are seismicity rate changes in the midcontinent natural or manmade?, paper presented at 2012 Seismological Society of America Annual Meeting, San Diego, Calif.

Frohlich, C., C. Hayward, B. Stump, and E. Potter (2011), The Dallas-Fort Worth earthquake sequence: October 2008 through May 2009, *Bull. Seismol. Soc. Am.*, *101*, 327–340.

Gibbons, S. J., and F. Ringdal (2012), Seismic monitoring of the North Korea nuclear test site using a multichannel correlation detector, *IEEE Trans. Geosci. Remote Sens.*, *50*, 1897–1909, doi:10.1109/TGRS.2011.2170429.

Gibbs, J. F., J. H. Healy, C. B. Raleigh, and J. Coakley (1973), Seismicity in the Rangely, Colorado, area: 1962–1970, *Bull. Seismol. Soc. Am.*, *63*, 1557–1570.

Gomberg, J. S., K. M. Shedlock, and S. W. Roecker (1990), The effect of S-wave arrival times on the accuracy of hypocenter estimation, *Bull. Seismol. Soc. Am.*, *80*, 1605–1628.

Hansen, M. C. (2012), Earthquakes in Ohio, *Educ. Leaflet 9*, Div. of Geol. Surv., Ohio Dep. of Nat. Resour., Columbus. [Available at http://www.dnr.state.oh.us/Portals/10/pdf/EL/el09.pdf.]

Hansen, M. C., and L. J. Ruff (2003), The Ohio seismic network, *Seismol. Res. Lett.*, *74*, 561–564.

Healy, J. T., W. W. Rubey, D. T. Griggs, and C. B. Raleigh (1968), The Denver earthquakes, *Science*, *161*, 1301–1310.

Herrmann, R. B., S.-K. Park, and C.-Y. Wang (1981), The Denver earthquakes of 1967–1968, *Bull. Seismol. Soc. Am.*, *71*, 731–745.

Horton, S. (2012), Disposal of hydrofracking waste fluid by injection into subsurface aquifers triggers earthquake swarm in central Arkansas with potential for damaging earthquake, *Seismol. Res. Lett.*, *83*, 250–260, doi:10.1785/gssrl.83.2.250.

Hsieh, P. A., and J. S. Bredehoeft (1981), A reservoir analysis of the Denver earthquakes—A case study of induced seismicity, *J. Geophys. Res.*, *86*, 903–920.

Hubbert, M. K., and W. W. Rubey (1959), Role of fluid pressure in mechanics of overthrust faulting, *Geol. Soc. Am. Bull.*, *70*, 115–206.

Keranen, K., H. M. Savage, G. Abers, and E. S. Cochran (2013), Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 M_W 5.7 earthquake sequence, *Geology*, *41*, 699–702, doi:10.1130/G34045.1.

Kim, W.-Y., and M. Chapman (2005), The 9 December 2003 central Virginia earthquake sequence: A compound earthquake in the central Virginia seismic zone, *Bull. Seismol. Soc. Am.*, *95*, 2428–2445.

Klein, F. W. (2007), User's guide to HYPOINVERSE-2000, a Fortran program to solve for earthquake locations and magnitudes, *U.S. Geol. Surv. Open File Rep., 02-171*, 121 pp.
Madariaga, R. (1976), Dynamics of an expanding circular fault, *Bull. Seismol. Soc. Am.*, *66*, 639–666.
McGarr, A. (1976), Seismic moments and volume changes, *J. Geophys. Res.*, *81*, 1487–1494.
McGarr, A. (2012), Factors influencing the seismic hazard of earthquakes induced by fluid injection at depth, paper presented at SPE/SEG Workshop on Injection Induced Seismicity, Soc. of Pet. Eng., Broomfield, Colo, 12–14 Sept. 2012.
McGarr, A., D. Simpson, and L. Seeber (2002), Case histories of induced and triggered seismicity, in *International Handbook of Earthquake and Engineering Seismology*, edited by W. Lee, H. Kanamori, P. Jennings, and C. Kisslinger, chap. 40, pp. 647–664, Academic Press, London.
Meremonte, M. E., J. C. Lahr, A. D. Frankel, J. W. Dewey, A. J. Crone, D. E. Overturf, D. L. Carver, and W. T. Bice (2002), Investigation of an earthquake swarm near Trinidad, Colorado, August–October 2001, *U.S. Geol. Surv. Open File Rep., 02-0073*.
National Academy of Sciences (2012), *Induced Seismicity Potential in Energy Technologies,* 225 pp., Natl. Acad. Press, Washington, D. C.
Nicholson, C., and R. L. Wesson (1992), Triggered earthquakes and deep well activities, *Pure Appl. Geophys.*, *139*, 561–578.
Nicholson, C., E. Roeloffs, and R. L. Wesson (1988), The northeastern Ohio earthquake of 31 January 1986: Was it induced?, *Bull. Seismol. Soc. Am.*, *78*, 188–217.
Ohio Department of Natural Resources (ODNR) (2012), Preliminary report on the Northstar 1 class II injection well and the seismic events in the Youngstown, Ohio, area, report, 23 pp., Columbus, March.
Raleigh, C. B., J. H. Healy, and J. D. Bredehoeft (1976), An experiment in earthquake control at Rangely, Colorado, *Science*, *91*, 1230–1237.
Rubinstein, J. L., W. L. Ellsworth, and A. McGarr (2012), The 2001–present triggered seismicity sequence in the Raton Basin of southern Colorado/northern New Mexico, Abstract S34A-02 presented at 2012 Fall Meeting, AGU, San Francisco, Calif., 3–7 Dec.
Schaff, D. P. (2008), Semiempirical statistics of correlation-detector performance, *Bull. Seismol. Soc. Am.*, *98*, 1495–1507.
Schaff, D. P., and F. Waldhauser (2010), One magnitude unit reduction in detection threshold by cross correlation applied to Parkfield (California) and China seismicity, *Bull. Seismol. Soc. Am.*, *100*, 3224–3238, doi:10.1785/0120100042.
Seeber, L., and J. G. Armbruster (1993), Natural and induced seismicity in the Erie-Ontario region: Reactivation of ancient faults with little neotectonic displacement, *Geogr. Phys. Quat.*, *47*, 363–378.
Seeber, L., J. Armbruster, and W. Y. Kim (2004), A fluid-injection-triggered earthquake sequence in Ashtabula, Ohio: Implications for seismogenesis in stable continental regions, *Bull. Seismol. Soc. Am.*, *94*, 76–87.
Shi, J., P. G. Richards, and W. Y. Kim (2000), Determination of seismic energy from *Lg* waves, *Bull. Seismol. Soc. Am.*, *90*, 483–493.
Stover, C. W., and Coffman, J. L. (1993), Seismicity of the United States, 1568–1989 (Revised), *U.S. Geol. Surv. Prof. Pap., 1527*, 418 pp.
Tadokoro, K., M. Ando, and K. Nishigami (2000), Induced earthquakes accompanying the water injection experiment at the Nojima fault zone, Japan: Seismicity and its migration, *J. Geophys. Res.*, *105*(B3), 6089–6104, doi:10.1029/1999JB900416.
Tadokoro, K., M. Ando, and K. Nishigami (2005), Correction to "Induced earthquakes accompanying the water injection experiment at the Nojima fault zone, Japan: Seismicity and its migration," *J. Geophys. Res.*, *110*, B03305, doi:10.1029/2004JB003602.
Viegas, G., K. Buckingham, A. Baig, and T. Urbancic (2012), Large scale seismicity related to wastewater injection near Trinidad, Colorado, USA, paper presented at GeoConvention 2012, Can. Soc. of Pet. Eng., Calgary, Alberta, Canada.
Waldhauser, F., and W. L. Ellsworth (2000), A double-difference earthquake location algorithm: Method and application to the northern Hayward fault, California, *Bull. Seismol. Soc. Am.*, *90*, 1353–1368.
Yeats, R. S., K. Sieh, and C. R. Allen (1997), *Geology of Earthquakes*, 568 pp., Oxford Univ. Press, New York.
Zhao, L. S., and D. V. Helmberger (1994), Source estimation from broadband regional seismograms, *Bull. Seismol. Soc. Am.*, *84*, 91–104.
Zoback, M. D., and H.-P. Harjes (1997), Injection-induced earthquakes and crustal stress at 9 km depth at the KTB deep drilling site, Germany, *J. Geophys. Res.*, *102*, 18,477–18,491.
Zoback, M. D., and J. H. Healy (1984), In situ stress measurements to 3.5 km depth in the Cajon Pass scientific research borehole: Implications for the mechanics of crustal faulting, *J. Geophys. Res.*, *97*, 5039–5057.
Zoback, M. D., and J. Townend (2001), Implications of hydrostatic pore pressures and high crustal strength for the deformation of intraplate lithosphere, *Tectonophysics*, *336*, 19–30.
Zoback, M. D., and M. L. Zoback (1991), Tectonic stress field of North America and relative plate motions, in *Neotectonics of North America*, edited by Slemmons et al. pp. 339–366, Geol. Soc. of Am., Boulder, Colo.
Zoback, M. L. (1992), Stress field constraints on intra-plate seismicity in eastern North America, *J. Geophys. Res.*, *97*, 11,761–11,782.

