U.S. DEPARTMENT OF ENERGY | Fossil Energy

Office of Oil and Natural Gas

Induced Seismicity

Expanded unconventional oil and gas (UOG) development has led to increased seismicity in several areas of the country, including areas where it was previously very uncommon. The primary cause of these earthquakes, which can reach magnitude 3.0 to 6.0, is large-scale wastewater injection from oil and gas production. In order to provide useful information to regulators and those who manage wastewater, the Department of Energy (DOE) is funding collaborative efforts to 1) identify the risks, 2) assess the probability of occurrence and potential impact of each risk, and 3) provide strategies and technologies to help mitigate the risks. Research includes assessing the risks in different oil and gas producing regions; establishing seismic monitoring networks; developing tools for assessing seismic risk; and providing access to wastewater disposal volumes. Results to date show that not all induced seismicity is due to high volume injection wells but varies by region. A University of Texas study, funded by the DOE, found that in the Barnett shale play region, earthquakes occur near high volume injection disposal wells, whereas in the Eagle Ford play region, earthquakes are not near injection wells, but follow increases in extraction of water/petroleum.

Goals

The recent increase in induced seismicity related to UOG operations is a relatively new and emerging problem. DOE's immediate goals are to support R&D efforts to:

- Determine the relationship between fluid injection practices, regional geology and stress regime, and occurrence of earthquakes,
- Identify waste disposal strategies that avoid triggering seismic activity, and
- Assess likelihood and risk of induced seismicity.

What Is Known

Tectonic forces generate the vast majority of earthquakes, but under some circumstances human activities trigger seismicity. The dramatic increase in seismicity of magnitude 3 or higher in regions such as north central Oklahoma (Figure 1) correlates with wastewater disposal operations that inject fluids into deep subsurface rock formations. The primary source for induced seismicity near unconventional oil and gas plays is not from hydraulic fracturing but rather the deep disposal of water associated with oil and gas production (Oklahoma Geological Survey, 2015).

Three main geologic features are required to exist before an induced seismic event can occur: 1) an existing fault, 2) subsurface stress conditions that bring the fault close to failure, and 3) a change in subsurface stress conditions caused by fluid injection or withdrawal (production) activities (Figure 2). Several factors affect whether injected fluids will induce seismicity, including the distance between a fault and an injection well, permeability of the strata surrounding the fault, and the volume and rate of injection. In many regions, including Oklahoma and Ohio, there is a spatial correlation between induced seismic events and faults located in the older metamorphic and igneous rocks that underlie the disposal reservoir. Injection wells prone to induced seismic activity can be identified in advance, given enough data on subsurface geology, permeability, fault, regional/local stress, and seismic history. In some cases, seismic risk can be managed by simply reducing the amount of water injected and period of injection.

Induced seismic risk varies tremendously by region, and that has implications for managing waste disposal operations. For example, earthquakes felt in some oil and gas producing regions—such as the Eagle Ford in south Texas—are associated with fluid extraction, while in other regions—including central Oklahoma—they are triggered by fluid injection. In many oil and gas producing regions—for instance the Bakken in North Dakota—very few, if any, felt earthquakes are related to extraction or injection. With enough information, induced seismic risk can be calculated and quantified, and seismic hazard models can inform design requirements for earthquake-resistant construction

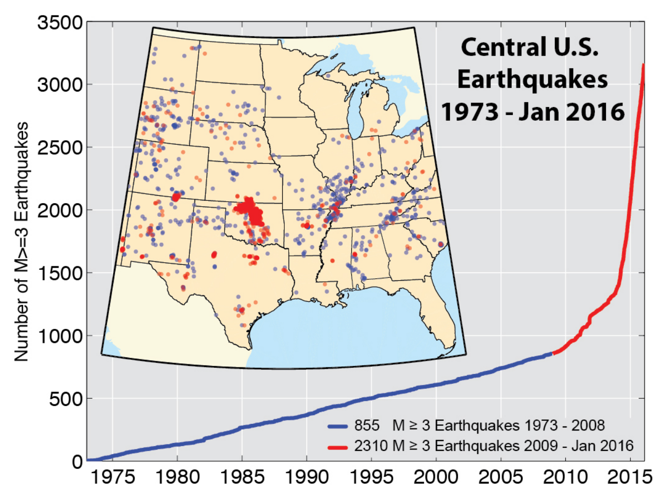

Figure 1. Earthquakes reported by the U.S. Geological Survey in 2016.

