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ReFINE Briefing Note

# What size of earthquakes can be caused by fracking?

Durham University

This research brief is based on the article: 'Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons' by Richard J. Davies, Gillian Foulger, Annette Bindley and Peter Styles, published online in Marine and Petroleum Geology, April 2013, and available for free download at: www.refine.org.uk

**Hydraulic fracturing**, more commonly known as 'fracking', is a process in which rocks are deliberately fractured by the injection of fluids under high pressure. During recent shale gas exploration in Lancashire, UK, hydraulic fracturing has been linked to earth tremors, causing public concern. To investigate the issue, Durham Energy Institute and Keele University have carried out a global review of published data on induced seismicity (man-made earthquakes). The work indicates that induced seismicity associated with fracking is typically much lower in magnitude than seismic events caused by mining, oil and gas field depletion and filling reservoirs with water.

**What is induced seismicity?**

Earth tremors and quakes occur when a geological fault moves suddenly, with **seismicity** being the technical term for such events in an area. This reflects the structure of the Earth's crust in that region, and the stresses being applied to it. **Induced seismicity** is where human activities cause a dormant fault to move. This can be by the removal of material, such as during mining, or by the addition of fluids that lubricate the fault zone. In the case of hydraulic fracturing, the induced seismicity is associated with the latter. Injecting fluids into shales to create fractures (Fig. 1) is thought to enable fracture networks to become connected to fault zones. As a consequence, the

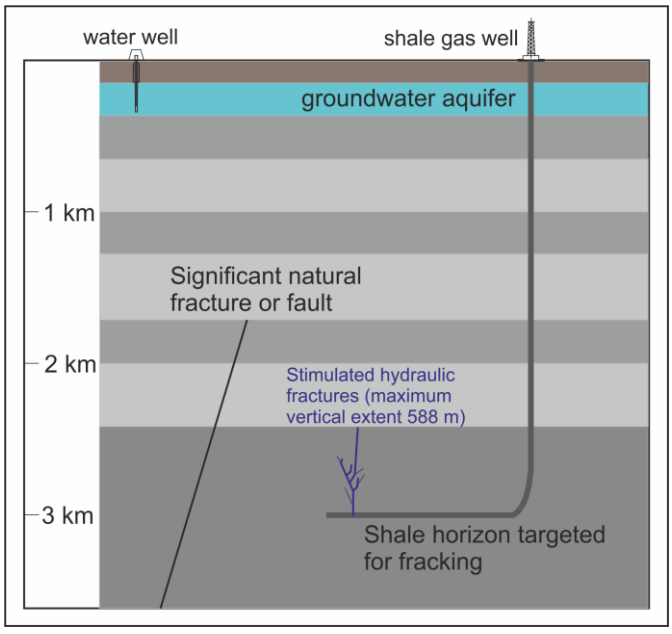



**Figure 1:** Simplified section through a shale gas production site. A well is drilled down into deeply buried, gas-rich shales. Fluids are then forced into the rock under high pressure, causing them to break and release trapped gas. Induced seismicity is thought to occur when this hydraulic fracturing enables fluids to move into a fault zone.

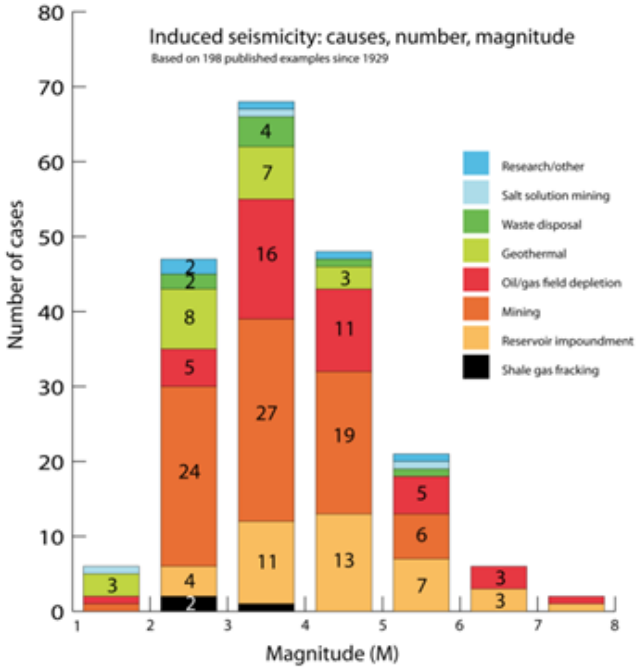
injected fluids or fluid pressure pulse might propagate into the fault zone, causing slippage. The mechanisms, magnitude and frequency of fracking-related induced seismicity are poorly understood, and until now have not been placed in a global context with other forms of induced seismicity.