Sent: Wednesday, May 09, 2012 2:45 AM
Subject: Couple denied mortgage because of gas drilling

Couple denied mortgage because of gas drilling

Brian Smith lives near Marcellus Shale well in Daisytown

http://www.wtae.com/news/local/investigations/Couple-denied-mortgage-because-of-gas-drilling/-/12023024/12865512/-/ohf26fz/-/index.html#.T6mu842bM44.facebook

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Ward: Gas company financing is preventing residents from getting mortgages

Published: August 1, 2011

http://thedailyreview.com/news/ward-gas-company-financing-is-preventing-residents-from-getting-mortgages-1.1182565

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Fracking Boom Gives Banks Mortgage Headaches

November 15, 2013

WHY FRACKING IS A PROBLEM FOR BANKS

BY ANDY PETERS, AMERICAN BANKER, NOVEMBER 12, 2013

An East Coast oil boom has promised potential riches to lucky landowners. But the oil rush may cause big headaches for some unlucky banks.

At least three institutions — Tompkins Financial (TMP) in Ithaca, N.Y., … Continue reading

Filed Under: Mortgages

NYPIRG Urges Cuomo to Reject dSGEIS Due to Conflicts of Interest

April 24, 2013

The New York Public Interest Research Group (NYPIRG) has sent a letter to New York State Governor Cuomo urging him to reject the Revised Draft Supplemental Generic Environmental Impact Statement (dSGEIS) due to a conflict of interest on the part of the consultants who worked on the socio-economic impact section. … Continue reading

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You Have to See It to Believe It: What It's Like to Have Fracking in Your Backyard

April 22, 2013

You Have to See It to Believe It: What It's Like to Have Fracking in Your Backyard

Residents in industry-friendly West Virginia share their experiences, photos and videos.
April 15, 2013
From Alternet, by Tara Lohan

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Gas Drilling, Homeowners Don't Mix

September 21, 2012

IF GAS DRILLING COMES TO THE SOUTHERN TIER, HOMEOWNERS HAVE PROPERTY-RELATED EFFECTS TO CONSIDER, WHETHER THEY HAVE ALREADY SIGNED A GAS LEASE OR ARE STILL CONSIDERING ONE

BY ELISABETH N. RADOW, PRESSCONNECTS.COM, SEPT. 18, 2012

Elisabeth Radow is the managing attorney of Radow Law and chairs the New York State … Continue reading

Filed Under: Experts, Mortgages

Mortgages for Drilling Properties May Face Hurdle

March 18, 2012

BY IAN URBINA, NEW YORK TIMES

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Last year more than 140,000 families, many of them with low incomes and living in rural areas, received … Continue reading

Filed Under: Mortgages, New York Times

Promises made, but not kept, and it's all legal

December 28, 2011

BY JOSHUA SCHNEYER AND BRIAN GROW, REUTERS

TRAVERSE CITY, Michigan – Late in the summer of 2010, hundreds of farmers in northern Michigan were fuming.

All had signed leases with local brokers permitting drillers to tap natural gas and oil beneath their land. All were demanding thousands of dollars in bonuses … Continue reading

Filed Under: Mortgages, News Stories

Home Mortgages, Homeowner Liability Affected by Gas Drilling

November 10, 2011

NEW YORK STATE BAR ASSOCIATION JOURNAL

NOVEMBER/DECEMBER 2011, VOL. 83, NO. 9, LEAD ARTICLE

". . . issues not often discussed, such as the owner's potential liability and the continued viability of the mortgage."

"Residential fracking carries heavy industrial risks, and the ripple effects could be tremendous. Homeowners can be … Continue reading

Filed Under: Impacts, Mortgages, Reports / Studies Tagged With: gas leases and homeowners liabilities, homeowners gas drilling leases, NYS Bar Association Journal, NYSBA Journal

Rush to Drill for Natural Gas Creates Conflicts With Mortgages

October 19, 2011

BY IAN URBINA, NEW YORK TIMES

As natural gas drilling has spread across the country, energy industry representatives have sat down at kitchen tables in states like Texas, Pennsylvania and New York to offer homeowners leases that give companies the right to drill on their land.

And over the past … Continue reading

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Houses for Shale

June 5, 2010

NEW MORTGAGES UNAVAILABLE FOR PROPERTIES WITH GAS DRILLING LEASES

BY LINDA FIELDS (PIKE COUNTY COURIER)

NORTHEAST Pa — Property owners may make money from leasing to Marcellus Shale gas drillers, and they may also find their property can't be financed for a new mortgage.

If gas is extracted and sold, … Continue reading

NOVEMBER/DECEMBER 2011
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NEW YORK STATE BAR ASSOCIATION
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Homeowners and Gas Drilling Leases: Boon or Bust?

By Elisabeth N. Radow

Also in this Issue

POINT OF VIEW

Gas drilling in Dimock, PA

Homeowners and Gas Drilling Leases: Boon or Bust?

By Elisabeth N. Radow

The Conundrum

Gas companies covet the shale gas deposits lying under homes and farms in New York's Marcellus Shale region and are pursuing leasing agreements with area property owners. Many homeowners and farmers in need of cash are inclined to say yes. In making their argument, gas companies reassure property owners that the drilling processes and chemicals used are safe. Yet aside from arguments about the relative safety of the extraction process are issues not often discussed, such as the owner's potential liability and the continued viability of the mortgage. The property owner can be particularly vulnerable when the drilling process involves high-volume, horizontal hydraulic fracturing, or "fracking."

For example, when Ellen Harrison signed a gas lease agreement in 2008, the company representative made no mention of fracking. Harrison received no details, only the chance for a "win-win" with "clean" gas for the locals and royalties for her. Like most Americans, Harrison has a mortgage loan secured by her home. All mortgages, Harrison's included, prohibit hazardous activity and hazardous substances on the property.

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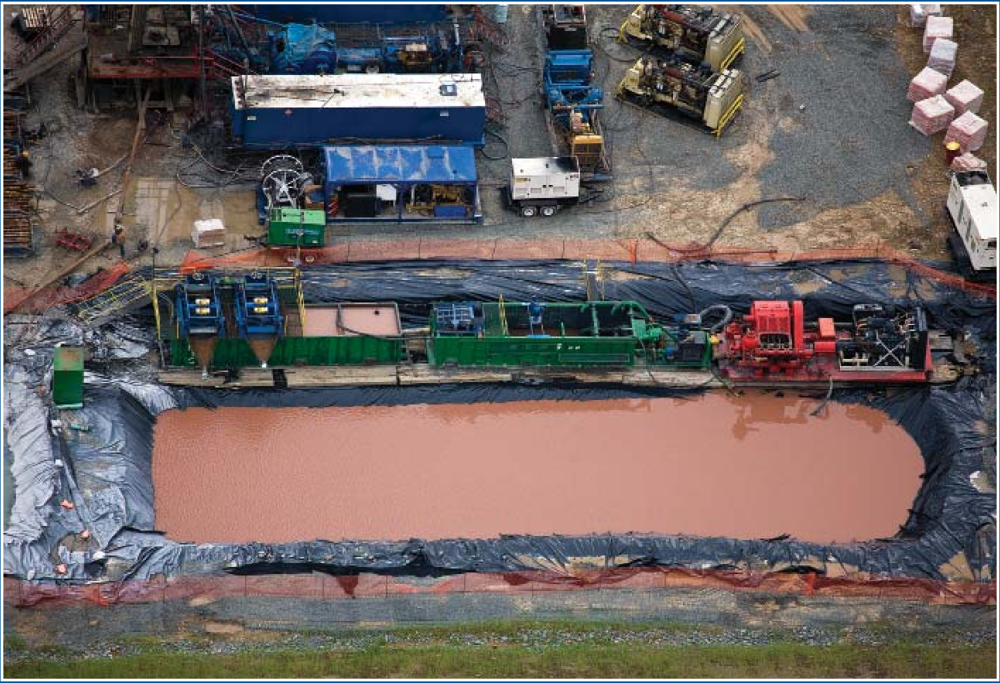

Waste pond at hydro-fracking drill site, Dimock, PA

Elisabeth N. Radow (eradow@cuddyfeder.com) is Special Counsel to the White Plains law firm of Cuddy & Feder LLP. Ms. Radow chairs the Hydraulic Fracturing Committee for the League of Women Voters of New York State. Ms. Radow's Law Note, *Citizen David Tames Gas Goliaths on the Marcellus Shale Stage*, was published in the 2010 Spring issue of the *Cardozo Journal of Conflict Resolution*. This analysis and the assertions made in this article are attributable to the author alone.

Photographs courtesy of J Henry Fair. Mr. Fair's work has appeared in the *New York Times, Vanity Fair, Time and National Geographic*. His new book, *The Day After Tomorrow: Images of Our Earth In Crisis* is a series of essays and startling images. www.industrialscars.com.

