Third Schatzalp Workshop on Induced Seismicity

Session 3: Natural or Induced, and Beyond

Towards a More Robust and Transparent Simplified Scheme for the Discrimination of Induced from Natural Seismicity

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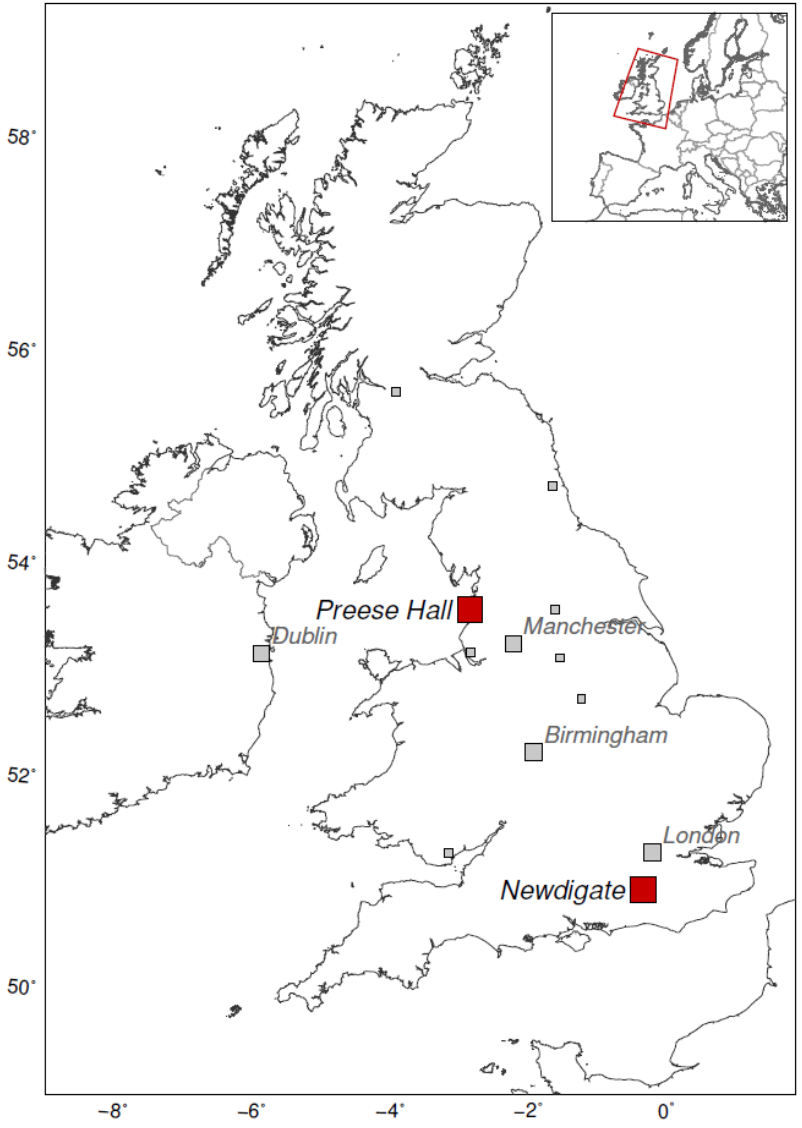
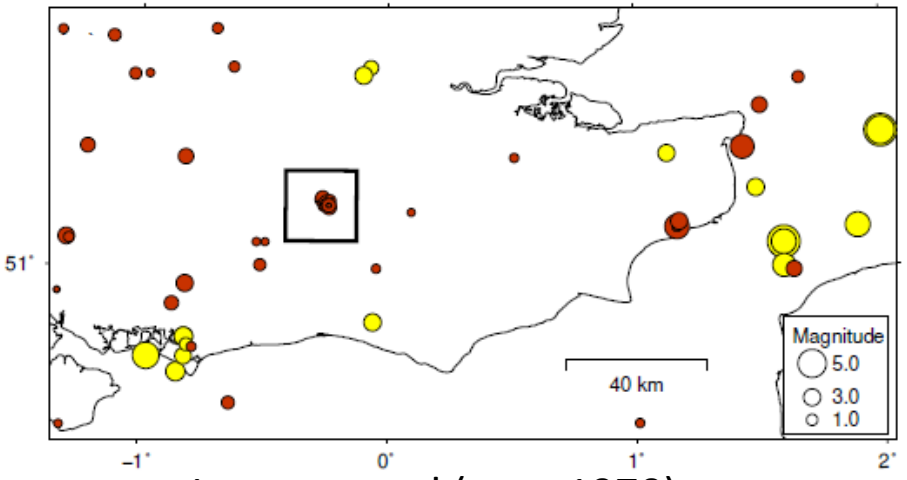
Background

