DATE DOWNLOADED: Thu Aug 4 11:20:30 2022
SOURCE: Content Downloaded from *HeinOnline*

Citations:

Bluebook 21st ed.
Julie Shemeta, Did the Earth Move: Induced Seismicity in Oil and Gas Operations, 14 Energy Litig. 8 (2015).

ALWD 7th ed.
Julie Shemeta, Did the Earth Move: Induced Seismicity in Oil and Gas Operations, 14 Energy Litig. 8 (2015).

APA 7th ed.
Shemeta, J. (2015). Did the earth move: induced seismicity in oil and gas operations. Energy Litigation, 14(3), 8-12.

Chicago 17th ed.
Julie Shemeta, "Did the Earth Move: Induced Seismicity in Oil and Gas Operations," Energy Litigation 14, no. 3 (Spring 2015): 8-12

McGill Guide 9th ed.
Julie Shemeta, "Did the Earth Move: Induced Seismicity in Oil and Gas Operations" (2015) 14:3 Energy Litig 8.

AGLC 4th ed.
Julie Shemeta, 'Did the Earth Move: Induced Seismicity in Oil and Gas Operations' (2015) 14(3) Energy Litigation 8

MLA 9th ed.
Shemeta, Julie. "Did the Earth Move: Induced Seismicity in Oil and Gas Operations." Energy Litigation, vol. 14, no. 3, Spring 2015, pp. 8-12. HeinOnline.

OSCOLA 4th ed.
Julie Shemeta, 'Did the Earth Move: Induced Seismicity in Oil and Gas Operations' (2015) 14 Energy Litig 8

-- Your use of this HeinOnline PDF indicates your acceptance of HeinOnline's Terms and Conditions of the license agreement available at *https://heinonline.org/HOL/License*
-- The search text of this PDF is generated from uncorrected OCR text.
-- To obtain permission to use this article beyond the scope of your license, please use: *Copyright Information*

Did the Earth Move? Induced Seismicity in Oil and Gas Operations

By Julie Shemeta – May 27, 2015

Induced seismicity, once an obscure phenomenon, is currently a red-hot environmental issue in North America, particularly regarding activity in Oklahoma, Ohio, Texas, Colorado, and British Columbia and Alberta, Canada. Many news media reports suggest hydraulic fracturing is the cause, but the occurrence of induced events is complex, and the cause and size of the induced earthquakes varies from area to area.

Background of Induced Seismicity

Induced seismicity refers to earthquakes caused by human activity. A thorough review of the topic is presented by the National Academy of Sciences study titled *Induced Seismicity Potential in Energy Technologies* published in 2013.

Earthquakes induced by oil and gas operations can occur when changes in the subsurface occur near preexisting faults due to activities such as wastewater injection (Oklahoma), hydraulic fracturing (British Columbia and Alberta, Canada; Ohio), or when large volumes of material are extracted or compacted (Groening field in the Netherlands). The orientation of a fault with respect to the surrounding stresses in the earth and subsurface changes due to human activity, such as pore pressure, may prompt a preexisting fault to slip and cause an earthquake. Wastewater disposal wells and hydraulic fracturing have both been suspected to have induced seismic events as large as magnitude 4.4 (hydraulic fracturing) and 5.6 (wastewater disposal).

Induced earthquakes related to wastewater injection are relatively rare. The United States has approximately 150,000 Environmental Protection Agency Class II injection wells, of which about 30,000 are disposal wells. The disposal wells vary in injection rate and injection target. An injection well is specially drilled to target a rock formation with high permeability. The disposal is typically performed under "vacuum"—i.e., disposing of water without additional pressure, where the weight of the wastewater column in the wellbore is enough to drive the water into the disposal interval. Wastewater injection wells are designed to be used for years and years for safe disposal, and very few of these wells have been associated with any seismic activity.

