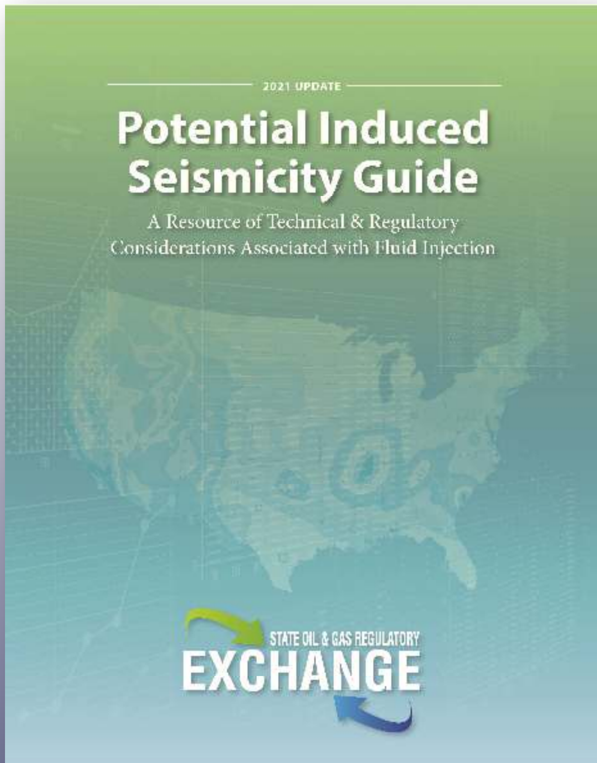
An Example of a Collaborative Effort Between Government, Industry, and Academia to Address Injection-Induced Seismicity