Research Results

Through the DOE funded Research Partnership to Secure Energy for America (RPSEA), University of Texas researchers analyzed data collected by the portable NSF EarthScope USArray program to evaluate seismic hazards in different oil and gas producing regions. Results show that regions need to be studied individually before crafting regulations for injection management strategies due to the following results:

- In the Barnett shale play region, earthquakes occur near high volume injection disposal wells.
- In the Eagle Ford play region, earthquakes are not near injection wells, but follow increases in extraction of water/petroleum.
- In the Bakken play region, there are high volume injection wells but almost no earthquakes.
- There were eight times as many earthquakes in the Fort Worth Basin as reported by the U.S. Geological Survey from 2009-2011, based on data collected by the transportable USArray.

Also funded through RPSEA, the Oklahoma Geological Survey in collaboration with the University of Oklahoma, the Oklahoma Secretary of Energy and Environment, and industry have:

- Improved the accuracy of locating earthquakes by adding permanent and portable seismic monitoring stations, the data from which is publically available through the Oklahoma Geologic Survey's Oklahoma Earthquake Catalog,
- Documented a major increase in salt water disposal in areas within seismically active areas,
- Mapped previously unidentified basement faults in Oklahoma that are now publically available in open file maps, and
- Developed 4-D integrated models for risk assessment.

Increased transparency and access to hydraulic fracture water volumes is now available through the Groundwater Protection Council FracFocus database, and access to disposal well injection volumes will also be accessible through the National Gateway database, which may be public in 2016.

Direction for Future Progress

Technology development and research opportunities include developing reliable physics-based models with predictive capabilities, as well as technologies to improve fault detection. This would include models that can predict rates; volumes of injection that would increase the risk of induced seismicity and the maximum magnitudes of such events. Software for 3-D modeling will improve the accuracy of geophysical calculations and new tools and sensors required for data collection on key stress-state related properties.

Policies and practices should emphasize expanding the fault database, digitizing state geologic survey maps, determining why earthquakes occur near some injection wells but not others, improving characterization of the subsurface environment for physics-based models, improving data density with 4D GPS navigation, improving site characterization of wastewater reservoirs and targeted geologic areas for detailed modeling of fluid flow and its behavior with soil and rock in targeted geological reservoirs.

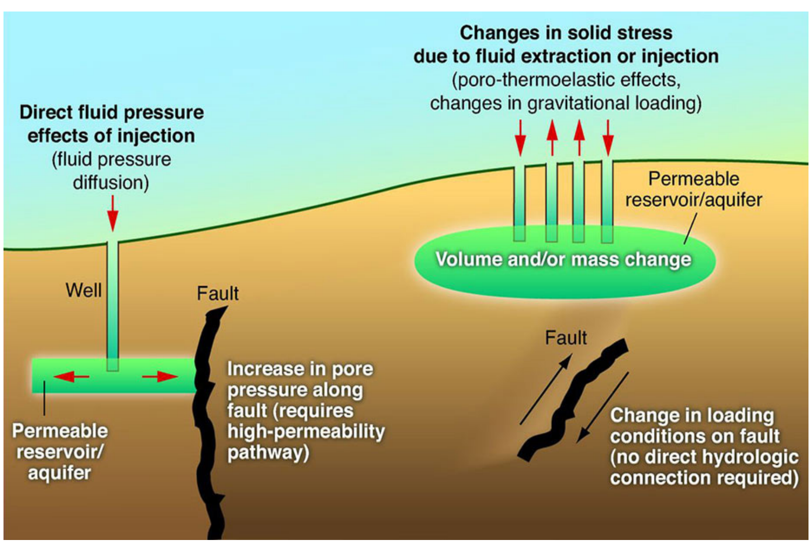

Figure 2. U.S. Geological Survey drawing of the effects of fluid injection and withdrawal can have on nearby faults.

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