Earthquake sequence near Newdigate, UK, March-July 2018

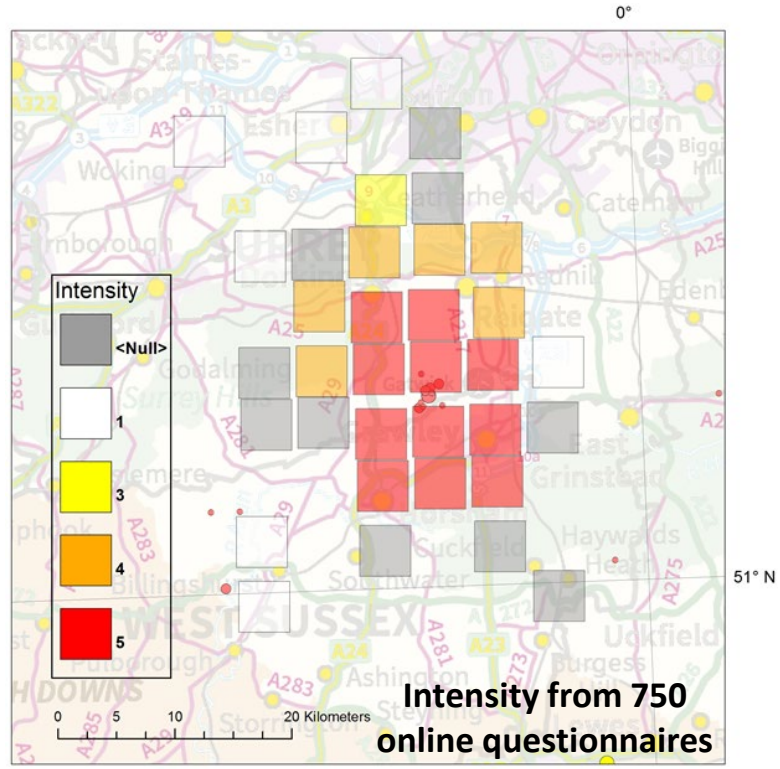
Largest event had magnitude M_L 3.0, four others exceeded M_L 2.0

Seven of the events were reported to be felt by local population, with a maximum EMS intensity of V for the largest earthquake



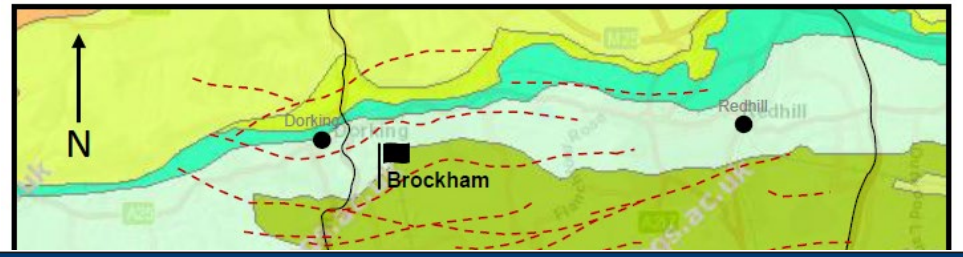


- Instrumental (post-1970)
- Historical (pre-1970)



Induced Events?

The events occurred in an area with many small oilfields, the closest being Brockham and Horse Hill



Courtesy of Andrew Hollis, Angus Energy

Local campaigners have been protesting oil companies in Surrey after earthquakes in the area were linked with drilling operations *(Office of Keith Taylor MEP)*

Groups opposed to oil production in The Weald protested following the earthquakes

And inevitably there were claims about fracking……

The 2018-2019 Newdigate, Surrey, UK seismic swarm: induced by nearby oilfield activites, or not?

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I have just driven past Newlands Corner, and for

Doesn't take a genius to

Howard Avery

THE TIMES

6th August 2018

Surrey quake fears

Sir, A moratorium is urgently needed on hydrocarbon exploration in the area of Surrey recently affected by 12 earthquakes. We believe that public health and the environment are not being adequately protected given the unstable geology, which had not been identified before permits were issued for the currently active drill sites.

The abrupt onset of the earthquake cluster recorded by the British Geological Survey at Newdigate since April 1 requires an explanation, and gives rise to our concerns about safety. Oil drilling, extraction and re-injection can cause earthquakes.

There are two oil sites in the immediate area: Horse Hill and Brockham. A causal link with either well site cannot be ruled out, so we need the full picture for the risk assessment. Well integrity in these circumstances is a serious concern.

The moratorium on drilling, re-injection and flow testing should be put in place immediately and remain in force until the records of fluid injection and local faulting activity have been comprehensively surveyed and interpreted, and the triggering mechanism for this quake cluster properly understood.

We call on the energy secretary and regulatory bodies to address this issue without delay.