**What is earthquake magnitude?**

Magnitude is the size of an earthquake, and can be measured in a number of ways. When discussing earthquake magnitude, most people think of the Richter scale, but this is a measure only of local magnitude. To assess the energy released by an earthquake, seismologists employ fundamental physics to determine **seismic moments**. From this, the moment magnitude scale is defined, and is now used alongside the Richter scale. Earthquakes with a magnitude under 3 are rarely felt by humans. A magnitude 3 earthquake releases about 30 times less energy than a magnitude 4 quake, and around 900 times less than that of a magnitude 5 quake.

**Induced seismicity: a global review**

The published data collated in the study are summarized in Figure 2, which shows the magnitude and frequency of induced seismicity caused by different activities. By examining almost 200 published cases of induced seismicity since 1929, our work provides the first global review of the subject, and places fracking-related seismicity in a broader context. It shows that induced seismicity can be produced by various human activities, not just the hydraulic fracturing of shale gas reservoirs, which is known from three locations. These include the damming of rivers to form reservoirs (impoundment; total=39), the




removal of hydrocarbons from oil and gas fields (depletion; total=42), mining (total=77), and the fracturing of rocks for geothermal energy generation (total=21).

**Which activities have caused the greatest induced seismicity?**

The greatest magnitudes of induced seismicity recorded are as follows: reservoir impoundment (max. M=7.9), oil and gas field depletion (7.3), mining (5.6), underground waste disposal (5.3), water injection into oil fields (5.1), geothermal energy generation (4.6), shale gas hydraulic fracturing (3.8), and seismicity research boreholes (3.1). By the very nature of the process of breaking rocks under pressure, hydraulic fracturing will generate induced seismicity, but the analysed data indicate that this has occurred at a low magnitude (see Fig. 3).

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**What size of earthquakes can be caused by hydraulic fracturing for shale gas?**

Induced seismicity associated with hydraulic fracturing has been identified in only three shale gas fields, in the UK, USA, and Canada. As shown in Figure 3, hydraulic fracturing for shale gas in these fields is known to have induced 79 seismic events with a magnitude >1. The largest of these was an earthquake of magnitude 3.8, which occurred in the Horn River Basin of British Columbia, Canada. It was felt, but caused no recorded damage. This and three other examples (two in the UK and one in the USA) are the only published examples of fracking-induced seismicity being felt.

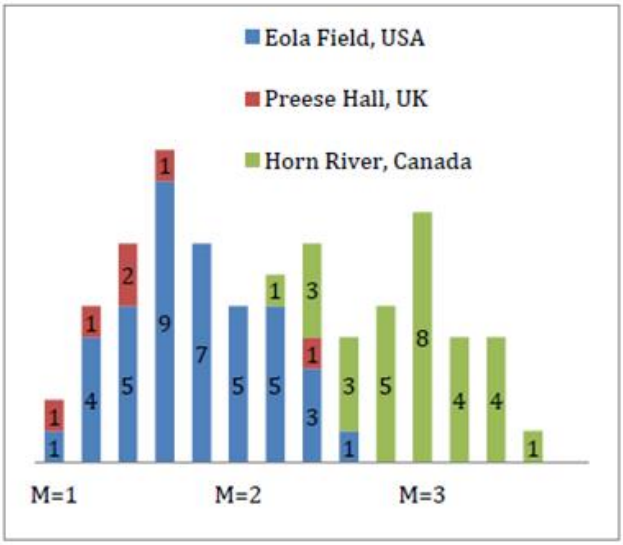


**Figure 3**: Fracking-induced seismic events of magnitude greater than 1. At three locations (the Eola Field, Oklahoma, USA; Preese Hall, Lancashire, UK; and the Horn River basin, British Columbia, Canada), 79 events with a magnitude >1 have been recorded. The highest-recorded magnitude of fracking-induced seismicity is 3.8 (Horn River, Canada).

**What can we conclude?**

Our study provides important context and information to the current debate surrounding the risks associated with the hydraulic fracturing of shales. We propose four primary mechanisms by which faults could be reactivated by fluids or fluid pressure waves during hydraulic fracturing:

1) directly from the well-bore;
2) through newly stimulated fractures;
3) through pre-existing fractures;
4) by moving through permeable rocks or along interfaces between beds of rock.

When compared with other sources of induced seismicity, such as mining and reservoir impoundment, hydraulic fracturing has been, to date, a relatively benign mechanism. This is possibly because comparatively low volumes of water are used in hydraulic fracturing, of the order of 2–11 Olympic swimming pools-worth, and the pumping duration is relatively short. It is possible that fault reactivation by hydraulic fracturing might cause induced seismicity larger than that recorded to date, but a fuller understanding of shale geology can mitigate against this risk. Based on the data presently available, the likelihood of fracking causing felt seismicity (M>3) is very small, though it cannot be ruled out.

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