Fracking Part 1: An Introduction

Rick Bradford, written 14 December 2022

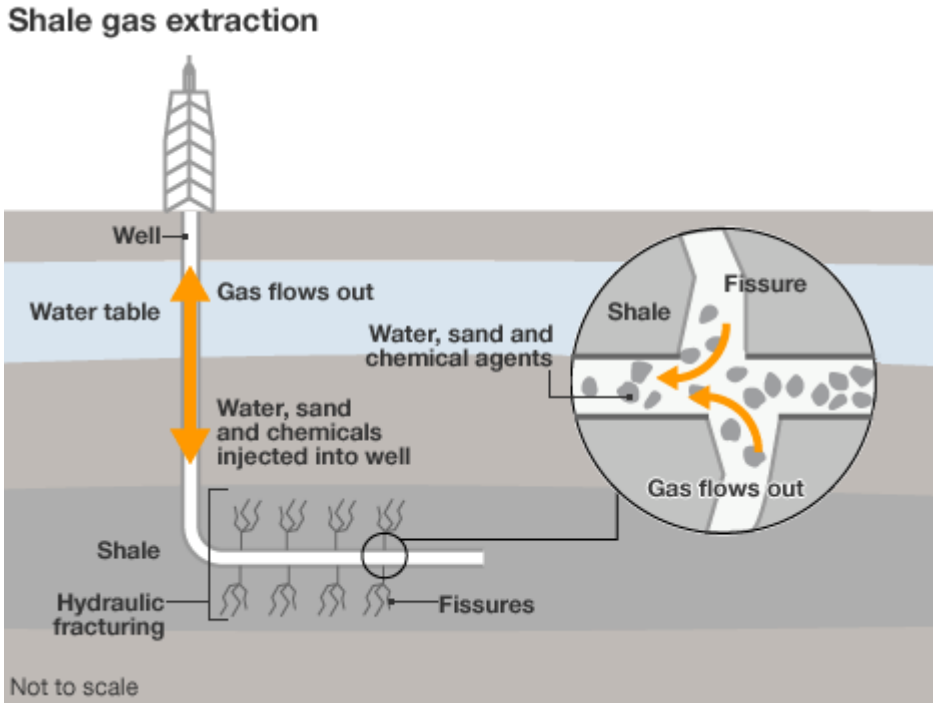
Cuadrilla's test fracking site, Lancashire, UK

This is an introduction to the basics of fracking inland gas wells which I wrote in 2013. I have made some updates, the chief of which is removal of the material relating to the possible association of fracking with earthquakes in the USA. This will be covered in detail in an accompanying Part 2.

What is fracking?

If you drill into geological strata containing gas or oil you do not necessarily get a lot of the hydrocarbon flowing out of the top of the hole. This will only happen if the geological strata are sufficiently porous to permit the fluid to flow through it - and thence into your bore hole. Often the strata are sufficiently porous to support flow at a commercially viable rate and this is the basis of conventional oil and gas wells. However, if the strata are not sufficiently porous then they can be made so by fracturing. This can be accomplished by injecting fluid (usually predominantly water) at very high pressure (~9000 psi). The resulting hydraulic fracturing (=fracking) renders the strata porous and can produce a profitable flow of gas or oil.

Figure 1



Are explosives used in fracking?

Yes.

Once a well has been drilled and cased, explosive charges are fired to perforate holes along the bore hole at selected intervals within the shale formation. Fracturing fluids, consisting of water, sand ('proppant') and chemicals, are pumped under high pressure into the well. The injection pressure generates stresses in the shale that exceed its strength, opening up existing fractures or creating new ones. The fractures extend a few hundred metres into the rock and the newly created fractures are propped open by the sand.

Is there anything else novel about fracking technology?

Yes.

Shale-strata fracking wells consist of the usual vertical bore hole, but to a greater depth than conventional wells (typically a mile or more). The unique requirement, however, is that the drilling be able to turn to the horizontal - perhaps for several miles. It is the horizontal part, lying entirely within the shale strata, which provides the gas or oil.