STUART GILFILLAN FGS, senior lecturer in geochemistry at School of GeoSciences, University of Edinburgh; STUART HASZELDINE FRSE, professor of geology, University of Edinburgh; BILL MCGUIRE, emeritus professor in geophysical and climate hazards, UCL; RICHARD SELLEY, emeritus professor of petroleum geology, Imperial College London

Surrey earthquakes: Scientists call for oil drilling ban as mysterious tremors continue to strike region

Warning comes after 12 earthquakes strike county in four months

Josh Gabbatiss Science Correspondent | @josh_gabbatiss |
Monday 6 August 2018 12:30 | 134 shares |

Local campaigners have been protesting oil companies in Surrey after earthquakes in the area were linked with drilling operations *(Office of Keith Taylor MEP)*

Oil & Gas Authority

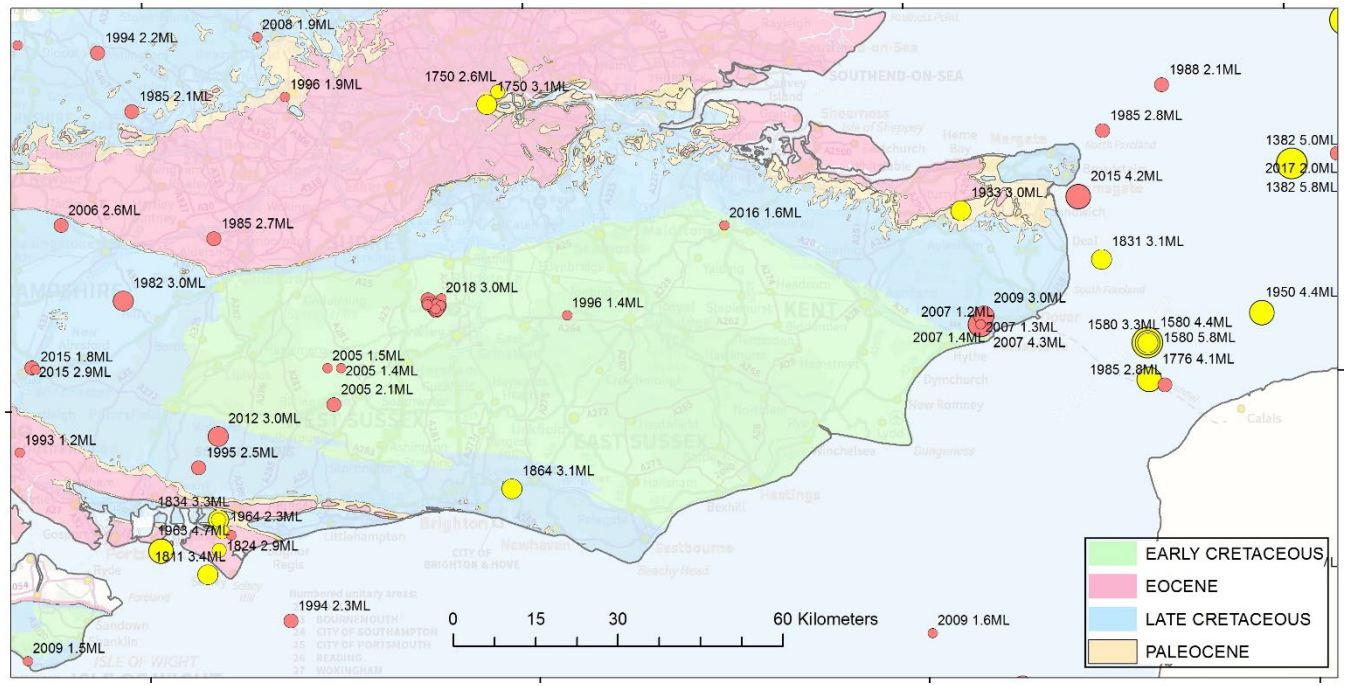
In response to the letter in *The Times*, the UK Oil & Gas Authority called a meeting in October 2018, which about 20 specialists—including signatories of the letter, the oil companies, and the British Geological Survey—to discuss the evidence regarding the possible connection of the earthquakes to the Brockham and Horse Hill oil fields