Ivan Wong

Senior Principal Seismologist
Lettis Consultants International

Commissioner, California Seismic Safety Commission

Helpful Data & Research for Class II UIC Programs

Groundwater & UIC Educational Series

27 April 2021

INTERSTATE Oil & Gas COMPACT COMMISSION

GROUNDWATER PROTECTION COUNCIL

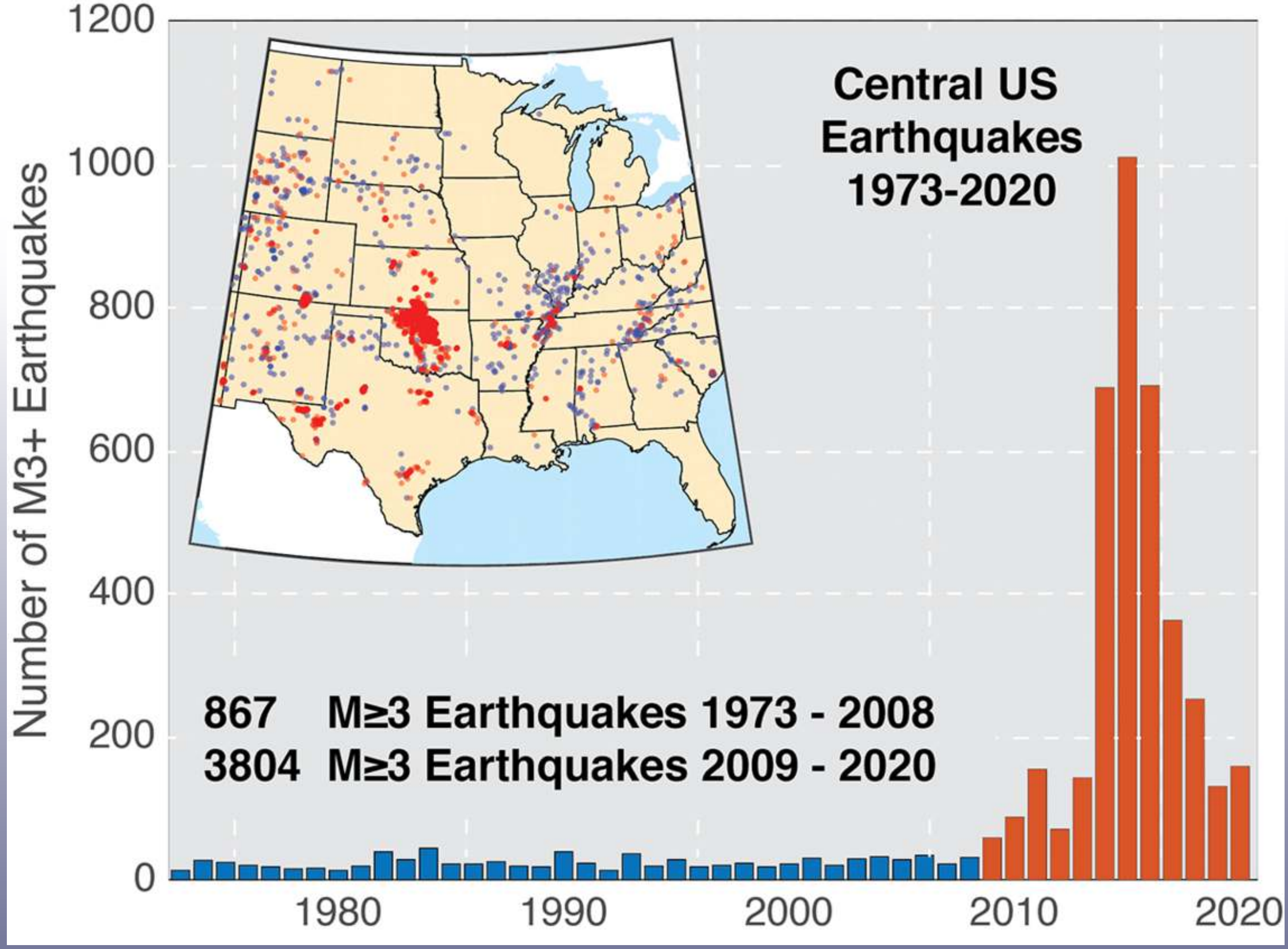
Introduction

- In 2014, as the issue of induced seismicity due to the underground injection of oil and gas wastewater was becoming increasingly more controversial and contentious, several representatives from state regulatory agencies and geological surveys primarily from the central U.S. decided that information sharing was needed to assist them in addressing the issue.
- Hence the Induced Seismicity by Injection Working Group (ISWG) was formed through an initiative of the Interstate Oil and Gas Compact Commission and the Ground Water Protection Council now known as the State Oil and Gas Regulatory Exchange (Exchange).
- The ISWG was composed of the state representatives supported by subject matter experts from industry, academia, federal agencies, and environmental organizations.