How widespread is fracking in the USA?

Hugely!

The number of gas-producing wells in the USA peaked at over half a million, though there are now rather less. However only a proportion of these are fracked. Fracking of inland wells started in the USA in the 1940s, but only became widespread from 2009. There are about a quarter of a million recorded and characterised fracking events associated with gas wells in the USA by 2022 (see https://www.fracfocus.org).

Is fracking new to the UK?

No.

Hydraulic fracturing has been common in the UK's North Sea oil and gas fields since the late 1970s (see Detlef Mader, 1989, *Hydraulic Proppant Fracturing and Gravel Packing*, Elsevier, p.174). Moreover, fracking has also been used in ~200 British ***inland*** sites since the 1980s (see the review by the Royal Society, Shale gas extraction in the UK, June 2012). This includes the Wytch Farm field in Dorset which produces the majority of UK onshore oil and is Europe's largest onshore oil field. Although widespread use of fracking has recently become associated with the USA, in fact it has been used throughout Western Europe on inland sites since the 1980s.

So why has fracking become controversial?

In common with many subjects made topical by the media, the label is misleading. The real issue is not fracking *per se*: it is hydrocarbon extraction from the unusually deep shale strata that is the issue. To do this, fracking is invariably required. But fracking itself is not new.

However, inland wells have been a relatively minor source of oil and gas in the UK to-date, so we have little experience of the disruption which very large-scale inland extractions might cause.

If fracking has long been accepted for shallower wells, why should there be an issue now for deeper wells?

Good question. Detractors appear to be wilfully ignoring this experience. But practical, full scale engineering experience should be given far greater weight in judging the issue than theorising or scaremongering. There is also the possibility that opposition to fracking originates from a completely separate agenda, e.g., an absolutist determination to stop all fossil fuel usage. (Since I wrote this originally it has become abundantly clear that there are extremist groups with this absolutist agenda and their belligerent actions appear to receive tacit support from much of the establishment authorities).

Will fracking cause gas to come out of my water tap?

No.

One of the most iconic symbols of the fracking debate in the USA some ten years ago was the video of a man setting his tap water on fire in the infamous 2010 anti-fracking documentary *Gasland*. The same footage has been shown on UK TV. In both cases the use of this footage in an article about fracking carries the deliberate implication that fracking, and specifically fracking for shale gas extraction, was to blame. But no evidence to this effect was presented. Viewers in the UK will mostly be used to their water being provided via extensive piping systems from a reservoir, often many tens of miles from their home. They may not immediately appreciate that the footage in question, taken in the town of Dimock, Pennsylvania, related to water from a domestic well. In this area it is usual for property owners to drill for their own water on their own property. *Gasland* did not seem to think it necessary to enlighten the viewer as to this fact. However, this is all you need know to begin to suspect that the source of the unwanted methane is far more likely to be shortcomings in the householder's own water well than anything to do with fracking. This suspicion is consolidated by interviews with other residents of the area who have endless stories of natural (biogenic) methane coming out of personal water wells going back 70 years. *Gasland* has been comprehensively deconstructed by a more recent documentary,

FrackNation,[1]. Whilst I recommend you view this, the suggestion that the anti-fracking lobby might be funded by the Russians lacks actual evidence. (False claims of the Russians being behind anything you don't like is endemic in the USA). Nevertheless, if the anti-fracking lobby has a case it is not best served by the sort of sensationalist presentation of *Gasland*, especially if it turns out to be entirely spurious.

Of course, since gas extraction involves gas flowing up long drilled holes, it is not impossible that the gas might go where it was not intended. All engineering is fallible. So even for Dimock it is not impossible that poor shale-well casing (a relatively common occurrence) might be implicated in some instances of methane-in-water (though not in all cases since the phenomenon has been around longer than fracking). However, there appears to be no reason to regard deep shale gas extraction via fracking to be any different from other gas wells in this respect. In both cases, preventing adverse outcomes is a matter of following sound engineering practice, particularly in regard to the integrity of the concrete well casing.