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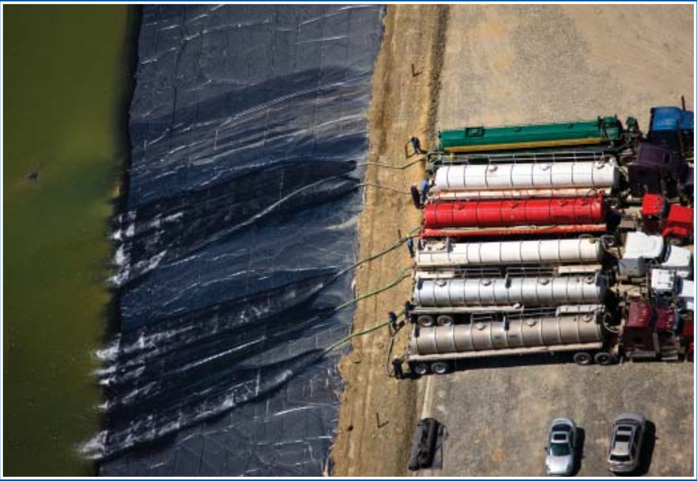
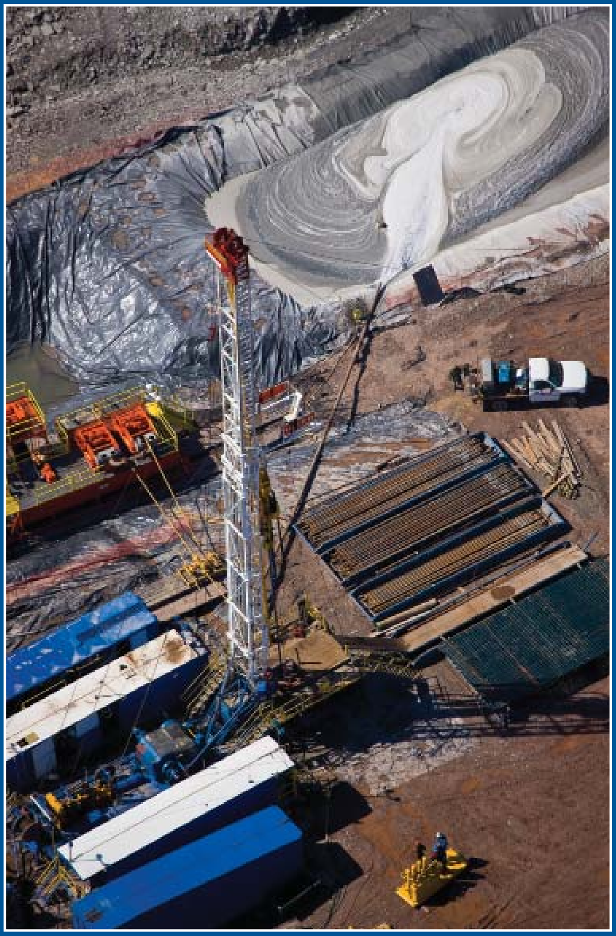


Tanker trucks filling water reservoir at hydo-fracking gas drilling operations near Sopertown, Columbia Township, PA



Overspray of drilling slurry at hydro-fracking drill site, Dimock, PA

Residential fracking carries heavy industrial risks, and the ripple effects could be tremendous. Homeowners can be confronted with uninsurable property damage for activities that they cannot control. And now a growing number of banks won't give new mortgage loans on homes with gas leases because they don't meet secondary mortgage market guidelines. New construction starts, the bellwether of economic recovery, won't budge where residential fracking occurs since construction loans depend on risk-free property and a purchaser. This shift of drilling risks from the gas companies to the housing sector, homeowners and taxpayers creates a perfect storm begging for immediate attention.

> A home represents a family's most valuable asset, financially and otherwise.

The introduction of fracking in homeowners' backyards presents a divergence from typical current land use practice, which separates residential living from heavy industrial activity, and the gas leases allocate rights and risks between the homeowner and gas company-lessee in uncharacteristic ways. Also, New York's compulsory integration law can force neighbors who do not want to lease their land into a drilling pool, which can affect their liability and mortgages as well.

The Marcellus Shale Region

The Marcellus Shale region, located across New York's Southern Tier, represents a portion of one of America's largest underground shale formations, with accessibility to gas deposits ranging from ground surface to more than a mile deep. The decade-old combined use of horizontal drilling and high-volume hydraulic fracturing is the current proposed means of extracting the trapped shale gas. Horizontal drilling, which dates back to 1929, became widely used in the 1980s, with the current technology providing lateral access to mile-deep shale in multiple directions from a single well pad.

To envision what this looks like, imagine one well pad that accommodates eight or more vertical wells with each well engineered to extend a mile or more in depth then turn and drill horizontally in its own direction, up to a mile through shale across residential properties and farms owned by a cluster of neighboring residents. High-volume hydraulic fracturing, first introduced by Halliburton in 1949, mixes millions of gallons of water with sand, brine and any of a number of undisclosed chemicals, which are injected into the well bore at pressure sufficient to rupture open the formation, prop open the mile-deep shale fractures with sand and release the trapped gas back into the well. Fracking-produced wastewater, with concentrated levels of these toxic chemicals, drilling mud, bore clippings and naturally occurring radioactive material, such as uranium, radium 226 and radon, is released from the well into mud pits and holding tanks, then trucked out for waste treatment or reused. Reuse of frack fluid, currently the favored practice because it spares the finite water supply, concentrates the waste toxicity. The Environmental Protection Agency estimates that 20%–40% of the fracking wastewater stays underground. The Marcellus Shale sits amid an intricate network of underground aquifers that supply drinking water in New York and surrounding states via municipal water supplies, private wells and springs. Shallow private wells constitute the primary source of drinking water for the upstate New York residences and farms where fracking for shale gas would take place, posing a cumulative threat to the state's complex matrix of aquifers that source our groundwater.

The Risks

The use of fracking expanded in 2005 when Congress exempted it through statutory amendments from complying with decades-old federal environmental laws governing safe drinking water and clean air. (This exemption is now commonly known as the Halliburton loophole.) Also in 2005, New York changed its compulsory integration law to pave the way for fracking.

According to the 2010 Form 10-Ks of Chesapeake Energy and Range Resources (both doing business in the Marcellus Shale region), natural gas operations are subject to many risks, including well blow-outs, craterings, explosions, pipe failures, fires, uncontrollable flows of natural gas or well fluids, formations with abnormal pressures and other environmental hazards and risks. Drilling operations, according to Chesapeake, involve risks from high pressure and mechanical difficulties such as stuck pipes, collapsed casings and separated cables. If any of these hazards occur it can result in injury or loss of life, severe damage or destruction of property, natural resources and equipment, pollution or other environmental damage and clean-up responsibilities,[1] all in the homeowner's backyard.

American culture traditionally favors land use that keeps heavy industrial activity out of residential neighborhoods. The reasons range from safety to aesthetics. A home represents a family's most valuable asset, financially and otherwise. In legal terms, homeownership or "fee simple absolute title" means a bundle of rights encompassing the air space above and the ground below the land surface. It entitles homeowners to build up and out, pledge the house and land as collateral for a mortgage loan, and lease or sell the property. Part of a home's purchase price pays for this bundle of rights. Another bundle of rights attributable to homeownership

CONTINUED ON PAGE 14

Continued from Page 12

consists of the actual roof over one's head; clean, running water; and access to utilities. A third bundle of rights is attributable to the intangibles that make a house a home, such as peaceful sanctuary, fresh air, and a safe, secure haven for budding children. Residential fracking challenges all of these attributes of home ownership.

Shifting Risk

Gas leases provide the bundle of rights from which gas companies generate financing and operate gas wells. Profitable gas *extraction* benefits from broad rights to access, extract, store and transport the gas, on the company's timetable. Gas leases contain these rights. Profitable gas *investment* benefits from latitude on timing of gas extraction and the latitude not to extract gas at all. Gas leases contain these rights too. The gas company has the sole discretion to drill, or not to drill. Leases provide the currency in trade. The longer the lease term, the more latitude a leaseholder has to manage market fluctuations. With its broad gas storage rights, a leaseholder can store gas from other sources, on-site and wait for the demand curve to peak before executing the most favorable transactions. In August 2011, the U.S. Geologic Survey estimated reserves of "technically recoverable" shale in the Marcellus Shale play at 84 trillion cubic feet, reflecting a significant reduction from DEC's long-standing website estimate of between 168 trillion and 516 trillion cubic feet. Shale gas projections have an inherent value, separate and apart from the extracted gas. People invest capital based on the anticipated reserves. Time will tell how the new estimates change if and where gas companies actually drill in New York. Some regions may be too difficult or expensive to access; others will be off-limits by law. The terms of the gas leases nevertheless entitle the gas lessee to maintain the leasehold, which can facilitate investor activity. The Form 10-K appended to the 2010 Chesapeake Energy Annual Report states,

> Recognizing that better horizontal drilling and completion technologies, when applied to new unconventional plays, would likely create a unique opportunity to capture decades worth of drilling opportunities, we embarked on an aggressive lease acquisition program, which we have referred to as the "gas shale land grab" of 2006 through 2008 and the "unconventional oil land grab" of 2009 and 2010. We believed that the winner of these land grabs would enjoy competitive advantages for decades to come as other companies would be locked out of the best new unconventional resource plays in the U.S. We

Hydro-fracking drill sites, feeder pipelines, and access roads and gravel banks for road building (Dimock, PA)

> believe that we have executed our land acquisition strategy with particular distinction. At December 31, 2010, we held approximately 13.2 million net acres of onshore leasehold in the U.S. and have identified approximately 38,000 drilling opportunities on this leasehold. We believe this extensive backlog of drilling, more than ten years worth at current drilling levels, provides unmistakable evidence of our future growth capabilities.[2]

The broad bundle of rights granted by gas leases enables gas companies to raise capital in the millions or billions of dollars once the up-front per-acre signing bonus is paid to the homeowner. This is beneficial for the drilling investment itself and for maintaining the company's competitive advantage. On the other hand, the effect of the lease encumbering the homeowner's residence can have repercussions for mortgage financing, as will be discussed below.