OGA Newdigate Seismicity Workshop – 3 October 2018

Summary and conclusion

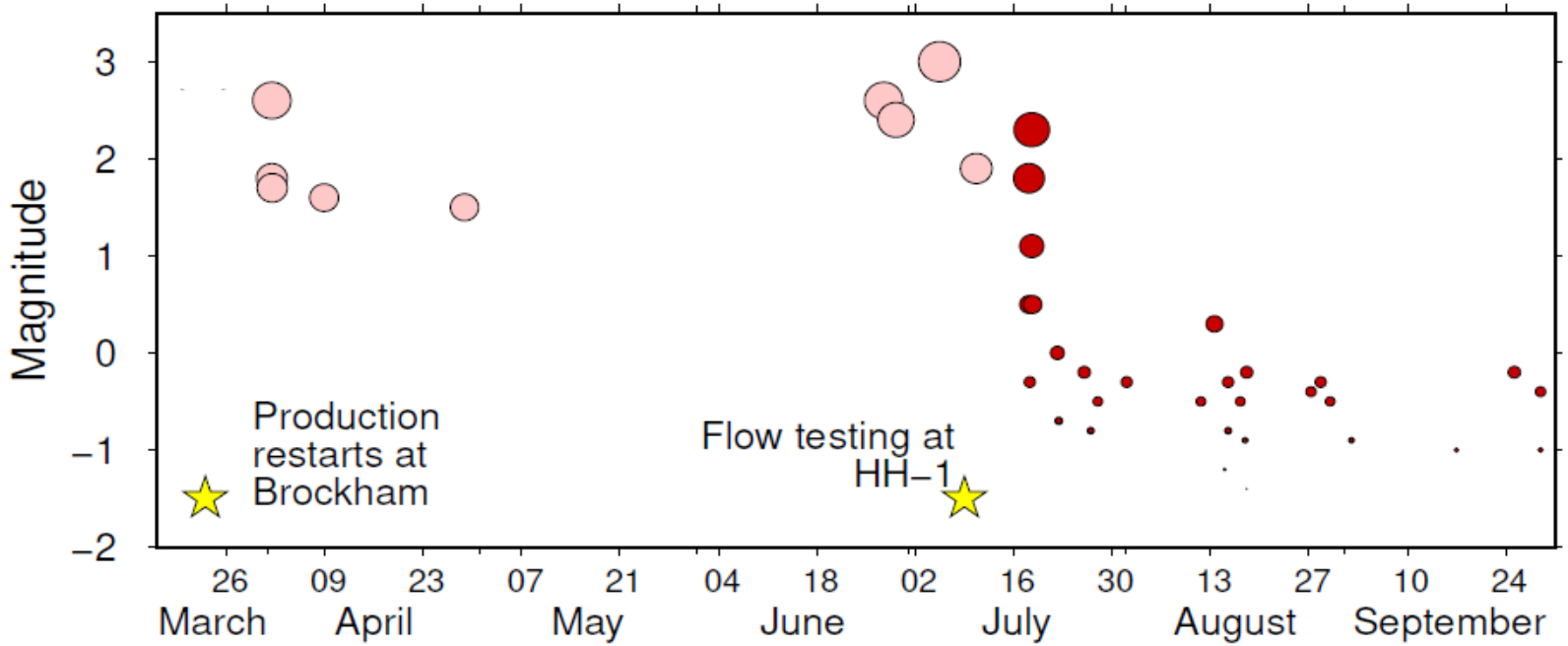
"The workshop participants concluded that, based on the evidence presented, there was no causal link between the seismic events and oil and gas activity although one participant was less certain and felt that this could only be concluded on 'the balance of probabilities' and would have liked to see more detailed data on recent oil and gas surface and subsurface activity."

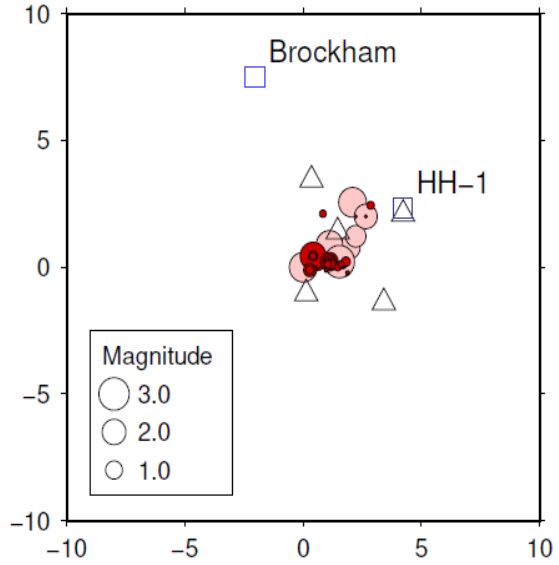
https://www.ogauthority.co.uk/media/5174/2018_11_23-newdigate-workshop-summary-finalv3.pdf