Will fracking cause earthquakes?

In this section I merely make an introduction to the earthquake issue in the UK. In Fracking Part 2 I will analyse US data. This section is what I wrote in 2013.

What do you mean by "an earthquake"? A lorry driving past your house may cause it to shake, perhaps up to Richter scale 3 (ML).

The Royal Society's 2012 review concluded that "*Seismic risks are low….Seismicity induced by hydraulic fracturing is likely to be of smaller magnitude than the UK's largest natural seismic events and those induced by coal mining*".

On 1st April 2011, the Blackpool area in north England experienced seismicity of magnitude 2.3 ML shortly after Cuadrilla Ltd hydraulically fractured a well at its Preese Hall site. Seismicity of magnitude 1.5 ML occurred on 27th May 2011 following renewed fracturing of the same well. As a result, hydraulic fracturing was suspended across the whole of the UK for ~18 months whilst reviews were carried out. Cuadrilla itself sponsored the first review, *Geomechanical Study of Bowland Shale Seismicity by Dr. C.J. de Pater and Dr. S. Baisch: Synthesis Report*, 2 November 2011. This synthesis report utilises independent technical reports prepared by Seismik (lead investigator Dr. Leo Eisner), Q-con (lead investigator Dr. Stefan Baisch), Geosphere (Dr. Tim Harper), StrataGen (lead investigator Dr. C.J. de Pater) and Baker-GMI (lead investigator R. Guises). Amongst other things the review concluded that 3 ML events would be the worst case for fracking and associated well extraction activities. The same upper bound was found by Green *et al* (2012): *Preese Hall shale gas fracturing: review and recommendations for induced seismic mitigation, Department of Energy and Climate Change.*

To put this in context, the UK experiences seismicity of magnitude 5 ML (felt by everyone nearby) about every twenty years, and of magnitude 4 ML (felt by many people) every three to four years. The UK has lived with seismicity induced by coal mining activities or the settlement of abandoned mines for a long time. British Geological Survey records indicate that coal mining-related seismicity is generally of smaller magnitude than natural seismicity and no larger than 4 ML. The events at Preese Hall, in contrast, were of a level comparable with background noise.

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It is hard to overstate the triviality of events of magnitude 2.3 or below which led to the banning of fracking in the UK.

The actual fracturing activities are likely to occupy only a few days in the life of a well which might be producing for tens of years. However some have claimed that a ~3 ML event is less likely to be associated with the fracking operation itself as with fluid movements thereafter, e.g., to dispose of waste water underground (due to pumped water encouraging movement of faults). Robert Mair, who chaired the Royal Society's 2012 review, has been quoted as saying, "We found that well integrity is of key importance but the most common areas of concern, such as the causation of earthquakes with any significant impact or fractures reaching and contaminating drinking water, were very low risk".

Will shale gas/oil extraction use huge quantities of water?
No.

This has been one of the claims made by the anti-fracking lobby. In perennially drought-ridden States like Texas it is understandable that people would be concerned about water usage. I quote one source which appeared to be reliable regarding the experience in the USA:-

"There is no question that hydraulic fracturing uses a lot of water: It can take up to 7 million gallons to frack a single well, and at least 30 percent of that water is lost forever, after being trapped deep in the shale. And while there is some evidence that fracking has contributed to the depletion of water supplies in drought-stricken Texas, a study by Carnegie Mellon University indicates the Marcellus region has plenty of water and, in most cases, an adequate system to regulate its usage. The amount of water required to drill all 2916 of the Marcellus wells permitted in Pennsylvania in the first 11 months of 2010 would equal the amount of drinking water used by just one city, Pittsburgh, during the same period, says environmental engineering professor Jeanne VanBriesen, the study's lead author. Plus, she notes, water withdrawals of this new industry are taking the place of water once used by industries, like steel manufacturing, that the state has lost. Hydrogeologist David Yoxtheimer of Penn State's Marcellus Center for Outreach and Research gives the withdrawals more context: Of the 9.5 billion gallons of water used daily in Pennsylvania, natural gas development consumes 1.9 million gallons a day (mgd); livestock use 62 mgd; mining, 96 mgd; and industry, 770 mgd".