Introduction

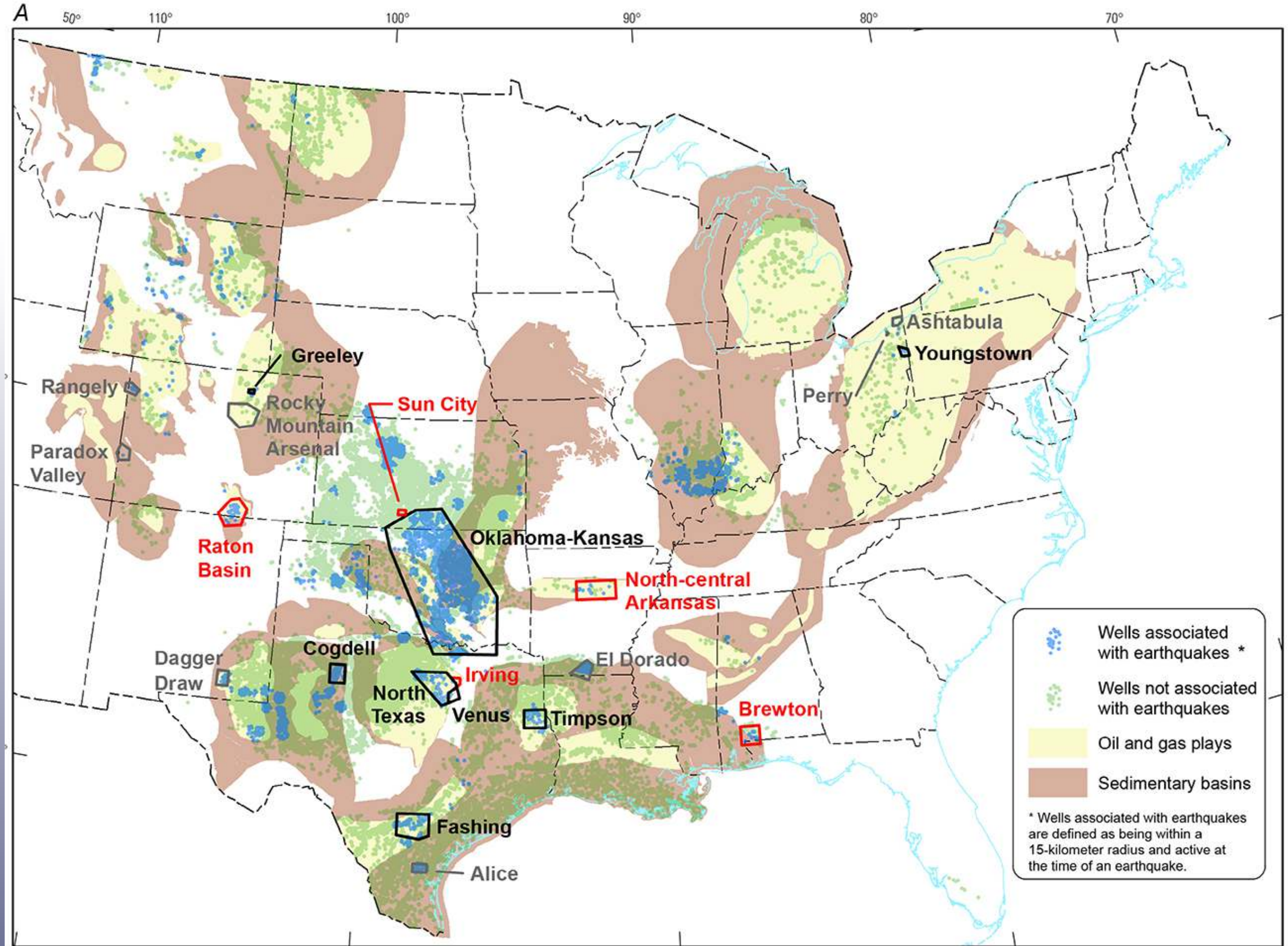
- The purpose of the ISWG was to produce a document which would help better inform stakeholders and the public on technical and regulatory considerations associated with the evaluation and response, seismic monitoring, information sharing, and the use of ground motion metrics related to induced seismicity.
- The document was also intended to summarize the range of approaches that have been used or are currently being used by states to manage and mitigate the induced seismicity risks.

The Issue



Courtesy of Justin Rubinstein, USGS

Areas of Induced Earthquakes (USGS, 2018)



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Texas Proposes Tougher Rules On Wells After Quakes

August 25, 2014 5:50 PM

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(credit: Spencer Platt/Getty Images)

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Ohio: Fracking waste tied to earthquakes

By Julie Carr Smyth, Associated Press   Updated 3/9/2012 4:07 PM

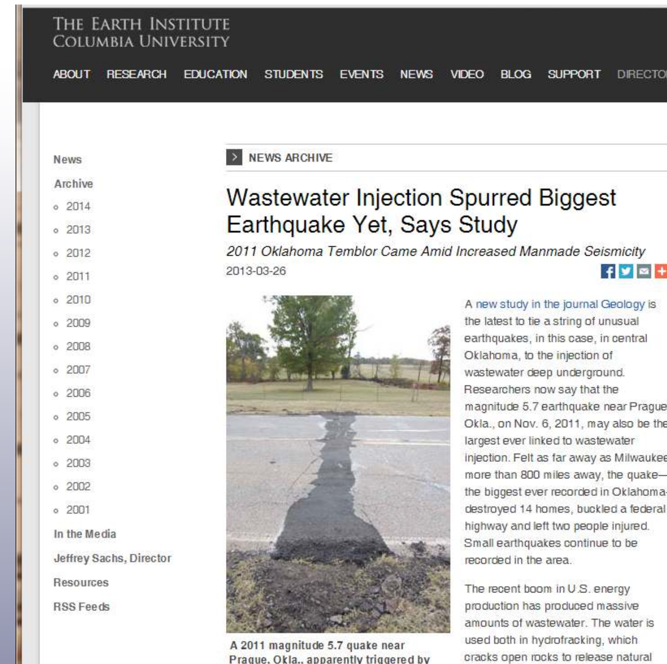
Comment

COLUMBUS, Ohio – A dozen earthquakes in northeastern Ohio were almost certainly induced by injection of gas-drilling wastewater into the earth, Ohio oil and gas regulators said Friday as they announced a series of tough new regulations for drillers.