Getting the Gas

Drilling companies derive the right to drill underneath residential (and non-residential) property in three ways:

- deed to the subsurface rights below the fee estate (a practice not typically used in New York);
- lease agreement with the fee owner; and
- compulsory integration, which involves government action that forces a property owner who wishes no drilling activity below its property into a drilling pool if the lessee otherwise has control of a statutorily prescribed percentage of land (in New York it is 60%).

A drilling application submitted to DEC must show the area (up to 640 aces), known as a spacing unit, assigned to the well. The spacing unit becomes officially established when DEC issues the well permit.

Deed to Subsurface Rights

A deed to the subsurface or mineral rights splits the fee estate between the surface property and the subsurface property, with separate deeds for each estate. Subsurface deeds are common in Western states where drilling is an established practice; it gives the deed holder the full range of rights to the subsurface. As with the surface deed, it is considered a real property interest and is also recorded in the land records against the section, block and lot for the surface property. The rights do not extend above the subsurface and should not, as a legal matter, interfere with the rights of the surface owner. As a practical matter, because of drilling lifecycle hazards, the surface owner may sacrifice some of the attributes of home ownership discussed in this article.

Standard Lease Agreement With Fee Owner

The standard space lease, between a building owner (landlord or lessor) and a tenant (or lessee) grants the right to occupy a specified space in the building for a finite time, in exchange for an agreed upon rent payable in regular installments. If the lease contains a percentage rent (a commercial lease concept based upon tenant revenue), it includes a formula for calculating the percentage rent and gives the landlord the right to inspect the tenant's books to verify that the landlord receives the agreed upon percentage. Except for the space leased to the tenant, the landlord retains all rights of ownership. When the lease expires, the tenant moves out, or the tenancy converts to a month-to-month tenancy. No duration of month-to-month holding over on the tenant's part converts the month-to-month arrangement into a lease for years. To end the relationship, either the landlord or tenant can give 30 days' written notice to the other.[3] To extend beyond the month-to-month relationship, the parties must enter into a new written lease.

In contrast, gas leases function more like a deed with a homeowner indemnity than a space lease – revealed by an assessment of the cumulative impact of the broad bundle of rights granted to the gas company-lessee and the corresponding bundle of rights relinquished by the homeowner. Standard pre-printed gas leases presented to New York homeowners by landmen and signed, *without negotiation*, represent the typical practice (until recently) in our state, and will be used here to illustrate the impact this has on the of rights and responsibilities of the homeowner. Depending upon the DEC's ultimate regulatory framework, homeowners who negotiate gas leases can expect similar impacts given the industrial sized risks involved.

The Use

A gas lease grants the right to extract the gas and a litany of related gas-constituents; it also grants the right to explore, develop, produce, measure and market for production from the leasehold and adjoining lands using methods and techniques which are not restricted to current technology.

The Space

In a standard gas lease, the physical leased space consists of the subsurface area within the property boundaries and undesignated portions of the surface lands

> to set up and store drilling equipment; create a surface right of way to use or install roads, electric power and telephone facilities, construct underground pipelines and so-called "appurtenant facilities," including data acquisition, compression and collection facilities for use in the production and transportation of gas products to, from and across the leased property; and store any kind of gas underground, regardless of the source, including the injecting of gas, protecting and removing gas, among other things.

The lessee's expansive, undesignated, reserved surface rights can result in acres going to support the operation, jeopardize a home mortgage and eliminate the homeowner's ability to build on the surface in areas the lessee determines would interfere with drilling operations. Without limiting the location, size and type of pipeline, the homeowner leaves open the chance of a high-pressure gas line running under the property.

The Term

The lease runs for a five-year primary term (a portion contain a five-year renewal term), which in a standard lease the lessee can unilaterally transform into an indefinite, extended term, without signing a new lease, for any of the following reasons:

> exploration anywhere in the spacing unit, or a well in the spacing unit is deemed "capable of production," or gas from the spacing unit is produced, or the spacing unit is used for underground gas storage, or the prescribed payments are made.

The term "capable of production" is defined broadly enough to include off-site preparatory work. Regardless of the stated lease term, once a well is "capable of production," the rights continue for as long as operations continue, possibly decades.

The Rent

Homeowners receive a signing bonus ranging from dollars to thousands of dollars per acre of leased land. This single payment can potentially tie up the property, indefinitely. References in so-called "paid-up" leases (common in New York) to other potential additional payments (except for the royalty payment) are deemed satisfied by the signing bonus. Absent negotiation, royalties consist of a percentage (typically 1/8 or 12.5%), net of production-related expenses and any loss in gas volume that reduces the revenue received. Late payments or failure to make a royalty payment can "never" result in an automatic lease termination. Homeowners share the royalty with other members of the drilling pool on a pro-rated basis. This is known as correlative rights. The larger the drilling pool, the smaller the royalty. Unlike the percentage rent provision in a commercial lease, a gas lease contains no detailed formula for calculating the net royalty payment, no pro-rata share corollary to calculate the relative percent the homeowner bears to the pool of all other property owners entitled to divide the royalty pie and no right to review the lessee's books and records.

Assignment

Space leases require a tenant to obtain landlord consent for a third-party lease assignment. In contrast, a gas lessee can sell and assign to or finance the gas lease (or any interest) with any party it selects, without providing notice to the homeowner. This continuing right deprives homeowners of control over confirming consistency between the initial lease and the terms of the assigned document – who ends up with the lease, who gets hired and allowed onto the family's private property and the quality of the drilling activity performed in their backyard. As the record title holder, homeowners remain potentially liable for the activity that occurs on their property, if it is not effectively delegated.

Hazardous Activity/Hazardous Substances

Space leases expressly prohibit hazardous activity and the presence or storage of hazardous substances on the property, such as chemicals and flammable or toxic petroleum products. Gas leases permit both the drilling activity and the use of hazardous substances and flammable products, such as the methane gas itself. Gas leases reserve the right to store gas of any kind, indefinitely, underground, regardless of the source, which can create additional risk to the homeowner's personal safety and adversely impact, as will be discussed, a homeowner's responsibility to its lender.

Easements

Gas leases contain grants of easements, which is not typical for a lease. This grant includes the lessee's right, even after surrendering the leasehold, to "reasonable and convenient easements" for the existing wells, pipelines, pole-lines, roadways and other facilities on the surrendered lands. Assuming its enforceability, a driller can surrender a lease and still assert a range of potentially perpetual surface and subsurface rights as superior to those of the fee owner without any further payment and without the obligation for repair, maintenance or resulting damage. However, unless the actual lease containing the easement grant gets recorded against the residential property in the public records, which, apparently is often not the case, the lessee has no assurance the easements will be protected. Even so, leases reserving potentially perpetual, undesignated easements for roads and pipelines raise expensive, long-term liability concerns for homeowners, their lenders and, potentially, fellow taxpayers.

Insurance/Indemnification-Risk Allocation to Homeowner

Space leases typically require the tenant to post a security deposit to cover late rent or property damage. Gas leases do not contain a similar provision. Space leases also require tenants to purchase general liability insurance naming the landlord as an additional named insured with an indemnity covering costs for uninsured damage and other costs occasioned by the tenant and its invitees. Risks associated with typical leasehold property damage belong to tenants since they control the space. Drilling leases typically omit these points. Absent negotiation, gas leases contain no insurance and no indemnification. Even assuming the existence of an indemnification, federal protection via the Halliburton loophole can provide cover. Unless anticipated DEC rules change, New York intends to require disclosure only of fracking chemicals by gas companies. While this represents a step in the right direction, it also gives companies an "out" by merely requiring them to disclose which chemicals they use. It does not necessarily make companies liable for the damage those chemicals cause. Eliminating the right to frack with toxic and carcinogenic chemicals by reinstating the laws amended by the Halliburton loophole would eliminate the shift of financial responsibility away from the gas company as it relates to this aspect of the gas drilling lifecycle. Regulating use of benign fracking additives that can boost risk would be useful as well. For example, radioactivity, a known danger at elevated levels, poses greater risks when it interacts with frack-fluid additives that contain calcium.[4] By not restoring liability to the companies that control drilling operations and coupling it with economic reasons to prevent casualties, a homeowner will have to first experience the property damage or personal injury, then successfully arbitrate or litigate against the gas lessee for reimbursement and remediation, a burden most homeowners can't afford or mentally handle. Even assuming a homeowner's fortitude to sue, focus on damages and remediation misses the fact that residential fracking introduces irreparable risks to homes and the families that live there.