As regards the British opinion, the 2012 Royal Society review states, "Estimates indicate that the amount (*of water*) needed to operate a hydraulically fractured shale gas well for a decade may be equivalent to the amount needed to water a golf course for a month; the amount needed to run a 1,000 MW coal-fired power plant for 12 hours; and the amount lost to leaks in United Utilities' region in north west England every hour" quoting the source as Moore (2012), *Gas works? Shale gas and its policy implications*, Policy Exchange: London,

I conclude that inordinate water usage is not an issue.

Are the additives used in the fracturing fluid kept secret?

No.

There was, at one time, some controversy in the USA about this, but drilling companies have now published the content of their drilling/fracturing fluids. In Britain there is a legal requirement to disclose their contents. They are typically ~95%

water and ~5% sand (the "proppant" which holds the fractures open) with ~0.17% chemical additives. The latter are mostly lubricants and viscosity reducers, scale inhibitors, acids (to assist fracturing) and biocides to kill off bacteria.

The exact chemical composition of fracking waters used in the USA can be found in the 6 million records available at https://www.fracfocus.org. Clearly, not secret.

Where does the water end up?

Typically about one-third of the water is not seen again, i.e., it remains in the shale deposits, with two-thirds re-emerging from the well as "produced water". However, this fraction is highly variable and insufficient experience exists as yet to judge what it would be in UK shales. The produced water is not the same as it was when it was injected. It picks up water from the shale and hence becomes saline; it entrains methane and contains a wide range of organic and inorganic compounds from the shale. Since virtually anything that is dug up from depth is radioactive to some degree, so is the produced water (extremely mildly so).

The produced water can be re-used by injecting back into the well, and this is encouraged to minimise both water usage and the volume of waste water. Drill sites must have temporary waste water storage facilities. In the US, open ponds have been used, but in the UK these are not permitted and closed-loop storage tanks would be required. Ultimately the waste waters must be disposed of permanently, possibly in purpose-drilled disposal wells. There is a raft of existing regulations in the UK including the Mining Waste Directive, the Water Framework Directive, the Borehole Sites and Operations Regulations 1995 and the Radioactive Substances Regulations. (From what I have read, radioactivity is unlikely to be a significant problem).

I haven't looked into this issue in great depth but if I were to spend more time on fracking then the safe, effective disposal of waste waters would be the area to address in more detail. Is "fracking" any worse in this respect than existing well and mining operations? And is existing legislation sufficient in the new context?

Could the fractures propagate to aquifers and hence pollute water sources?

It seems not, at least in theory.

The hypothesised threat is that the deep-injected fluids could migrate into groundwater via a network of fractures from the shale layer to the relatively shallow aquifers. Sources I have seen claim that basic geology prevents such a mechanism. A fracture caused by the drilling/fracking process would have to extend through the several thousand feet of rock that separate deep shale gas deposits from freshwater aquifers. The intervening layers of rock have distinct mechanical properties that would prevent the fissures from expanding the required mile or more toward the surface.

This mechanism was considered by the 2010 review sponsored by Cuadrilla, specific to the Bowland shale geology: "In the worst case, the fluid could migrate upwards along a potential fault plane by 2000 ft. Because of the presence of a very thick impermeable formation overlying the Bowland shale and the Permian anhydrites that will act as barrier, there is negligible risk of fluid breaching into permeable layers".

The 2012 Royal Society review, Shale gas extraction in the UK, also considers this postulated mechanism and likewise concludes it to be of very low risk.