Among the new regulations: Well operators must submit more comprehensive geological data when requesting a drill site, and the chemical makeup of all drilling wastewater must be tracked electronically.

Northeastern Ohio and large parts of adjacent states sit atop the Marcellus Shale geological formation, which contains vast reserves of natural gas that energy companies are rushing to drill using a process known as hydraulic fracturing.

By Amy Sancetta, AP



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Jeffrey Sachs, Director
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NEWS ARCHIVE

Wastewater Injection Spurred Biggest Earthquake Yet, Says Study

2011 Oklahoma Temblor Came Amid Increased Manmade Seismicity

2013-03-26

A new study in the journal Geology is the latest to tie a string of unusual earthquakes, in this case, in central Oklahoma, to the injection of wastewater deep underground. Researchers now say that the magnitude 5.7 earthquake near Prague, Okla., on Nov. 6, 2011, may also be the largest ever linked to wastewater injection. Felt as far away as Milwaukee, more than 800 miles away, the quake—the biggest ever recorded in Oklahoma—destroyed 14 homes, buckled a federal highway and left two people injured. Small earthquakes continue to be recorded in the area.

The recent boom in U.S. energy production has produced massive amounts of wastewater. The water is used both in hydrofracking, which cracks open rocks to release natural

A 2011 magnitude 5.7 quake near Prague, Okla., apparently triggered by

Signs of the Times (2011-2014)


Mother Jones

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ENVIRONMENT

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Fracking's Latest Scandal? Earthquake Swarms

Turns out that when a barely regulated industry injects highly pressurized wastewater into faults, things can go terribly wrong.

—By Michael Behar | March/April 2013 Issue

Vladimir/Shutterstock


REUTERS

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Study raises new concern about earthquakes and fracking fluids

BY SHARON BEGLEY


RT QUESTION MORE. LIVE

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Fracking causes rumbles in California

Published time: July 05, 2012 21:39
Edited time: December 24, 2013 16:04

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A gas flare burns at a fracking site (REUTERS/Stringer)


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Fracking could have caused East Coast earthquake

Published time: August 24, 2011 16:36
Edited time: December 24, 2013 16:08

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United States, Mineral: A sign on the door lets visitors know that City Hall, which shares a building with the local DMV office, was closed after the building was damged by yesterday's 5.8 earthquake August 24, 2011 in Mineral, Virginia. (AFP Photo / Scott Olson)


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LOCAL NEWS

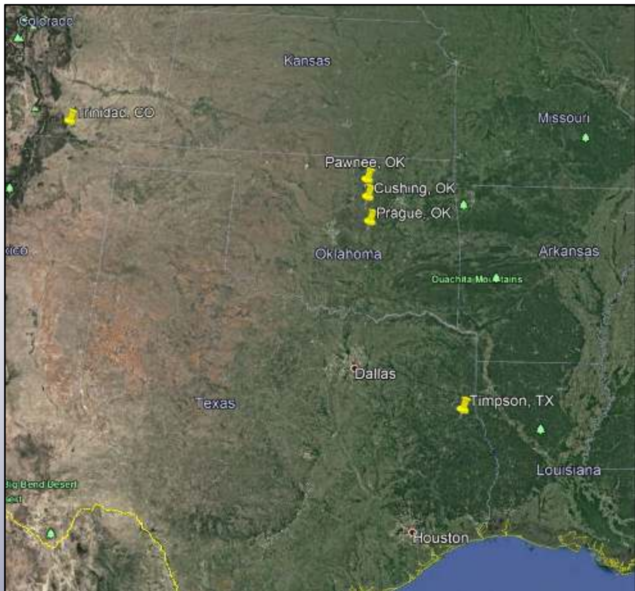
North Texas earthquakes more nuisance than crisis

Posted Saturday, Nov. 16, 2013

BY BARRY SHLACHTER
barry@star-telegram.com

AZLE — The earth is literally jumping along a stretch of real estate from Fort Worth's Eagle Mountain Lake and Azle to the Parker County