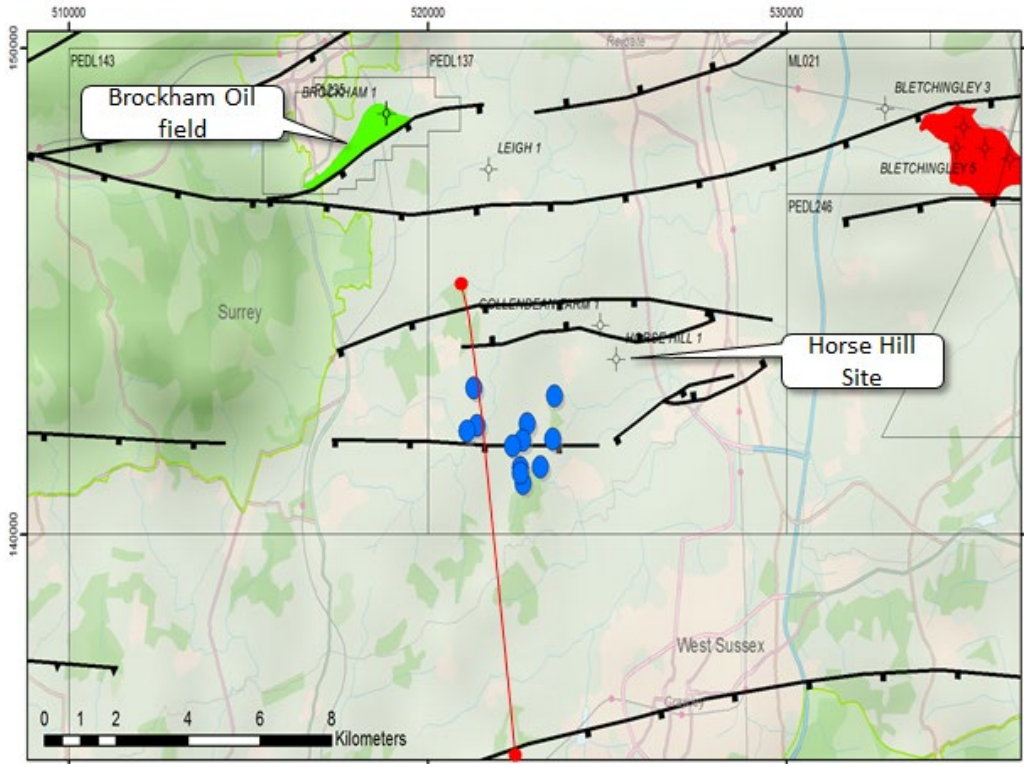
The shallow earthquakes are not inconsistent with previous activity in this part of the UK, where focal depths in sedimentary basins are generally much smaller than in other areas

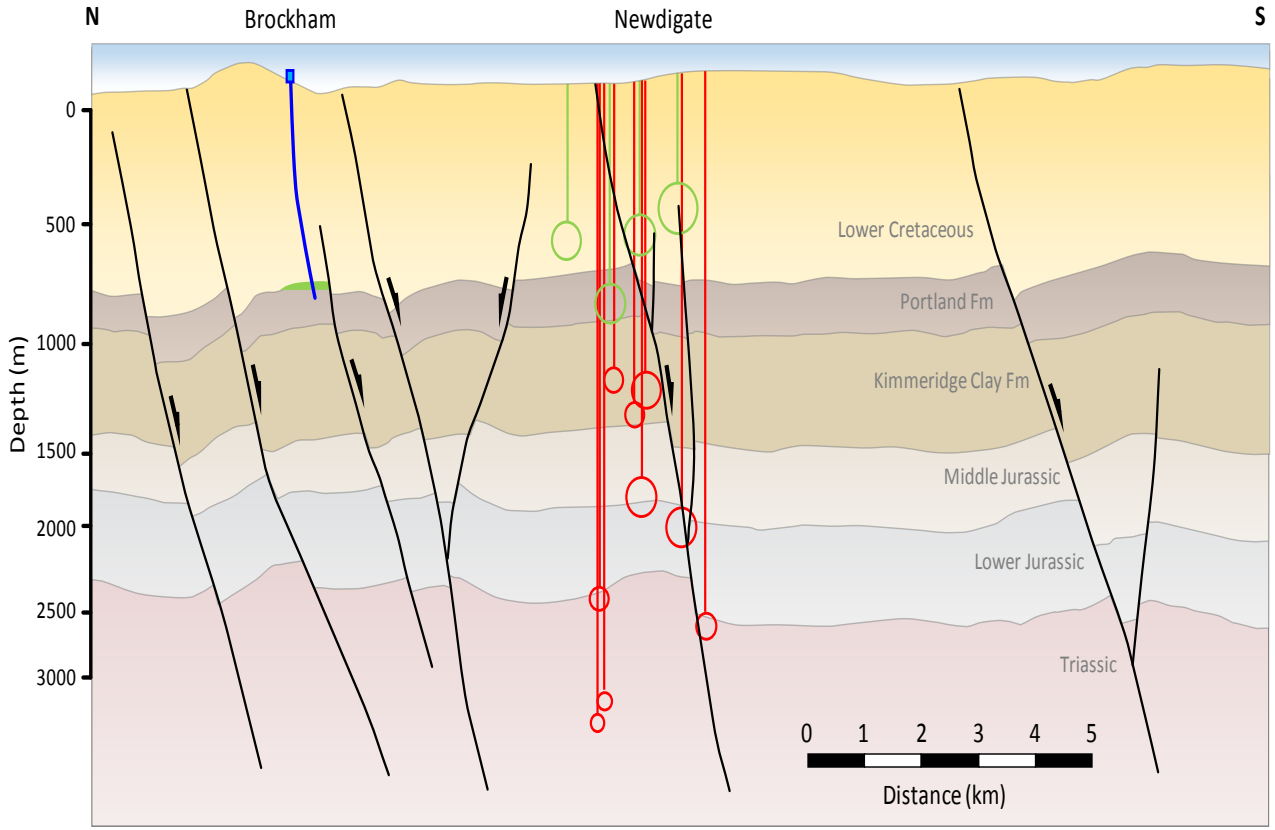
The epicentres were much closer to Horse Hill (~4 km) than to Brockham (~8 km), but the events started before any operational activities at the Horse Hill well





The Brockham field is separated from the earthquakes by several normal faults that are likely to act as baffles to fluid propagation





Induced or Natural Events?