Has deeply injected water ever migrated into drinking water?

This is a spectre which the anti-fracking (actually the anti-fossil fuel) lobby have been keen to "big up", though the fears seem to be based mostly on surmise rather than evidence.

I address here the issue of potential contamination of drinking water from below, due to fracking being postulated to open fissures between the shale strata and the aquifers. A completely separate – and far more likely scenario – is contamination arising either from fracking waters stored on the surface, or from faulty well casings leading to leakage from the lining of the well. Both these are very credible scenarios, but both are manageable and a matter for proper engineering control.

Daniel Soeder, in *Fracking and Water (2020)*, notes that "no study has found aquifer contamination from below by upward-migrating frack fluids to be a significant concern."

In my 2013 article I did identify one case that seemed to require close attention. This is the town of Pavillion, Wyoming. In 2010, the US Environmental Protection Agency (EPA) issued a draft report saying that the controversial practice of fracking was to blame for the pollution of an aquifer below Pavillion – the first time such a claim had been based on a scientific analysis.

There were some strange goings-on in 2010 which I recorded in my 2013 article thus,

"*The (EPA) study drew heated criticism over its methodology and awaited a peer review that promised to settle the dispute. Strangely, and to the great surprise of environmentalists and energy industry supporters alike, the EPA announced in June this year that it was handing over the leadership of these Pavillion investigations to Wyoming State. The report will not now be peer reviewed or finalised. The EPA thus appears to be backing-off from the controversy. The research by the State of Wyoming will be funded by EnCana, the very drilling company whose wells may have caused the contamination. So this turn-around by the EPA stinks*."

However, the final position was a complete volte-face as stated in the EPA's 2019 report,

"*Evidence did not indicate that hydraulic fracturing fluids have risen to shallow depths utilized by water-supply wells. Based on an evaluation of hydraulic fracturing history and methods used in the Pavillion Gas Field, it is unlikely that hydraulic fracturing has caused any impacts to the water-supply wells*."

I conclude the threat of contamination of drinking water from below, due to fracking opening fissures between the shale strata and the aquifers, is without evidential basis and considered highly improbable.

Could well blowouts happen?

Of course.

All oil/gas wells are potentially subject to blowouts, and blowouts have happened on fracking wells in the US. The threats are to the safety of the workers and the pollution that would result from an uncontrolled flow of fracking fluids, oil, etc. Once again, though, I cannot see anything unique to fracked wells here. A conventional oil well will kill people and cause pollution if it blows-out. Since Deepwater Horizon we all know about the protective role of the Blowout Preventer (and various other valves). So this comes down to sound engineering build and operation, as per usual.

How much shale gas is there in the UK?

Early estimates of the total gas-in-place in England, specifically the Bowland Shale and the Hodder Mudstone deposits, were made by Andrews (2013), *The Carboniferous Bowland Shale gas study: geology and resource estimation* (British Geological Survey). This indicated a massive volume of methane in the range 822 to 2281 trillion cubic feet (tcf). (I presume all gas volumes relate to STP, i.e., 0°C and 1 bara).

However, the more recent analysis by Whitelaw et al (2019), *Shale gas reserve evaluation by laboratory pyrolysis and gas holding capacity consistent with field data*, indicates a far smaller volume of gas-in-place within the Bowland Shale of only 140 tcf.

In addition there are reserves in the Midland Valley of Scotland, the Strathclyde and Clackmannan Group. Monaghan (2014), *The Carboniferous shales of the Midland Valley of Scotland: geology and resource estimation*, has estimated the amount of gas-in-place to be between 50 and 135 tcf. This would bring the UK total to at least 190 tcf

However, most of this gas will not be economically recoverable. Assuming 10% is economically recoverable, then 19 tcf is available in the UK. The UK currently consumes 2.8 tcf of methane annually, so this would represent only about 7 years supply. However, in the current energy climate it may be more significant to observe that if shale gas made a 20% contribution then we're looking at it lasting about 35 years.