Significant Induced Earthquakes



- 2011 **M** 5.7 Prague, Oklahoma, earthquake - damaged some local homes, broke windows, cracked masonry, and collapsed a turret at St. Gregory's University
- 2011 **M** 5.3 Trinidad, Colorado, earthquake - caused structural damage to unreinforced masonry as well as nonstructural damage, including cracked masonry, fallen chimneys, broken windows, and fallen objects
- 2011 **M** 3.9 Youngstown, Ohio, earthquake. No significant damage.
- 2012 **M** 4.8 Timpson, Texas, earthquake - caused fallen chimneys and damage to masonry walls
- 2016 **M** 5.0 Cushing, Oklahoma event - resulted in cracks to buildings and fallen bricks and facades on City Hall and the Lions Club
- 2016 **M** 5.8 Pawnee, Oklahoma earthquake - damaged brickwork and cracked sheetrock at a number of structures

- Also **M** 4.6 event in British Columbia, **M** 4.7 and 5.7 in Sichuan, China due to hydraulic fracturing and the **M** 5.5 in Korea due to EGS.

2011 M 5.7 Prague, Oklahoma Earthquake

2011 M 5.3 Trinidad, Colorado Earthquake

2012 M 4.8 Timpson, Texas Earthquake

POTENTIAL INDUCED SEISMICITY GUIDE – A Resource of Technical and Regulatory Considerations Associated with Fluid Injection

- The guide is the third edition of a document previously called
  - *Potential Injection-Induced Seismicity Associated with Oil & Gas Development – A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation*
    - First Edition 2015 by StatesFirst Induced Seismicity
    - Second Edition 2017 by StatesFirst Induced Seismicity
- Previous two versions focused on Class II wells. This version now includes hydraulic-fracturing seismicity and includes a discussion of CCS. Also the guide covers western Canada.

ISWG

- AK - Steve Masterman, Alaska Geological and Geophysical Survey
- AR - Lawrence Bengal and Scott Ausbrooks, Arkansas Oil & Gas Commission
- CA - John Parrish, California Geological Survey
- CO - Bob Koehler and Matt Lepore, Colorado Oil & Gas Conservation Commission
- OH - **Rick Simmers** and Bob Worstall, Ohio Department of Natural Resources, Division Oil & Gas Resources Management
- KS - **Rex Buchanan**, Kansas Geological Survey
  Ryan Hoffman, Kansas Corporation Commission
- OK - Tim Baker, Oklahoma Corporation Commission
  Austin Holland, Oklahoma Geological Survey
  Michael Teague, Oklahoma Secretary of Energy & Environment
- IL - Richard Berg and Robert Bauer, Illinois State Geologic Survey
- IN - Herschel McDivitt, Indiana Division of Oil and Gas
  John Rupp, Indiana Geological Survey
- TX - Leslie Savage and Craig Pearson, Railroad Commission of Texas
- UT - John Baza and John Robers, Utah Division of Oil, Gas, & Mining
- WV - Jason Harmon and Zac Stevison, West Virginia Department of Environmental Protection

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Rick Simmers, Ohio Department of Natural Resources, Division of Oil & Gas (Co-chair) (2015 & 2017)

Ed Steele, GE Global Research, (2015 & 2017)

Ivan Wong, AECOM/Lettis Consultants (2015 & 2017)

Bob Worstall, Ohio Department of Natural Resources, Division Oil & Gas Resources (2015 & 2017)

Mike Nickolaus, GWPC

2021 Guide Contributors

Tara Gross - GWPC
Amy Childers - IOGCC
Mike Nickolaus - GWPC
Todd Shipman - Alberta Geol. Survey
Ed Steele - Consultant
Kris Nygaard - Exxon Mobil
Kurt Hildebrandt - USEPA
Leslie Savage - Texas Railroad Comm.
Tom Tomastik - ALL Consulting
Michael Young – TBEG
Lori Wrontenbery – IOGCC
Rex Buchanan – KGS
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Steven Dade - ODNR
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Jake Walter - OGS
Kurt Schrantz - Schrantz Consulting
Ivan Wong - Lettis Consultants
Shawn Maxwell – Ovintiv Services
Aaron Velasco – Texas Railroad Commission
Robert Voorhees – Underground Inject. Tech. Council

Purpose

- The Guide is designed to provide state and provincial regulatory agencies with an overview of current technical and scientific information, along with considerations associated with evaluating fluid-induced seismicity, managing the associated hazard and risk, and developing response strategies.
- It is not intended to offer specific regulatory recommendations to agencies but is intended to serve as a resource.
- Also, unlike prior studies by the National Research Council, EPA, Stanford University, and others, this document is not intended to provide a broad literature review.