A notable outcome from the OGA meeting was that both the proponent for the events being induced and several participants who arrived at the opposite conclusion, made their case on the basis of applying the criteria of Davis & Frohlich (1993)

Seismological Research Letters, Volume 64, No. 3–4, July–December, 1993

DID (OR WILL) FLUID INJECTION CAUSE EARTHQUAKES? - CRITERIA FOR A RATIONAL ASSESSMENT

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ABSTRACT

Occasionally, the injection of fluids into deep wells causes or triggers earthquake activity. We propose two lists of yes-or-no questions to assess 1) whether an ongoing injection project has induced an earthquake that has already occurred; or 2) whether a proposed injection project is likely to induce a nearby earthquake. The answers to these questions form a descriptive profile of the injection project that

OGA Newdigate Seismicity Workshop – 3 October 2018

"The Davis and Frohlich (1993) criteria provide a reasonable framework within which to assess in a general sense whether events might be anthropogenic. However, the participants felt that these criteria also generate ambiguities. An alternative, more robust set of criteria, developed by academia, perhaps including a more quantitative assessment, would be desirable, especially in cases such as this where significant public interest is involved."

Davis & Frohlich (1993) Criteria

Temporal Correlation

1. Are these events the first known earthquakes of this character in the region?

2. Is there a clear correlation between injection and seismicity?

Spatial Correlation

3a. Are epicentres near wells (< 5 km)?

3b. Do some earthquakes occur at or near injection depths?

3c. If not, are there known geologic structures that may channel flow to the sites of earthquakes?

Injection Practices

4a. Are changes in fluid pressure at well bottoms sufficient to encourage seismicity?

4b. Are changes in fluid pressure at hypocentral locations sufficient to encourage seismicity?

All questions answered, if possible, with "yes", "no" or, in some cases, "yes?" or "no?"

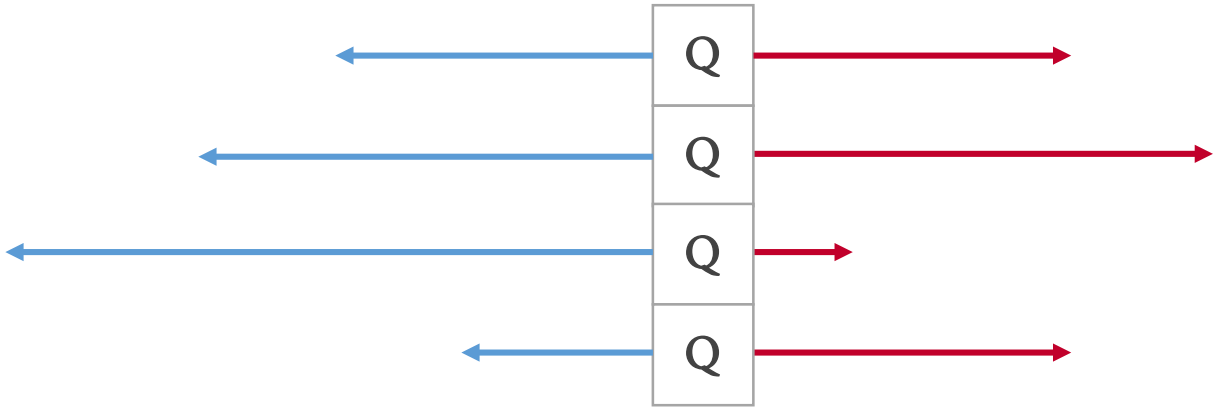
Final assessment determined by sum of "yes" and "yes?" responses (which are treated as being equivalent)

A Critique of the Davis & Frohlich (1993) Criteria

- Each question is given equal weight, although some factors may be far more important than others in determining whether or not seismic events are induced or natural
  - *Assign different weights to different questions to reflect their importance*
- "Yes" and "Yes?" treated as equivalent (=1)
  - *Assign scores to questions that reflect the degree of certainty*
- "No", "no?" and questions that could not be answered all treated as equivalent (=0)
  - *Remove unanswerable questions from scoring*
- The final rating does not give any indication of how good is the available evidence
  - *Provide a separate rating for the completeness of the available data*
- No questions posed regarding evidence that might support a tectonic origin
  - *Positive scores for induced, negative scores for tectonic*