Gas Lease Mortgages

New York law[5] recognizes minerals (before extraction) as real property. In May 2011, a Chesapeake Energy subsidiary, Chesapeake Appalachia, pledged mineral rights on over 1,000 Bradford County, Pennsylvania, mineral leases as collateral for a $5 billion line of credit mortgage loan with Union Bank of California, while in July, 2011, another Chesapeake Energy subsidiary, Appalachia Midstream Services, pledged pipeline rights-of-way on over 2,000 Bradford County properties to access an unspecified line of credit mortgage loan with Wells Fargo. Although the mortgage was properly recorded in the county recorder's office against the section, block and lot of the fee/surface property, the news of a $5 billion loan linked to their property surprised mortgage-seeking homeowners. Legally, Chesapeake's mortgaged interests are distinguishable from the surface owner's, so that shouldn't interfere with a home loan, but residential fracking might. It is worth noting that Wells Fargo, one of Chesapeake's lenders, stands among national lenders that do not grant mortgage loans to homeowners with gas leases.

Homeowner Predicament

Despite DEC website warnings about the potential adverse impacts of gas leases,[6] the government plays no role in the lease process. Contract law favors the rights of private parties to enter into arm's-length transactions without government intervention. Yet, when large numbers of complaining upstate homeowners recount consistent practices employed by the landmen that resulted in pre-printed standard gas leases signed without negotiation, it would be appropriate to involve the New York Attorney General, to examine the facts. In consumer protection contexts, the government (on its own or as a result of litigation) has seen fit to offer protection. Homeowners who signed gas leases do not constitute consumers *per se*, but the analogy supports Attorney General involvement to restore to the landowner the bulk of rights attributable to fee ownership and, by extension, the property's value. Paradoxically, for example, gas leases reciting "good faith negotiations" between the parties lock in homeowners with lessee-favored termination clauses. Unlike space leases that terminate on a stated expiration date, gas leases give lessees latitude to extend a stated lease term, indefinitely, by asserting it is "capable of production" or "paid up" or otherwise, subject to "force majeure," asserting New York's de facto drilling moratorium as the event beyond their control. "Force majeure" litigation is now on the dockets across New York's Southern Tier.

> Assuming its enforceability, a driller can surrender a lease and still assert a range of potentially perpetual surface and subsurface rights as superior to those of the fee owner.

Municipal Backlash; Indefinite Leases

Municipalities within the 28 counties sitting on top of New York's Marcellus Shale differ on the benefits of fracking. Municipalities in favor of fracking focus on local economic growth.[7] Municipalities opposing fracking take into consideration competing established economies, such as agriculture and tourism. By asserting home rule, municipalities have enacted moratoria, amended master plans or codes to prohibit heavy industry, including gas drilling, and banned drilling on public land or altogether.[8] In September 2011, Anschutz Exploration Corp. filed a lawsuit against the Town of Dryden asserting the supremacy of the state to issue a drilling permit over the right of the municipality to amend its zoning law to prohibit drilling or storage of natural gas.[9] The outcome of this case will have significant ripple effects throughout the state.

When municipalities favor fracking, homeowners with questions or concerns are on their own. Residents who do not wish to renew and residents who are committed to leasing but want to renegotiate terms when their lease expires, as with an expired space lease, are meeting some resistance from the gas companies, who are using General Obligations Law § 15-304 (GOL) to reinstate expired leases. That statute states that before a recorded drilling lease expires by its own terms, the owner "may" serve a cancellation notice to the lessee triggering a lessee right to file an affidavit affirming that the lease is in full force and effect. Then, more papers get filed to confirm and preserve that right. Unlike the space lease which terminates on a certain date, GOL § 15-304 gives drillers a second chance which (so long as the driller has recorded the full lease) can tie an unwilling homeowner indefinitely to a gas lease the homeowner no longer wants. Homeowners electing not to give the statutory notice live in limbo, uncertain as to where they stand.

If a lessee decides to drill for gas but lacks the total acreage it needs, the lease provides the statutorily required leverage to form a so-called "spacing unit" by forcing unwilling property owners surrounding the voluntarily leased property into a drilling pool, a process called compulsory integration.

Compulsory Integration

Involuntary compulsory integration represents the most controversial method drilling companies use to access gas. Compulsory integration (or forced pooling) exists by statute in 39 states.[10] It replaced the common law rule of "capture" which allowed Person A to legitimately collect and own gas from Person B's supply if it flowed into Person A's well. To capture gas before a neighbor did, surface wells proliferated in close proximity to one another, causing the overall gas pressure to drop and making gas extraction inefficient for all involved. It also blighted the surface lands. Today, Environmental Conservation Law § 23-0901 (ECL) deputizes a driller, subject to a DEC hearing, to force an unwilling property owner into a spacing unit if the drilling company otherwise controls 60% or more of the acreage in the spacing unit either by lease, deed or voluntary integration,[11] which itself involves lease swaps among leaseholders to form the spacing unit.

Proponents assert that forced pooling makes the drilling infrastructure investment more cost efficient by maximizing access to gas while also maintaining the surface landscape and fairly compensating the noncontributing "integrated" homeowner with a shared net 12.5% royalty. Opponents consider it a form of eminent domain. The constitutionality of forced pooling under a predecessor statute was confirmed in dicta by the New York Court of Appeals in *Sylvania v. Kilborne*, itself citing the United States Supreme Court, which held that "a state has constitutional power to regulate production of oil and gas so as to prevent waste and to secure equitable apportionment among landholders of migratory gas and oil underlying their land fairly distributing among them the costs of production and the apportionment."[12]

Yet, the updated statute's effect eliminates the homeowner's right to control the homestead, creates financial risk for the driller's acts by not expressly holding the driller responsible, and jeopardizes access to a mortgage or the ability to sell the property. The ECL permits objection by a homeowner to the forced pooling within prescribed guidelines (having a scientific basis) none of which includes asserting a conflict with other (existing or intended) contract obligations, such as a mortgage. ECL § 23-0503, empowers DEC to schedule an adjudicatory hearing if it determines that "substantial and significant issues have been raised in a timely manner." Whether a driller's rights of involuntary compulsory integration come after, or trump, sanctity of contract between a homeowner and its mortgage lender needs clarification.

$6.7 Trillion Secondary Mortgage Market

The Federal Housing Finance Agency (FHFA) was created in July 2008 on the heels of the mortgage crisis, to provide supervision, regulation and housing mission oversight of Fannie Mae and Freddie Mac and the Federal Home Loan Banks (FHLB) and to support a stable and liquid mortgage market. As of September 2010, according to FHFA, the combined debt obligations of these government-sponsored entities totaled $6.7 trillion, with Fannie Mae and Freddie Mac purchasing or guarantying 65% of new mortgage originations. FHFA, as conservator of the secondary mortgage market, has a fiduciary responsibility to promote the soundness and safety of the secondary mortgage market. It is in FHFA's interest to limit mortgage defaults.

Most American homeowners hold a mortgage loan and 90% of all residential mortgage loans are sold into the secondary mortgage market (exceptions exist for million dollar homes which do not get sold by the lending bank). It is assumed that most upstate New Yorkers who signed gas leases have a mortgage, will want one in the future or want that right for a future purchaser. Mortgage lending favors low-risk activity on its mortgaged properties. Fannie Mae, Freddie Mac and the FHLB establish lending guidelines for appraisers and underwriters that dictate whether a home is a worthy investment. This helps to facilitate their combined mission to attract investors, such as pension funds, who provide liquidity in the secondary mortgage market. Primary lenders, in turn, rely on their borrowers' compliance with mortgage covenants mirroring these lending guidelines for the life of the loan.

Assuming 10% of the existing secondary mortgage market portfolio includes residential properties subject to drilling activity, this amounts to $670 billion of secondary mortgage market debt; assuming the number is only 1%, this amounts to $67 billion. Eventually, gas drilling may span up to 34 of the lower 48 states, including densely populated cities such as Fort Worth, Texas. If so, a substantial portion of the secondary residential mortgage market portfolio may be at risk from residential fracking.

