

## How many man-made earthquakes pre-fracking?

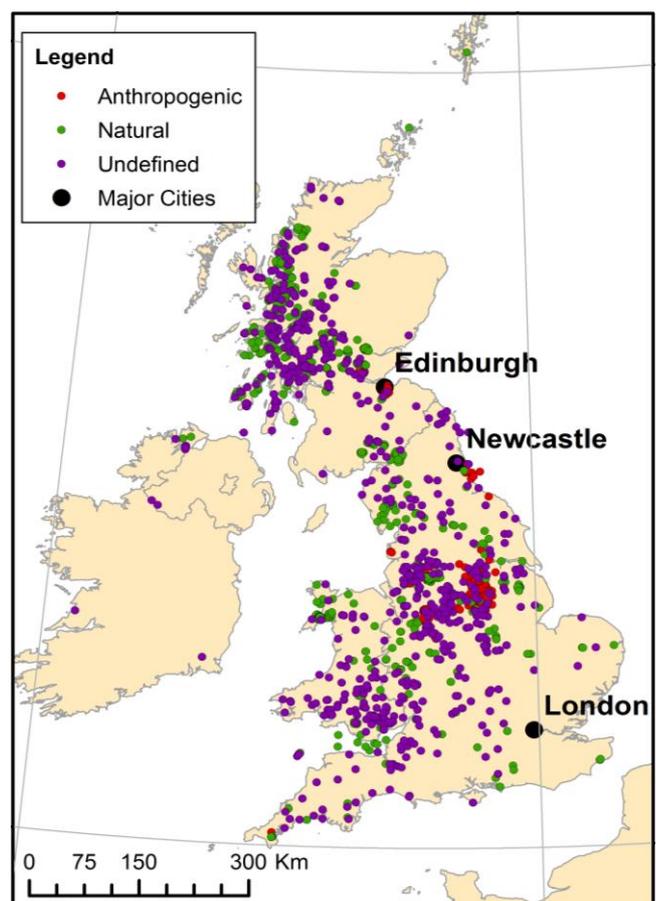


This research is based on “Anthropogenic earthquakes in the UK: A national baseline prior to shale exploitation” by Miles Wilson, Richard Davies, Gillian Foulger, Bruce Julian, Peter Styles, Jon Gluyas and Sam Almond. The paper was published in *Marine and Petroleum Geology* and is available for free download at [www.refine.org.uk](http://www.refine.org.uk).

Earthquakes occur when energy stored in the Earth’s crust is suddenly released, causing the Earth to move along geological fault lines. Large earthquakes tend to occur in unstable regions near tectonic plate boundaries, such as California and Japan. Geologically stable areas such as the UK receive smaller earthquakes, most of them detectable only with scientific equipment. The fracking of Britain’s first shale gas well in 2011 is known to have triggered an earthquake that was felt at the surface. Similar events have been recorded in the USA and Canada. If fracking is to take place in the UK, it will be necessary to understand how any potential man-made earthquakes will contribute to Britain’s overall seismicity, how large they may be, and to put any fracking related events into context with other causes of seismicity in the UK.

### How can man-made earthquakes be caused?

Man-made or “anthropogenic” earthquakes have a variety of recognised causes such as oil and gas exploration, coal mining, geothermal exploitation, and the filling of reservoirs. Seismicity is usually caused when faults that are close to moving, “critically stressed”, are caused to slip due to a change in the forces acting on the fault.



**Figure 1:** Distribution and cause of all 1769 UK earthquakes with a magnitude greater than or equal to 1.5 since 1970. From Wilson et al., 2015.

This change can be due to removal of material such as coal or oil, or the addition of liquids such as fracking fluid. Detectable seismicity may also occur if old mine workings collapse.