Increased Seismicity in Oklahoma

The recent and dramatic increase in seismicity in Oklahoma since 2009 is unprecedented in terms of the rate and size of the suspected number of potentially induced events. *See* W.L. Ellsworth, "Injection-Induced Earthquakes," 341 *Science* 1225942 (July 12, 2013). The recent development of several dewatering plays in Oklahoma and southern Kansas, which produced as much as 50 percent to 90 percent produced water cut with the hydrocarbon, are suspected to have played a major role in the seismicity increase but are not the only cause for the increase. Long-term wastewater injection near a fault zone near Prague, Oklahoma, has been cited as the possible cause of a series of earthquakes in late 2011, the largest of which was a magnitude 5.6 earthquake that caused damage to nearby structures. *See*Kathleen Keranen et al., "Potentially Induced Earthquakes in Oklahoma, USA: Links Between Wastewater Injection and the 2011 Mw 5.7 Earthquake Sequence," 41*Geology* 699 (June 2013). The Oklahoma Geological Survey (OGS) issued a statement on April 21, 2015, stating that "the rates and trends in seismicity in Oklahoma are very unlikely to represent a naturally occurring process." *See* Richard D. Andrews & Austin Holland, OGS, Statement on Oklahoma Seismicity (Apr. 21, 2015). The OGS also launched a new website dedicated to earthquakes in Oklahoma. In particular, central and north-central Oklahoma earthquakes were identified as potentially triggered by the injection of produced water into disposal wells.

Hydraulic Fracturing

Hydraulic fracturing (fracking) is the process of injecting water and trace chemicals at high rates and pressures to

© 2015 by the American Bar Association. Reproduced with permission. All rights reserved. This information or any portion thereof may not be copied or disseminated in any form or by any means or stored in an electronic database or retrieval system without the express written consent of the American Bar Association.

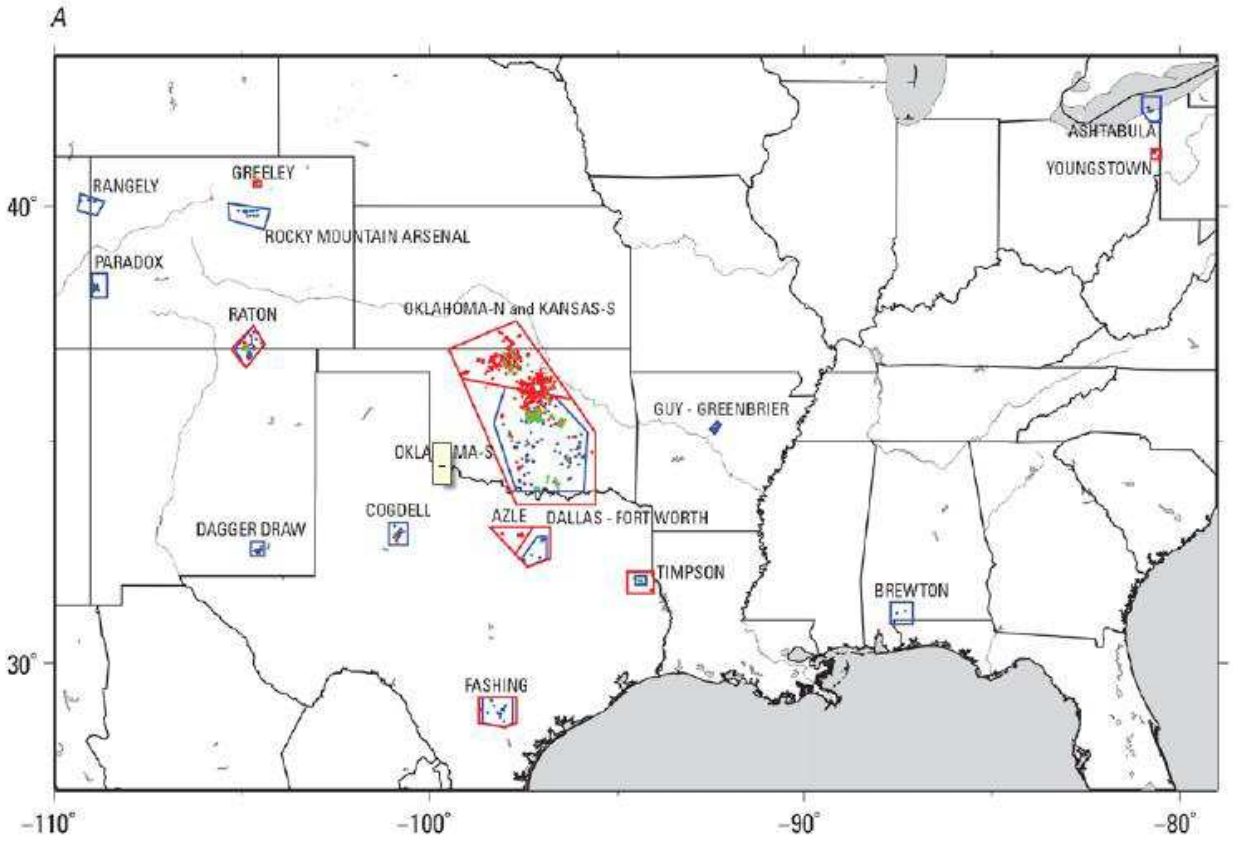
create subsurface fractures along the length of a horizontal or vertical wellbore and then "propping" the fracture open with sand or other materials. This process allows the hydrocarbons to flow from reservoirs that are too impermeable to permit gas or oil to flow without the stimulation. The hydraulic fracturing process is short-lived, typically taking a few days to perform separate frack "stages" systematically along the wellbore.