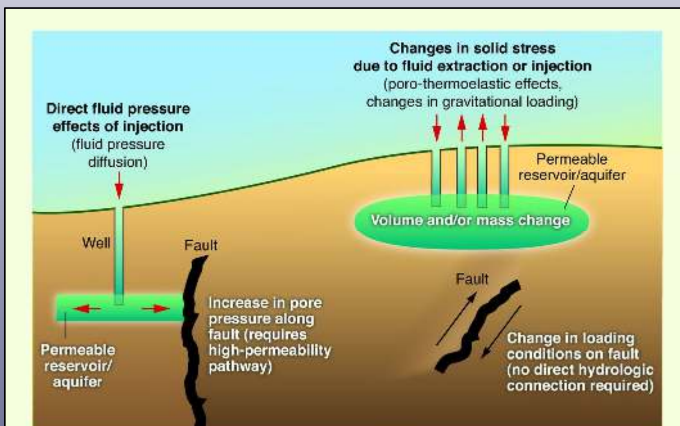
Purpose (continued)

- Management and mitigation of the risks are best considered at the state level, with specific considerations at local or regional levels.
- A one-size-fits-all approach is not feasible, due to significant variability in local geology and surface conditions, including such risk factors as population, building conditions, infrastructure, critical facilities, and seismic monitoring capabilities.
- Induced seismicity due to hydraulic fracturing was included in the Guide because its recognized that there is an increasing number of cases of hydraulic-fracturing induced earthquakes and the increasing magnitudes of such events.

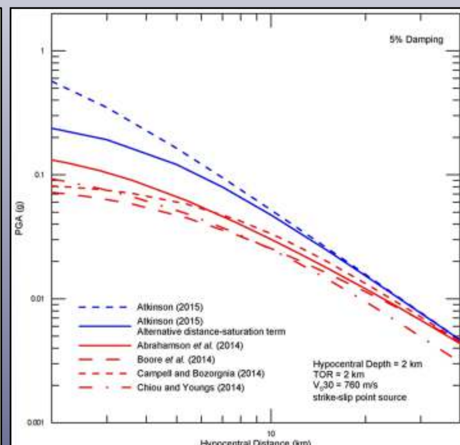
Table of Contents

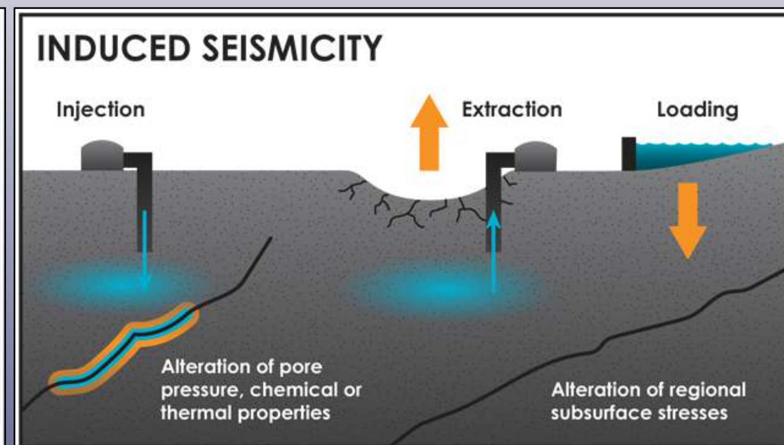
Chapter 1 Understanding Induced Seismicity

- Key concepts of earthquake science, such as magnitude, seismic monitoring, locating earthquakes, ground motion, and hazard.
- The hazards and risks related to induced seismicity and the difference between hazard and risk i.e., economic impacts, damage, anxiety, etc.
- The ways in which fluid injection might cause induced earthquakes, including the concept that the main physical mechanism responsible for triggering injection-induced seismicity is increased pore pressure on critically stressed faults.
- Ground motion models currently being used and the need to develop models specific to injection-induced earthquakes.