Proposed New Scheme

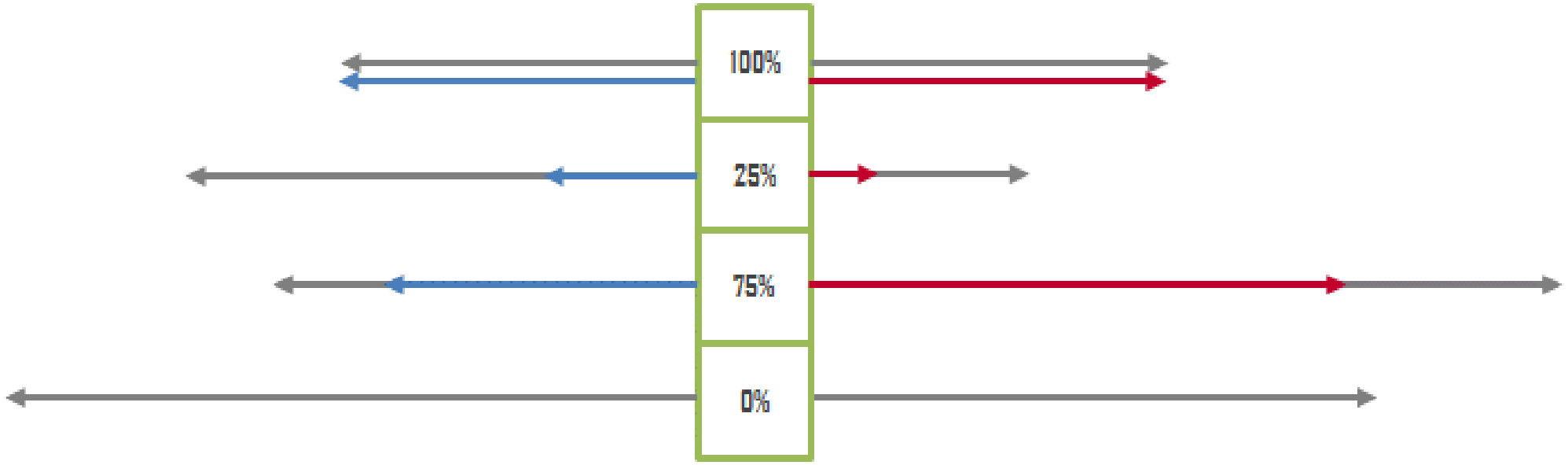
Questions for which different positive (induced) and negative (induced) scores can be assigned



Assess the completeness of the data available to make the assessment (*i.e.,* to respond to these questions and assign scores)

Evidence Strength Ratio (ESR)

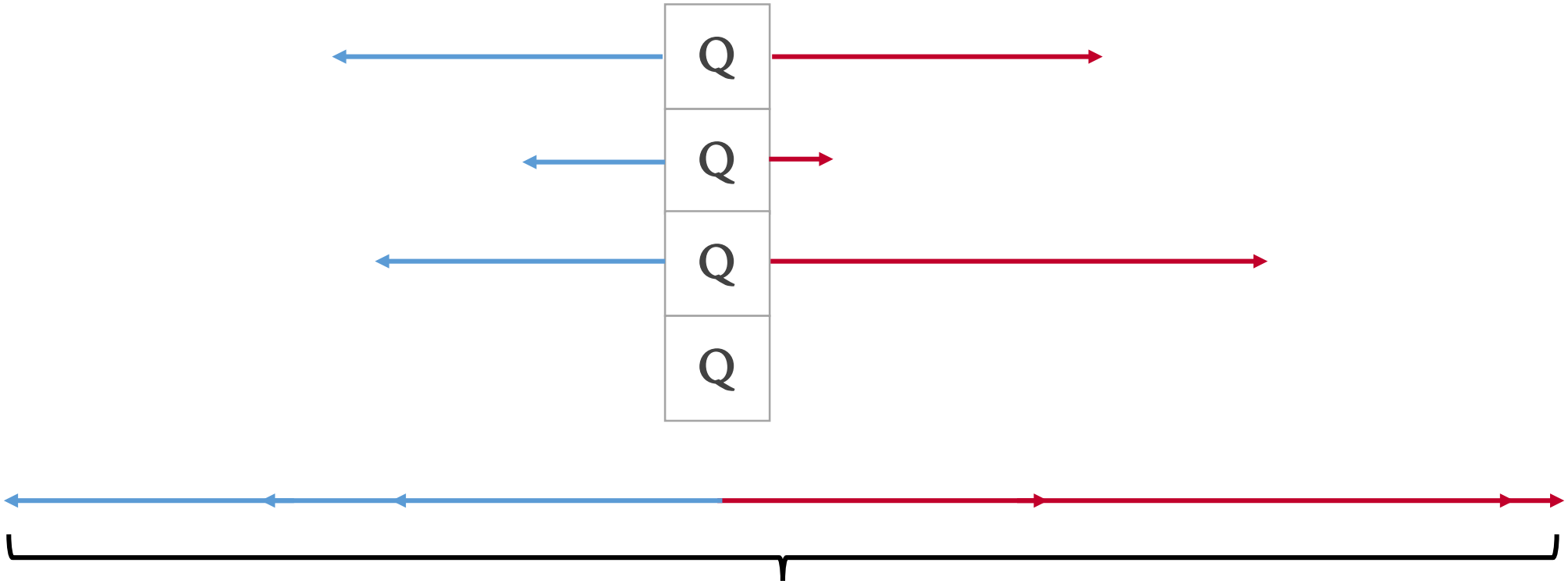
A parameter to qualify the degree of constraint on the assessment