Just a handful of hydraulically fractured wells in the United States have documented seismic events. Recently, however, there have been several cases of suspected induced seismicity during hydraulic fracturing operations in Canada, including the Horn River Basin in British Columbia and the Duvernay Shale in Alberta, where the largest suspected frack event was measured at magnitude 4.4. The event occurred in the Fox Creek area of northern Alberta on January 22, 2015. In 2012, the British Columbia Oil and Gas Commission issued a report documenting a variety of potentially induced earthquakes ranging in size from magnitude 2.0 to 3.8, which were suspected to be related to hydraulic fracturing operations in the Horn River Basin. *See* British Columbia Oil & Gas Comm'n, *Investigation of Observed Seismicity in the Horn River Basin* (2012).

Is There an Increased Seismic Hazard?

The United States Geological Survey (USGS) published a report on April 23, 2015, that attempts to quantify the associated hazard from potentially induced seismic events from oil and gas activity in the United States (see the figure below). *See* M.D. Petersen et al., USGS Open-File Report 2015–1070, *Incorporating Induced Seismicity in the 2014 United States National Seismic Hazard Model—Results of 2014 Workshop and Sensitivity Studies* 69. These potentially induced earthquakes were removed from the catalogue of events used to assess the hazards from naturally occurring earthquakes, where statistical methods are used to assess the location and timing of future earthquakes. The induced earthquake hazard will depend on industry activity. Therefore, the time-independent statistical methods normally applied to assess earthquake hazards cannot be used. Based on a variety of models to assess the induced seismicity catalogue, the USGS study suggests induced seismicity in Oklahoma contributes significantly to the ground-shaking hazard. Indeed, the preliminary modeling in the study shows a factor of nearly 100 higher annual rate of ground motion exceedance from induced seismicity near Oklahoma City compared with the hazard from naturally occurring events.

© 2015 by the American Bar Association. Reproduced with permission. All rights reserved. This information or any portion thereof may not be copied or disseminated in any form or by any means or stored in an electronic database or retrieval system without the express written consent of the American Bar Association.



Earthquake locations and areas of potentially induced earthquakes in the central and eastern United States.

Reaction by Regulators

The reaction to induced seismicity by U.S. state and Canadian province regulators is mixed. Induced earthquakes potentially caused by wastewater injection in the Guy-Greenbrier area of Arkansas in 2010 and 2011 prompted state regulators to create an injection "Moratorium Zone" in the vicinity of the earthquake activity. Permission to inject in the area requires a hearing by the Arkansas Oil and Gas Commission.

In Ohio, regulators rewrote permits for hydraulic fracturing, which call for special earthquake monitoring if drilling near a known fault or any mapped seismicity activity greater than magnitude 2.0, with a special map to indicate the areas of the increased regulations. *See*Recent Earthquake Epicenters in Ohio (map) (July 29, 2014). Hydraulic fracturing operations in Ohio falling within the mapped special areas are required to install a seismic network in areas that fall within three miles of a known active fault, and the network must be capable of detecting and locating a magnitude 1 event. If a seismic event greater than 1.0 occurs during well operations, the work is suspended while the cause of the seismicity is investigated. *See*Press Release, Ohio Dep't of Natural Res., Ohio Announces Tougher Permit Conditions for Drilling Activities Near Faults and Areas of Seismic Activity (Apr. 11, 2014).