It is clear from the above discussion that the uncertainty in the reserves of inland shale gas in the UK are huge. In reality, there may be far more than the above lower-bound estimates, and if so this would become clearer as extraction took place.

Worldwide, the technically recoverable reserves of shale gas have been estimated to be 7,300 tcf (of which 665 tcf is in the USA) and non-shale gas more than double that.

Will "fracking" be a blot on the UK landscape?

I don't know, but the large number of wells that might be required is a significant concern.

I expect there is little difference between a fracked well and any other gas/oil well in this respect. Fracking technology does have the advantage of long horizontal well sections which means that one drill site can extract from within a circle of radius several miles. Conventional wells might have required many separate drill sites.

Environmentalists will frighten you with pictures like this,

...but does it really have to look like this? I suspect not. Here's three others that don't look so bad...

For me the issue is the spacing between wells. I have seen sources claiming 8 to 16 wells per square mile. I find this odd, though, since horizontal well bores of a mile in length (and assuming many bores are possible in a range of directions) would imply a 2 mile spacing between wells. I suspect these two scenarios would make a huge difference to the visual impact.

To extract the 19 tcf of UK shale gas would require several thousand wells. All these would require vehicular access. Trucks and tankers would need to visit, possibly quite regularly. Whilst the US has been able to absorb ~500,000 wells, I suspect they have the wide open, and sparsely populated, regions available to do so. In crowded Britain it would be another matter. I find this aspect to be of significant concern.

Conclusions

There are clear issues associated with large scale inland extractions of oil or gas in an overcrowded island, though these are not unique to fracked wells. The most significant problems are,

- Potentially serious deleterious impact on the landscape, and the need for regular, heavy vehicles to access extensive areas previously 'unspoilt';
- Poor well integrity leading to fracking fluids causing pollution;
- Secure storage and ultimate disposal of waste waters.

The latter two points are essentially 'routine' issues which should be possible to address through good engineering design/build and operation. Neither are unique to "fracked" wells, or even to wells in general (mining and many other industrial activities can have similar issues). The first bullet is of greater concern since it may be largely unavoidable during operation. However, decommissioning to green field is perfectly feasible in the longer term, especially if site pollution is avoided (the latter two bullet points).

It is not entirely clear that induced earthquakes are unique to fracked wells, either, as other operations associated with inland oil or gas wells, e.g., waste water disposal, may be the chief culprit. The latter may be more manageable. Certainly minor earthquakes have long been associated with industrial activities, especially mining. So context is necessary before one technology is outlawed based on a criterion that other existing technologies would also fail.

I close on the observation that banning fracking in the UK based on two seismic events, of magnitudes 1.5 and 2.3, is clearly completely preposterous. Figure 2 shows how common are minor earthquakes in the UK (the map relates to a mere 20 year period). The British Geological Society gives the following logarithmic expression for the number, N, of earthquakes occurring per year above a magnitude M in the UK,

$$\text{Log10}(N) = 3.82 - 1.03M$$

(illustrated graphically by Figure 2). This tells us that earthquakes with magnitudes between 1.5 and 2.3 occur in the UK 160 times per year as it is. Quakes between magnitudes 2 and 3 occur 52 times per year in the UK. If the Cuadrilla test well events are regarded as an unsafe outcome, then we should all flee the country immediately…except that almost everywhere else is far worse.

In truth an event of (say) magnitude 2.3, or even somewhat higher, was inevitable. Cuadrilla were therefore set up to fail. The ban was obviously intended before they started, and the "test" was never a fair one.

Figure 2: British Geological Survey's Map of UK Earthquakes, 2000 – 2020. Minor earthquakes are extremely common.