### Measuring UK Seismicity

Earthquake measurements are taken at various seismic stations around the UK. These stations contain sensitive equipment that monitors ground movement. Combining data from multiple seismic stations allows seismologists (earthquake scientists) to estimate the size, depth and location of earthquakes. The first seismic stations were installed in Scotland around 1970, and there are currently about 150 stations spread throughout the UK. These stations can reliably detect seismic events of magnitude 1.5 (an event often too small to feel at the surface) and higher.

### What causes the UK's Earthquakes?

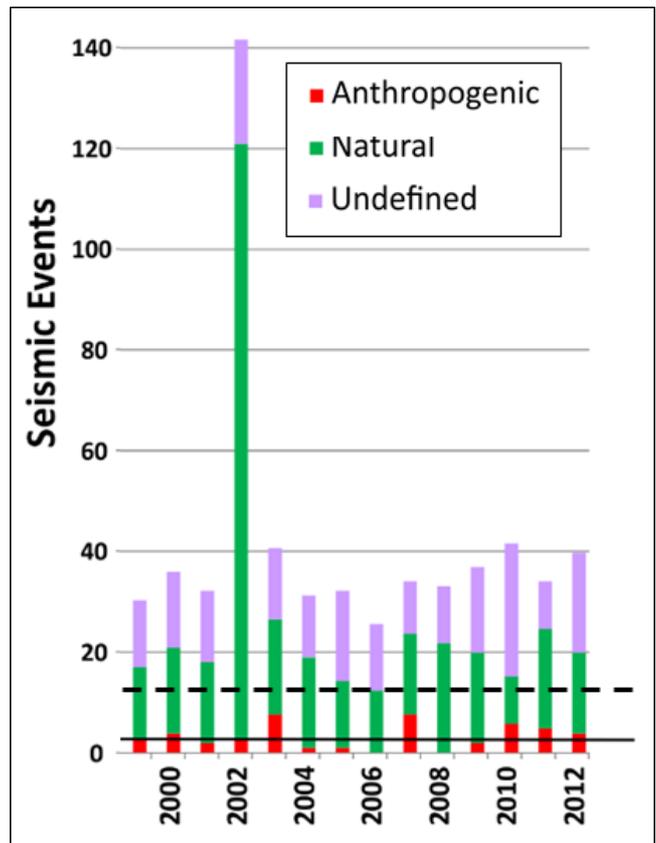
The British Geological Survey (BGS) monitors seismic (earthquake) activity in the UK. We analysed records of 8000 onshore seismic events from 1970-2012 (Figure 1). All 8000 events were examined using criteria such as location, depth and a region's seismic history to estimate the cause. For example, a shallow earthquake occurring close to active or historic coal mine workings may be assumed to have been caused by human mining activity. Whereas events occurring at great depth or in remote, less stable regions are more likely to be naturally occurring. Those events with a magnitude of  $\geq 1.5$  (the reliable detection limit) were focussed on in more detail.

We estimated that at least 40% of earthquakes (greater than or equal to magnitude 1.5) in the UK between 1970-2012 were naturally occurring. Natural earthquakes in the UK may have various causes; from gravitational effects of the Mid-Atlantic Ridge, to isostatic rebound following the last ice age. At least 21% of the UK's earthquakes in the same period are thought to be man-made. The vast majority of earthquakes deemed to be man-made in the UK appear to be related to coal

mining. This is backed up by a strong correlation between coal production and seismicity, with the pit closures during the 1980-90s coinciding with a noticeable drop in number of events

### Conclusions

ReFINE research estimates that at least 21% of earthquakes in the UK since 1970 have been caused by human activity and that these are mostly linked to coal mining. On average the UK experiences approximately 3 man-made earthquakes per year (figure 2), with a maximum of 8 events in a year. This baseline will allow researchers to determine the impact of any potential fracking activity on the occurrence of man-made earthquakes in the future.



**Figure 2:** Number and cause of seismic events since 1999. *Solid line* – average baseline of 3 man-made events per year. *Dashed line* – baseline of 12 events per year, assuming half of undefined events are man-made.