Source: Science.Sciencemag.org





Other Chapter 1 Topics

- Development of integrated technologies i.e., “FSP” software
- Short-term USGS National Seismic Hazard Maps
- Forecasting potential induced seismicity
- Hydraulic fracturing versus Class II well injection
- Decreasing rates since 2015 in Oklahoma due to regulatory response including stopping injection at problematic wells

Chapter 1
Future Research

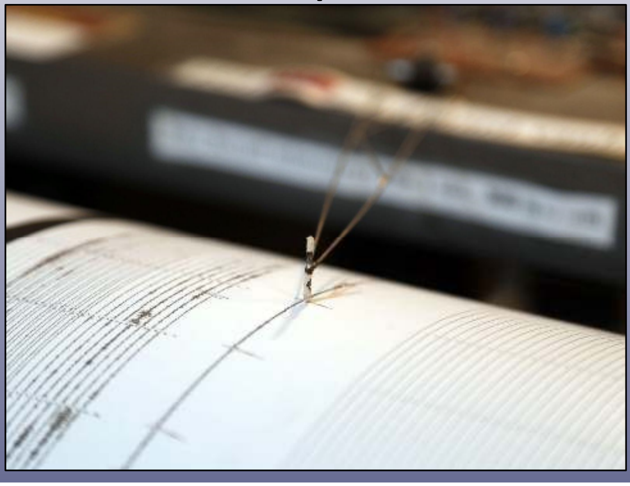
- What new methods and techniques can be used to better identify the presence of critically-stressed faults in proximity to injection sites?
- Are ground motions of induced earthquakes different from those caused by natural earthquakes?
- Can the largest induced earthquake be estimated?
- Can we further develop induced earthquake forecasting on a regional and site-specific basis?
- Can advanced seismic waveform processing techniques be developed to offer higher sensitivity in analyzing earthquake data.

Chapter 2 Assessing Potential Injection-Induced Seismicity

Evaluating Causation for Injection Wells

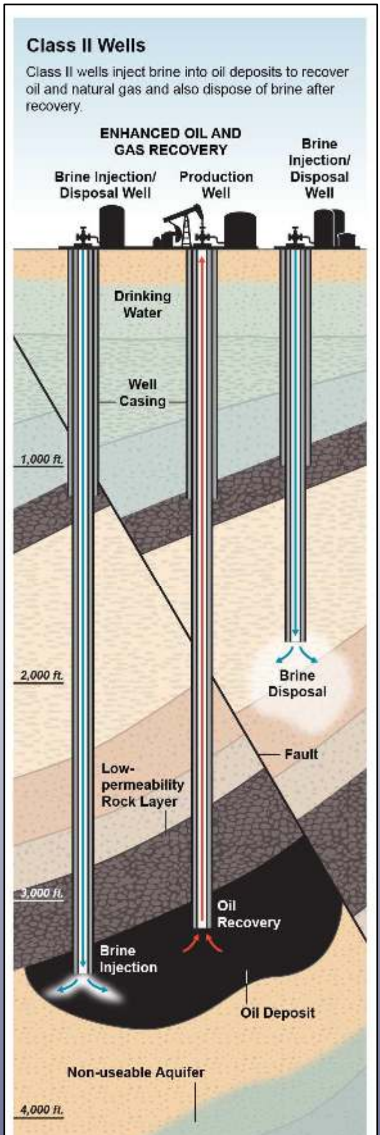
While most injection sites do not trigger earthquakes, induced seismicity can occur under certain conditions.

- Sufficient pore pressure buildup from disposal activities
- Critically-stressed faults (“faults of concern”)
- A pathway allowing the increased pressure to communicate with the fault



Chapter 2 (continued)

- Assessing seismicity based on historic records and contemporary and current and ongoing seismicity
- Discussion of national versus regional (state) versus local seismic monitoring.
- Development of seismic networks by state agencies.
- Understanding differences between hydraulic fracturing and waste water disposal