Seismic activity occurring in March 2014 in Mahoning County, Ohio, near a hydraulic fracturing operation in the Utica Shale caused the operations in the well to be suspended by orders of the Ohio Department of Natural Resources. In Canada, the Alberta Energy Regulator released new guidelines in February 2015 for hydraulic fracturing operations in the Duvernay Zone, Fox Creek area of Alberta, which require operators to comply with a "traffic light" seismic protocol

© 2015 by the American Bar Association. Reproduced with permission. All rights reserved. This information or any portion thereof may not be copied or disseminated in any form or by any means or stored in an electronic database or retrieval system without the express written consent of the American Bar Association.

where operations are varied depending on the level of seismicity activity observed. *See* Alberta Energy Regulator, Subsurface Order No. 2 (Feb. 19, 2015).

Industry Response

Oil and gas operators have had a reserved response regarding the induced seismicity issue. Many companies have internal induced seismicity working groups and have actively participated in special work groups and oil and gas industry trade groups to help develop guidelines and mitigation plans for companies in the event of an induced seismic event. Sparse scientific research has been publicly released by oil and gas companies, the Blackpool hydraulic fracturing earthquake being an exception. Cuadrilla Resources made all its technical reports available to the public following the magnitude 2.3 earthquake that was recorded in 2011 during a hydraulic fracturing operation.

Final Thoughts

The recent spotlight on induced seismicity has greatly increased the amount of research on the topic. There are efforts to better record injection volumes, rates, and depth of disposal wells and to create improved access to the injection databases. The research areas of interest include understanding the geological conditions in the subsurface such as the state of stress in the earth, faults (a better characterization of them), and how injected fluids and pressure changes travel in the subsurface.

The recent USGS study in Oklahoma suggests the majority of the recent earthquakes in central Oklahoma are occurring on reactivated ancient faults that extend from the Arbuckle Group (the injection formation for many waste disposal wells in the area) into the crystalline basement rocks. D.E. McNamara et al., "Earthquake Hypocenters and Focal Mechanisms in Central Oklahoma Reveal a Complex System of Reactivated Subsurface Strike-Slip Faulting," 41 *Geophysical Research Letters* (Apr. 23, 2015). Ground shaking from induced events is also under detailed examination as researchers gain more insight into and understanding of the risks and hazards of induced seismicity. A recent study suggests ground shaking from induced events may be less than tectonic earthquakes. *See* S.E. Hough, "Shaking from Injection-Induced Earthquakes in the Central and Eastern United States," 104 *Bull. Seismological Soc'y Am.* 2767– (2014).

Instrumentation typically used to collect earthquake data may not be present or not able to detect and locate smaller potentially induced earthquakes (i.e., a magnitude of less than 3) with accuracies better than a half mile, nor give accurate depth estimates, as many of the areas experiencing induced seismicity are not in tectonically active seismic areas and the existing earthquake networks are sparse. Operators in many places have installed proprietary seismic networks for recording and locating earthquakes, but for the most part, they have been reluctant to share their data with the public or research community. Regulations requiring the collection of earthquake data under the conditions of the permit, such as in Ohio and parts of Canada, may lead to a better understanding of the issue. However, it is not clear if the earthquake data required by permit will be available to the public research community.

The technical issues surrounding induced seismicity are complex, and the subsurface data needed to characterize the areas are often sparse and expensive to obtain. Even in well-understood subsurface areas, the faults that slip are below the active injection zones or hydrocarbon-bearing zones and are located in the crystalline basement rocks below the hydrocarbon reservoirs and geological formations used for the injection of waste, where even less subsurface information is known or understood.

The timing of induced seismicity can vary as well. Seismic events occur contemporaneously with injection or may be delayed by days, months, or even years in cases of long-term wastewater injection. Pinpointing a particular well to a series of earthquakes can be problematic because, in many areas, the pathway for the fluid and pore pressure perturbations is poorly understood. The USGS and many universities in Canada, the United States, and around the

© 2015 by the American Bar Association. Reproduced with permission. All rights reserved. This information or any portion thereof may not be copied or disseminated in any form or by any means or stored in an electronic database or retrieval system without the express written consent of the American Bar Association.

world have active research groups and consortia examining the issue. The high interest by the public, operators, regulators, and researchers will continue to drive forward increased understanding of this hot-button issue.

Keywords: energy litigation, earthquakes, hydraulic fracturing, fracking, induced seismicity

Julie Shemeta is the president and founder of MEQ Geo Inc.

© 2015 by the American Bar Association. Reproduced with permission. All rights reserved. This information or any portion thereof may not be copied or disseminated in any form or by any means or stored in an electronic database or retrieval system without the express written consent of the American Bar Association.