Loan Underwriting Reveals Collateral Flaws With Residential Fracking

Home Appraisal

All mortgage loans require a property appraisal, title insurance covering the lender or its assignees and homeowner's insurance. Home and land appraisals are based upon like-properties, similarly situated, and are used to determine market value, the loan-to-value ratio and the maximum loan amount. Reliable appraisals of properties subject to gas leases are difficult to obtain and potentially prohibitively expensive; it would require a comprehensive title search of area properties encumbered by gas leases. Often a memorandum of the gas lease and not the lease itself is recorded, and a read-through of the entire gas lease is required to make a fair comparison between lease-encumbered properties. Underwriters need to evaluate the risks and know who pays for them; without the full lease in hand, they can't make such an evaluation.[13]

Evaluating the driller's identity can be another underwriting challenge; with unrecorded lease assignments, lenders don't know who is performing the heavy industrial activity on their residential collateral. Federal Housing Authority guidelines for federally insured mortgage loans, which make up a portion of the secondary mortgage market debt, require that a site be rejected "if property is subject to hazards, environmental contaminants, noxious odors, offensive sights or excessive noise to the point of endangering the physical improvements or affecting the livability of the property, its marketability or the health and safety of its occupants,"[14] all of which are potential characteristics of residential fracking.

Flare at hydro-fracking gas drilling operations near Sopertown, Columbia Township, PA

Lender's Title Insurance

A lender's title policy insures the mortgage lien, as of the date of the policy (up to the loan amount), against loss or damage if title is vested in someone other than the homeowner. Gas leases signed after the policy date are not covered by the policy. Gas leases in effect when the policy is issued will be listed as a title exception. Coverage won't include the gas lease or any claims arising out of it. Title endorsements don't eliminate this exception to coverage. Underwriters consider these exceptions a red flag, sufficient to jeopardize the loan. Lenders financing properties subject to compulsory integration won't discover the title encumbrance from a title search because ECL § 23-0901 makes no apparent reference to recording the DEC determination of compulsory integration in the land records. New York title policies expressly exclude from coverage loss or claims relating to any permit regulating land use. It remains unclear whether a gas drilling permit which includes forced pooled property would fall within this exclusion. Either the Legislature will clarify the statute or the ambiguity will be a source of future litigation. Rating agencies and secondary mortgage market investors should be apprised if a loan portfolio which they have rated or in which they have invested, as the case may be, contains gas leases or forced pooled properties, since both add new risk.

Homeowner's Insurance

All residential mortgage lenders require homeowner's insurance from their borrowers. Even the most comprehensive homeowner's coverage, known as "broad risk form" or "special form" insurance excludes the types of property damage associated with the drilling lifecycle, such as air pollution, well-water contamination, earth movement and other risky commercial activity performed on residential property.

The Mortgage: No Hazardous Activity/Substances, No Gas/Gas Storage, No Radioactive Material

Residential mortgages prohibit borrowers from committing waste, damage or destruction or causing substantial change to the mortgaged property or allowing a third party to do so. This includes operations for gas drilling. Standard residential mortgages prohibit borrowers from causing or permitting the presence, use, disposal, storage, or release of any "hazardous substances" on, under or about the mortgaged property. In mortgages, "hazardous substances" include gasoline, kerosene, other flammable or toxic petroleum products, volatile solvents, toxic pesticides and herbicides, materials containing asbestos or formaldehyde and radioactive materials. Borrowers are also prohibited from allowing anyone to do anything affecting the mortgaged property that violates any "environmental law." "Environmental law" means federal, state and local law that relates to health, safety and environmental protection. Mortgages obligate borrowers to give lenders written notice of any release, or threat of release, of any hazardous substances and any condition involving a hazardous substance which adversely affects the value of the mortgaged property.

Mortgages prohibit the activities gas leases permit to preserve the property's marketability. For example, shallow water wells and springs, typical in the northeast, represent the home's drinking water source; they become susceptible to contamination from drill site spills and leaks or flooding from frack wastewater. Frack fluid chemicals, pollutants and naturally occurring radioactivity in the waste have been reported to far exceed levels considered safe for drinking water. A contaminated well cannot be easily remediated, if at all. A home or a farm without on-site potable water may not sell. Migrating methane gas from the drilling process risks explosions both inside and outside of the home.

Because water and migrating methane gas each defy boundaries, following minimal underwriting setback requirements between the home and the drill site may prove inadequate to protect a water well from irreparable contamination or a home from explosion. A bank can consider these factors when approving a mortgage loan, and once financed, when declaring a mortgage loan in default.

Homeowner and Lender Vulnerability

The 2010 Form 10-K issued by Chesapeake states:

> There is inherent risk of incurring significant environmental costs and liabilities in our operation due to our generation, handling and disposal of materials, including waste and petroleum hydrocarbons. We may incur joint and several liability, strict liability under applicable U.S. federal and state environmental laws in connection with releases of petroleum hydrocarbons and other hazardous substances at, on, under or from our leasehold or owned properties, some of which have been used for natural gas and oil exploration and production activities for a number of years, often by third parties not under our control. For our non-operated properties, we are dependent upon the operator for operational and regulatory compliance. While we maintain insurance against some, but not all risks described above, our insurance may not be adequate to cover casualty losses or liabilities, and our insurance does not cover penalties or fines that may be assessed by a governmental authority. Also, in the future we may not be able to obtain insurance at premium levels that justify the purchase.[15]

In the Form 10-K appended to its 2010 Annual Report, Range Resources adds:

> We have experienced substantial increases in premiums, especially in areas affected by hurricanes and tropical storms. Insurers have imposed revised limits affecting how much the insurer will pay on actual storm claims plus the cost to re-drill wells where substantial damage has been incurred. Insurers are also requiring us to retain larger deductibles and reducing the scope of what insurable losses will include.[16]

Signing a gas lease without lender consent is likely to constitute a mortgage default. At any time before or after the drilling begins, a lender can demand the borrower to either terminate the lease or pay off the loan. Since the gas companies have pledged the gas leases as collateral for loans or brought in investors based upon the potential income the gas lease can produce, facilitating a lease termination may require protracted litigation. Further, it is not likely that most homeowner-borrowers will have the ready cash to repay the loan. This places the lender in an untenable position.

Residential fracking, perpetual unfunded easements and long-term gas storage beneath mortgaged homes create a cumulative threat to the repayment of mortgage loans tranched in secondary mortgage market portfolios. Homeowners suffering irreparable property damage, such as well water contamination, structural damage or casualty from a gas explosion, won't have coverage from homeowner's insurance and may have no recourse against the gas company holding the lease. This is so even if homeowners sue and succeed in court since the gas companies' own disclosure statements state they are underinsured. New York State Comptroller Thomas Di Napoli has proposed an up-front gas company–funded emergency fund to remediate those emergencies that can be fixed. As of yet, the gas industry, the Governor, the state Senate and the Assembly have not offered support for such a fund. The Form 10-K for Chesapeake Energy and Range Resources, for example, cite the risks attendant to gas drilling. They do not indicate the source of funding to support the numerous risks from the drilling activity. Unless this source of funding can be identified, the secondary mortgage market, as holder of 90% of the nation's home mortgages, may be left with the clean-up bill. Ultimately, financial responsibility could fall on the taxpayers.

New York homeowners who signed gas leases without the facts about this unconventional drilling claim they did not know the risks involved. These homeowners did not know that they violated their mortgage by entering into the gas lease or have potentially no insurance coverage in case of a drilling loss. Impacted homeowners can write to New York's Attorney General to (1) document their experience; (2) request a reprieve from a mortgage loan default; and (3) institute a "no gas drilling" policy until it is determined that the mortgaged collateral won't be at risk from the driller's plans. To achieve this, gas leases should be revised to modify or omit the risky clauses, such as gas storage, surface rights and undesignated, unfunded easements. In the alternative, the gas leases can be terminated. Homeowners need help before gas permitting begins, in order to spare the homestead and the home mortgage market too.

New Mortgages for Homeowners With Gas Leases and New Construction[18]

Even before the drilling commences, many upstate New York homeowners with gas leases cannot obtain mortgages. Bank of America, Wells Fargo, Provident Funding, GMAC, FNCB, Fidelity and First Liberty, First Place Bank, Solvay Bank, Tompkins Trust Company, CFCU Community Credit Union and others[17] are either imposing large buffer zones (too large for many borrowers) around the home as a condition to the loan or not granting a mortgage at all.

Once lenders connect the "no hazardous activity" clause in the mortgage with the mounting uptick in uninsurable events from residential fracking, this policy can be expected to expand. Originating lenders with gas industry business relationships may decide to assume the risk, make mortgage loans to homeowners with gas leases and keep the non-conforming loans in their own loan portfolio. However, there is a limit to what an originating bank can keep in its own loan portfolio. Eventually, cash infusions from the secondary mortgage market will become a necessity; and secondary mortgage market lending guidelines will be a reality. If homeowners with gas leases can't mortgage their property, they probably can't sell their property either (this assumes the purchaser will need mortgage financing to fund the purchase). The inability to sell one's home may represent the most pervasive adverse impact of residential fracking.

Real estate developers and contractors rely on construction financing and financeable homeowners to stimulate construction starts. New York's upstate construction future depends upon the ability to sell what one builds. Washington County, Pennsylvania, for example, reported improved home sales servicing the gas industry in 2010, but apparently not of properties built on drill sites.