Source: Michiganradio.org

Chapter 2 (continued)
Key Data to Understand Injection Well Disposal Zones

- Fluid data:
  - Volumes, rates, pressures (downhole – averaged and maximum)
  - Physical properties: fluid density and temperature, compressibility, viscosity
  - Fluid chemistry
  - In-situ fluid properties: physical and chemical, phases present (gas or liquid)
- Geological data:
  - Reservoir thickness and areal extent
  - Reservoir porosity, permeability and initial pressure
  - Mechanical properties – elasticity, ductility
  - Stratigraphy – especially presence of confining layers above and below
  - Presence and orientation of faults and fractures
  - In-situ stresses, vertically and horizontally, due to rock mass and fluids

Chapter 3
Risk Management and Mitigation Strategies

- The two basic questions risk assessment from induced seismicity addresses:
  - How likely is an injection operation to pose an induced-seismicity hazard?
  - What is the risk – the probability of harm to people or property – if seismicity is induced?
- The strategies are different for Class II wells and hydraulic fracturing
- Science-based approaches to assessing and managing induced seismic risk from injection include:
  - Characterizing the site
  - Built environment
  - Estimating maximum magnitudes
  - Operational scope
  - Predicting hazards from ground motion

Risk mitigation options in siting and permitting new Class II disposal wells in areas of concern may include:

- Obtain local stakeholder input concerning risks
- Select a different location for new disposal wells
- Avoid injection into the crystalline basement or even into formations that directly overly the basement
- Locate faults in the vicinity of the proposed project area based on seismic reflection survey data or geologic mapping and placing the well outside the at-risk area where injected fluid may not significantly and adversely perturb the pore pressure/stress state
- Avoid direct injection of fluids into optimally oriented and critically stressed faults of concern

Risk Management Systems

- Risk management systems should be designed and implemented to be responsive and mitigate potential risks independent of specific completion methodologies that are being employed.
- Whether a Traffic-Light System and/or Area of Interest are implemented as the risk mitigation approach, the approach should be implemented considering the risk exposures for the local community.
- It is desirable for the system to enable flexibility in the implementation risk mitigation elements such that protocols and procedures may be specifically tailored and adaptable for each unique situation.

Chapter 4
Considerations for External Communications

- The communication planning process may include preliminary scans, stakeholder involvement, tying communication strategies to risk, conducting mock exercises and other training
- Communication plan elements may include scenario analysis, external and internal audience analysis, definition of key messages and communication strategies, communication team roles and responsibilities, materials and resources, and potential answers to frequently asked questions
- Incorporating lessons learned may include understanding how communication takes place, documenting how decisions were made, avoiding definitive statement or promises, and improving a communications plan

Source: Medium.com

Several key aspects of communication

- Clear and direct communication with the public is an important responsibility of states that are managing the risks of induced seismicity
- Earthquakes can come with no warning and in areas that have not have previous seismicity
- Earthquakes may grow with time and activity may go on for days
- Initial official reports of locations and magnitudes can be inaccurate
- The USGS "Did You Feel It?" system and Shakemaps are good early indicators of intensity and location
- Need to recognize that public anxiety levels can be high and significant to deal with regardless of damage levels; and
- Determining causes of earthquakes may be difficult and jumping to conclusions should be avoided.

Summary

- The guide discusses the potential for induced seismicity and identifies some strategies for evaluating and addressing the effects of such events.
- Management and mitigation of the associated are best considered at the state level, with specific considerations at local or regional levels.
- A one-size-fits-all approach is not feasible, due to significant variability in local geology and surface conditions, including such risk factors as population, building conditions, infrastructure, critical facilities, and seismic monitoring capabilities
- The ISWG recognizes that the science surrounding induced seismicity is undergoing significant changes and that the guide has and will need to be updated to provide readers with the most-up-to-date information.
- Through the collaboration of regulators and the oil and gas industry, the rate of induced seismicity and significant induced earthquakes due to Class II well disposal appears to have been effective in the past few years.

A Look Ahead

- Although the rate of induced seismicity has been declining, the scientific community is still debating whether there remains a potential for future significant induced events.
- Outside the U.S., earthquakes such as the events in China and Korea suggest that induced seismicity is still a challenging issue.
- The Groningen gas field in the Netherlands is a good example of small magnitude induced earthquakes (< M 4) that remains a problem in areas with vulnerable buildings.
- Seismicity due to hydraulic fracturing in the U.S. and particularly in western Canada may be the next big challenge for the industry.
- We still have lots to learn about induced seismicity so we need to keep our foot on the pedal in terms of research and mitigative actions.

THANKS!