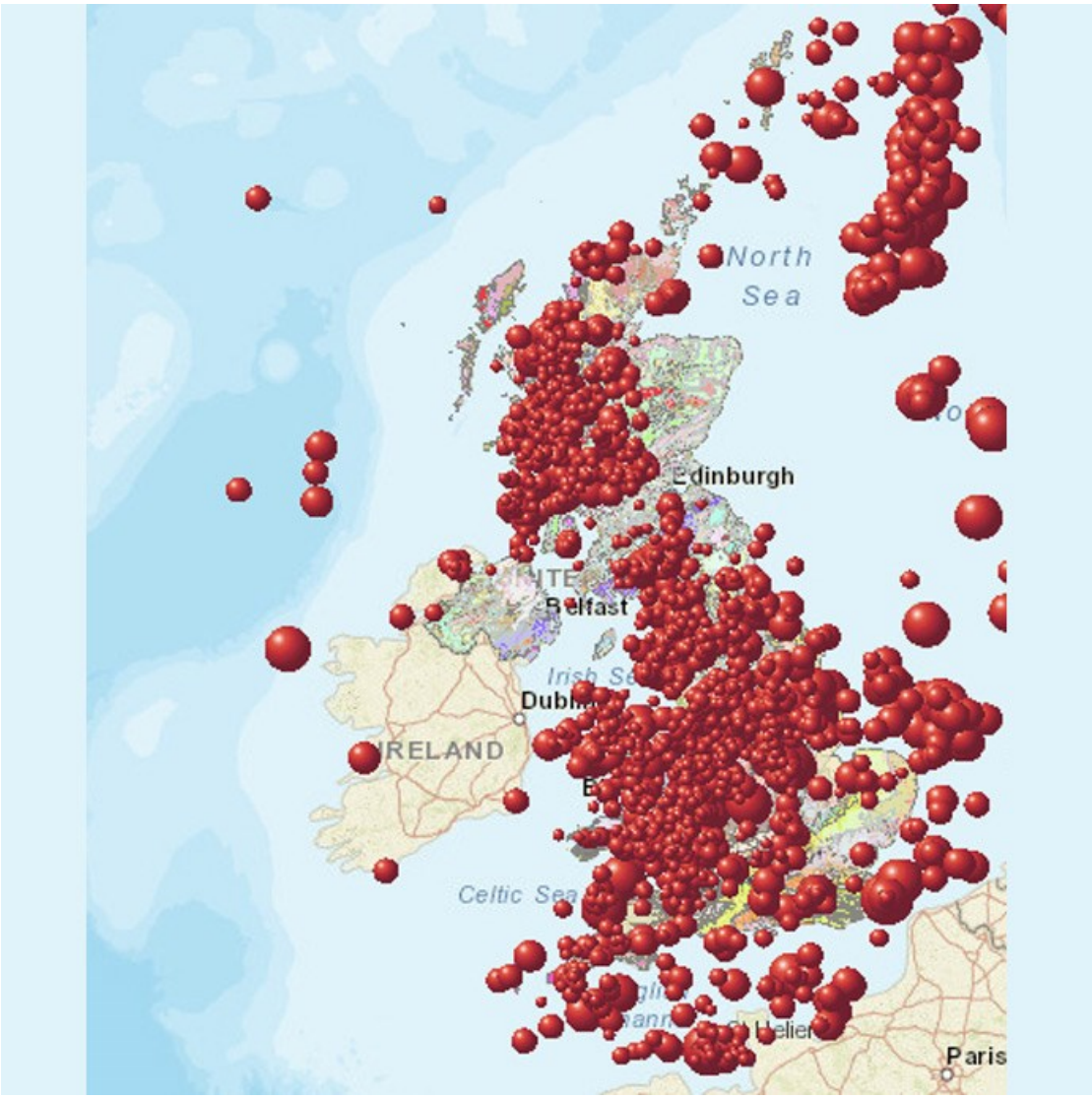

Figure 3: Logarithmic relationship between earthquake frequency and magnitude (UK), from the British Geological Society.