The Conundrum Revisited

The energy and housing sectors both rely on investor dollars to fund their future. Pension funds and other money sources that still invest in housing but now consider natural gas the preferred investment raise a potential paradox: Will individuals' retirement funds expand as their homeownership rights fade away? The conundrum to consider: how can a nation with $6.7 trillion in residential secondary mortgage market debt that measures economic recovery by construction starts and new mortgage loans also accommodate risky and underinsured residential fracking involving a still-unknown quantity of this residential mortgage collateral? Before New York embraces fracking as a new frontier, it would be wise for our corporate and government leaders focused on the vitality of our housing and energy sectors to address and resolve this conundrum. ■

1. Chesapeake Energy Corp., *10-K: Annual Report Pursuant to Section 13 and 15(d)* 27 (2011) (Chesapeake Energy 10-K: Annual Report); Range Resources, Uncovering Tomorrow's Energy: 2010 Annual Report 13 (2010) (Range Resources 2010 Annual Report).

2. Chesapeake Energy 10-K: Annual Report 4.

3. N.Y. Real Property Law § 232-b.

4. Mark Greenblatt, *Texas drinking water makes pipes and plumbing radioactive*, KHOU.com (May 18, 2011) at http://www.khou.com/home/-I-Team-Texas-drinking-water-makes-pipes-and-plumbing-radioactive-1221408194.html.

5. N.Y. Jurisprudence, Mines § 7; *see* N.Y. Uniform Commercial Code § 9-102.

6. Div. of Mineral Res., A Landowner's Guide to Oil & Gas Leasing, Dep't of Envtl. Conservation (2008), http://www.dec.gov/docs/materials_minerals_pdf/brochure.pdf.

7. Cornell University Professor Susan Christopherson cautions against boom-bust impacts. *See* Susan Christopherson, *Marcellus Gas Drilling*, Cornell Univ. 2011, http://www.greenchoices.cornell.edu/development/marcellus.

8. Joe Hoff, *Moratoria, Bans, Resolutions Opposed to Hydrofracking: A Local and Global Sampling*, R-Cause (Sept. 20, 2011) www.r-cause.net/bans-moratoria.

9. *Anschutz Exploration Corp. v. Town of Dryden & Town of Dryden Town Bd.*, Supreme Court, Tompkins County; N.Y. Environmental Conservation Law § 23-0303(2) (ECL).

10. ECL § 23-0901; Marie C. Baca, *State Law Can Compel Landowners to Accept Gas and Oil Drilling*, Pro Publica (May 19, 2011), http://projects.propublica.org/tables/forced-pooling.

11. ECL § 23-0901.

12. *Sylvania Corp. v. Kilborne*, 28 N.Y.2d 427 (1971) (quoting *Hunter Co. v. McHugh*, 320 U.S. 222 (1943)).

13. *See* Greg May, VP, residential lending, *Gas and Oil Leases Impact on Residential Lending*,Tompkins Trust Co., White Paper,(Mar. 24, 2011), http://www.tompkins-co.org/tccog/Gas_Drilling/Focus_Groups/Assessment%20Documents/White%20Paper.pdf

14. Dep't of Hous. & Urban Dev., *Valuation Analysis for Single Family One-to-Four Unit Dwellings* (4150.2) (2011).

15. Chesapeake Energy 10-K: Annual Report 29, *supra* note 1.

16. Range Resources 2010 Annual Report 13, *supra* note 1.

17. Greg May, VP, residential lending Tompkins County Trust, telephonic update of white paper, *supra* note 13, and Joseph Heath, Esq.

18. *See* Ian Urbina, *Rush to Drill for Natural Gas Creates Conflicts With Mortgages*, N.Y. Times, Oct. 20, 2011, p. 1. Mr. Urbina's article used Elisabeth Radow's August 11, 2011, letter to Freddie Mac and the federal agency that oversees Freddie Mac, warning the agencies about potential conflicts in the mortgage market, as a documentary source for his piece. The letter may be viewed at http://www.nytimes.com/interactive/us/drilling-down-documents-8.html#document/p12/a33448.

Testimony Submitted to the Delaware River Basin Commission. September 11, 2013
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My name is Elisabeth Radow. I am grateful for the opportunity to submit testimony to Executive Director Carol Collier on behalf of the Delaware River Basin Commission (DRBC). I am a lifelong New Yorker, the managing attorney of Radow Law PLLC and a mother. I chair the Committee on Energy Agriculture and the Environment for the League of Women Voters of New York. The League of Women Voters of New York, New Jersey, Pennsylvania and Delaware have submitted joint testimony to the DRBC previously. Today I submit testimony on my own behalf. My work has been sourced and cited in national publications such as the New York Times, Huffington Post and MORE Magazine and has been published in several law journals. My law practice includes real estate development, real estate finance and increasingly, the effects of gas drilling operations on property ownership.

The basis for my testimony today comes from my research identifying the impacts of unconventional shale gas drilling on property value, risk allocation between the gas drilling company and the homeowner and the increasing inability of homeowners to obtain and maintain a mortgage and homeowners insurance in the presence of gas drilling.

The majestic Delaware River provides drinking water to 15 million people. The responsibility of the DRBC as stewards of this water supply for so many Americans is an awesome one. What I wish to stress is that how the DRBC discharges that obligation will also profoundly and permanently affect the ability of all citizens living in the Delaware River Basin states to have a safe place to call home. Across America, in shale rich-states, property ownership is being revolutionized by the proliferation of the multi-step, heavy industrial drilling operations on the land surface and subsurface of private homes and farms.

Home represents a family's most valuable asset, financially, spiritually and otherwise. From a property value standpoint, think of home as a bundle of rights: the right to construct, obtain a mortgage loan, lease and sell the property; the right to clean running water, electricity, a roof over ones' head; a safe place to raise children, crops or cattle, or all of the above. Americans pay for these rights when we purchase our property, and expect these rights to continue until we sell. We want the property value to increase. So does the state. Our tax base depends upon it. Now there is mounting evidence that banks will not extend mortgage loans and insurance companies will not renew homeowners' insurance policies for homeowners with gas leases and in some cases their neighbors without gas leases. These trends have potentially grave implications for community vitality and personal wealth in areas with fracking and must be examined and clearly understood by policy makers such as the DRBC.

What about unconventional shale gas drilling is producing these threats to homeowner and community wealth and security? Up to now, home has represented the one place people have control of the destiny of their economic assets. Standard gas leases grab homeowner control of property use by giving the gas company the right to establish surface operations, create perpetual, unfunded, road and utility easements, and the right to store gas underground from any source. The standard leases do not require the gas company to fund or perform the maintenance, repair and ultimate restoration of the easements and other surface uses. So that expense stays with the property owner. They give the gas company the free right to sell the lease or take in investors without homeowner consent. This means the homeowner has no control over who comes onto their private property to drill, or the quality of the work they perform.

Gas drilling introduces hazardous activity and hazardous substances, practices which are expressly prohibited by standard mortgages. Consider that while the mortgage lender expects the home to retain its value for the 30 year life of the loan, a gas driller, and by extension its investors, on that very same property, cares more about extracting the most gas for the least expense and least regulation.

Publicly traded gas company 10-K's filed with the Securities and Exchange Commission characterize the drilling lifecycle as subject to many risks. The list of hazards includes: blow-outs, explosions, pipe failures and uncontrollable flows of natural gas, or well fluids. The same public disclosure documents report that the gas drillers are not fully insured for their operations and fail to state that they have available cash reserves to pay for uninsured casualties, property damage and environmental pollution resulting from their operations.

Well-water contamination can occur at one or more points in the drilling process, including from leaks, spills and cracked well casings and the inappropriate road spreading, disposal and treatment of the toxic, radioactive hydraulic fracturing waste. A recently released EPA power point presentation of its Dimock PA water analysis reflects an apparent nexus between gas drilling operations and contaminated water. http://desmogblog.com/2013/08/05/censored-epa-pennsylvania-fracking-water-contamination-presentation-published-first-time. As is currently happening, properties without potable water will lose substantial value and farms without potable water will fail causing personal economic catastrophe. If this impact continues, it could have major ripple effects on the tax base.

While water contamination from gas drilling operations is the most discussed and most obvious adverse impact to a home's use and value, structural damage to the residence represents another cause for concern. Gas drilling operations involve seismic testing which causes vibrations, moving earth, use of explosives, drilling wells and fracturing shale using extreme high pressure and deep well injection of the toxic waste, where permitted. For example, the Youngstown, Ohio region logged more than 100 earthquakes in 2011 which have been linked to deep well injection of hydraulic fracturing waste. http://www.nbcnews.com/science/fracking-practices-blame-ohio-earthquakes-8C11073601?ocid=msnhp&pos=4 According to the US Geological Survey, "the number of earthquakes has increased dramatically over the past few years within the central and eastern United States. More than 300 earthquakes above a magnitude 3.0 occurred in the three years from 2010-2012, compared with an average rate of 21 events per year observed from 1967-2000. USGS scientists have found that at some locations the increase in seismicity coincides with the injection of wastewater in deep disposal wells."
http://www.usgs.gov/blogs/features/usgs_top_story/man-made-earthquakes/

Any of these invasive gas drilling operations can cause a home's foundation to falter and walls to crack making the residence unsafe to inhabit. For example, recently, two couples in Johnson County, Texas filed a lawsuit for property damage allegedly resulting from fracking-related earthquakes.

While there is no government sponsored registry of gas drilling related impacts to homeowners, these accounts abound. Many are reflected on the FrackTracker Internet database. I am providing the link so the DRBC can review and confirm the mounting accounts.
http://www.fractracker.org/2013/03/pacwas-list-of-the-harmed-now-mapped-by-fractracker/

Standard gas leases fail to mention insurance. Homeowners remain potentially liable for the activity that occurs on their property, if it is not effectively delegated to the gas company in the lease or effectively addressed by the gas driller. Homeowners insurance excludes from coverage industrial activity and leaves homeowners vulnerable to losing their insurance coverage. This was confirmed in a July 2012 press release by Nationwide Mutual Insurance Company stating that:

> Nationwide's personal and commercial lines insurance policies were not designed to provide coverage for any fracking-related risks.…. From an underwriting standpoint, we do not have a comfort level with the unique risks associated with the fracking process to provide coverage at a reasonable price. Insurance is a contract and it is designed to cover certain risks. Risks like natural gas and oil drilling are not part of our contracts, and this is common across the industry**.**
> (http://www.nationwide.com/newsroom/071312-FrackingStatement.jsp)**.**

This fact was reconfirmed in a March 2013 news report which stated: Fracking-related damage, insurance industry insiders say, is not covered under a standard homeowner's insurance policy. Neither is damage caused by floods, earthquakes or earth movement, which insurers call exclusions. "(Fracking is) deemed an exclusion in the same way earthquake or earth movement is," according to the Insurance Information Institute, a nonprofit institute funded by the insurance industry. According to State Farm Insurance, the insurance underwriter does not have a fracking endorsement for private residences. While State Farm does have earthquake, earth-movement and sinkhole endorsements available in most areas, the endorsement may not cover fracking related impacts. http://m.shalereporter.com/industry/article_2cbf4e02-4f96-52cb-9264e169b706b05a.html

In August 2013, Lebanon, New York's town supervisor Jim Goldstein disclosed in an open letter that a constituent had their homeowner's insurance renewal for their home and farm in Lebanon denied because there is a gas well on their property. Mr. Goldstein confirmed through the insurance agent, who writes a lot of policies in southern Madison County, that this is a new trend and will come up as property owners fill out renewal applications. The property owner reported no history of payment problems or incidents on the property**.**

90% of all mortgage loans are sold into the secondary mortgage market. The standard mortgage used in the secondary mortgage market prohibits the transfer of an interest in the real property (which includes entering into a gas lease) without lender consent; and the presence of hazardous materials and hazardous activity consistent with the practices characterized by unconventional gas drilling operations. People with mortgage loans who signed gas leases without lender consent violated their mortgage; yet, as long as the borrower pays the loan, the lender may not become aware of the default. However, a mortgaged residence without homeowner's insurance constitutes an incurable mortgage default. If the homeowner/borrower cannot obtain replacement coverage in the marketplace, he or she would have to pay the substantially more expensive "forced insurance" premiums arranged through the originating bank or loan servicer (which coverage inures only to the benefit of the bank, not the homeowner), or risk losing the mortgage loan altogether and face foreclosure.

What if a homeowner doesn't have a mortgage yet, but wants one? Because most loans are sold by the originating lender into the secondary mortgage market, mortgage loans are underwritten based upon guidelines issued by the secondary mortgage market. These guidelines have restrictions which could put the originating bank on the hook for buying back the loan if a homeowner allows gas drilling after obtaining a mortgage and the gas drilling results in well water contamination, structural damage or other property damage, or the home becomes uninsured. In recognition of the risks, some national banks are taking precautions when asked to loan on properties with gas leases; others are just saying "no" to residential mortgage loans with residential fracking. Because the property's conformity to secondary market standards will be questioned, an originating lender who elects to make a mortgage loan is more likely to keep the loan in its private loan portfolio and not sell it into the secondary mortgage market. With finite reserves, originating banks can make only a limited number of portfolio loans.

One national bank is taking charge of borrowers who sign a gas lease while also having an outstanding mortgage: Sovereign Bank, N.A., now requires borrowers to sign and record a mineral, oil and gas rights rider to the mortgage which stays in effect for the duration of the mortgage. It prohibits leasing the surface and subsurface of the property for minerals, oil or gas extraction; and requires the borrower to take affirmative steps to prevent renewal or expansion of rights under any existing lease or similar prior grant. The covenant restricting this use entitles the bank to bring the property back into conformity and requires the borrower to pay all bank and attorneys' fees incurred as a result.

Key Bank's Mortgage Group has lending guidelines which provide:

> No mortgages will be written on properties that have a gas well.
> Key Bank can deny a mortgage to homeowners whose properties are within 600 feet of a gas well.
> No mortgages will be written on properties with a gas lease. .
> Property owners with gas leases and gas companies can be held liable for damages.
> http://neogap.org/neogap/

In another case, JPMorgan Chase refused to amend the terms of an existing borrower's refinancing agreement to permit a gas lease with BP. Chase's spokeswoman stated: "It's becoming wide-spread across the industry. Servicers and lenders are becoming more unwilling to approve a loan on these properties," "At the end of the day, we may not even own the loan." http://www.vindy.com/news/2013/mar/10/banks-build-roadblocks-to-riches-from-dr/?print

If a person cannot obtain a mortgage loan or keep a mortgage loan because of the risks associated with gas drilling operations, the house will be difficult to hold onto or sell. Where does that leave the homeowner? Either vulnerable to foreclosure, trapped in the home or forced to abandon it. If current trends continue, homeowners living in gas drilling regions, even those who elect not to sign a gas lease but who are compelled through compulsory integration or forced pooling to join a spacing unit; or other people living in close proximity to homeowners with gas drilling on their property, may find themselves swept into the same net facing bankers and insurance underwriters electing not to loan or renew homeowners insurance because of the migrating risks, such as water contamination and seismic activity, associated unconventional gas drilling. What effect would this have on the home value of people who do not even support the gas drilling? Does the DRBC or a DRBC State open itself up to litigation for forcing a property owner against their will into a spacing unit if that homeowner is subsequently turned down for a mortgage loan or homeowners' insurance? How will the ripple effects of this affect the tax base?

New concerns regarding the ability to mortgage and insure a home are also arising out of the proliferation of retooled older pipelines and newer ones crisscrossing under residences throughout the Country. For example, on May 29, 2013 Exxon owned Pegasus pipeline burst open spilling at least hundreds of thousands of gallons of tar sands crude oil into the residential neighborhood of Mayflower, Arkansas requiring dozens of families to evacuate. In August, 2013 two unrelated pipeline explosions occurred in Illinois, one in Erie which required 80 families to temporarily evacuate their homes, another in Van Buren County which killed a man, destroyed his home and caused the temporary evacuation of 25 homes, affecting 35-40 people. What would such spills do to the Delaware River Basin and its residents? Time will tell whether mortgage lenders and insurance underwriters will revise their underwriting standards to exclude coverage for homes located in close proximity to high pressure pipelines.
http://www.bloomberg.com/news/print/2013-09-02/decades-of-ruptures-from-defect-show-perils-of-old-pipe.html
http://www.arktimes.com/arkansas/ArticleArchives?tag=Pegasus%20pipeline%7C%7CExxonMobil
http://thinkprogress.org/climate/2013/08/13/2457691/cornfield-explosion-in-western-illinois
http://thesouthern.com/news/local/natural-gas-caused-deadly-house-explosion/article_06a3d02e-06bc-11e3-969a-0019bb2963f4.

Because of the connection to water contamination from the multi-phase drilling and fracking process and the vulnerability of homes to structural damage, what will happen to the property investment of families living across the Delaware River Basin if the DRBC elects to proceed with drilling in this water rich region? Where will these people go if their property is harmed? Who will buy the affected homes? For what price? Again, what will happen to the tax base?

The assertion by the oil and gas industry that unconventional shale gas drilling using current technology can be performed safely lacks credibility. Industry public disclosure documents, risk assessment by the insurance industry and regular reports of property damage and environmental impacts affecting homes across the nation support a contrary conclusion. Indeed, the growing reluctance of the mortgage and insurance industries to handle fracking affected properties, a reluctance driven by the long tradition of objective calculation of risk in both of these industries, presents an irrefutable answer to the claims of the oil and gas industry that unconventional gas drilling can be performed safely.

I urge the Delaware River Basin Commission not to endorse unconventional gas drilling in light of the expensive, uninsured risks it poses to homeowners and the potential it has for inflicting enormous economic losses, potentially in the many millions of dollars on homeowners and communities in the Delaware River Basin. The oil and gas industry asks that we consider the benefits of unconventional shale gas drilling. I ask that you consider the costs, including the potential financial devastation of hundreds, if not thousands or more, of innocent homeowners and just say “No” to fracking. Thank you.