$$\mathrm{ESR} = \frac{(|\text{Maximum } -\text{ve points given available data}| \; + \; |\text{Maximum } +\text{ve points given available data}|)}{\text{Total number of } +\text{ve and } -\text{ve points that can be scored in the framework}} \times 100$$

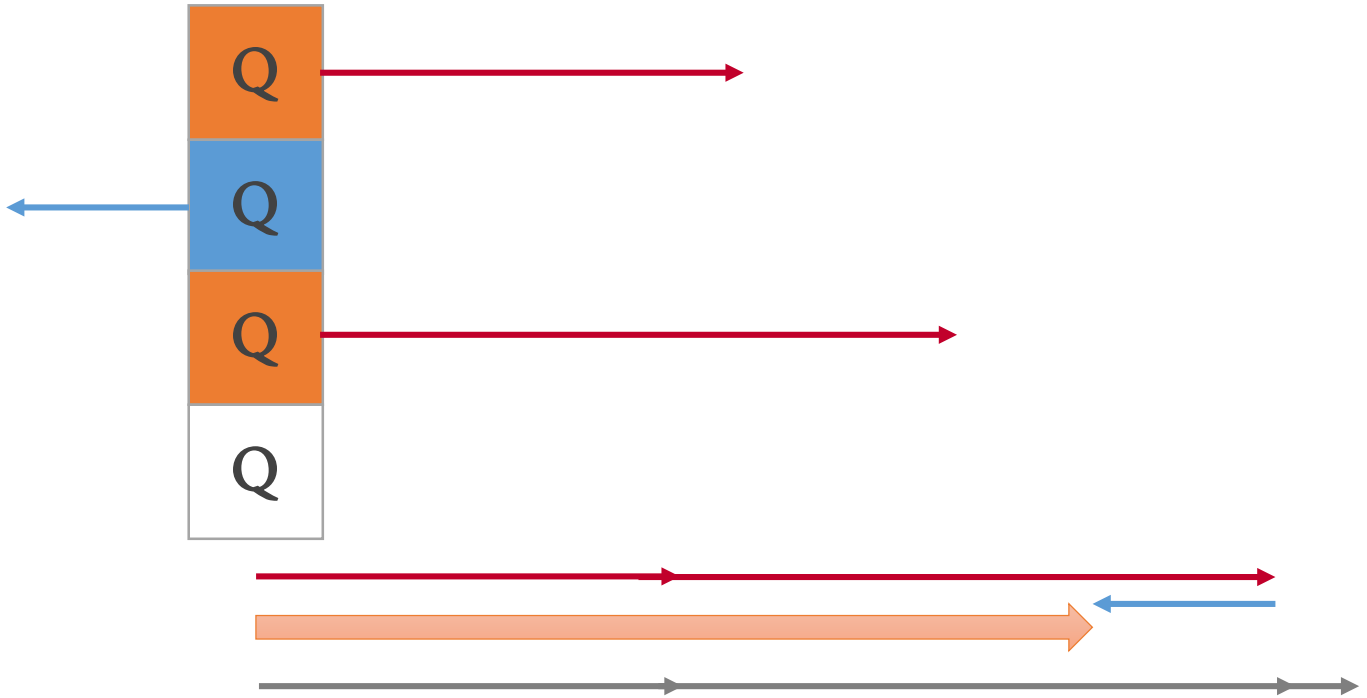
Induced Assessment Ratio (IAR)

Having determined the ESR, the case is assessed using only the available scores:



The total length of this bar reflects the ESR

Induced Assessment Ratio (IAR)



$$IAR = \frac{\text{Summed score}}{|\text{Maximum points given available data}|} \times 100$$

Application to UK Cases

Newdigate sequence, 2018

Time of Assessment	Horse-Hill 1		Brockham	
	ESR	IAR	ESR	IAR
Early (June 2018)	20%	+15%	46%	-8%
Final	92%	-79%	92%	-33%

Preese Hall, 2011

Time of Assessment	Preese Hall	
	ESR	IAR
Early (April 2011)	42%	+75%
Final	82%	+83%

Concluding Remarks

Regulators and operators require simple assessment procedures to distinguish induced/triggered seismicity from natural earthquakes, for which question-based schemes such as that proposed by Davis & Frohlich (1993) are well suited

We propose a new framework that maintains the simplicity of such approaches while addressing shortcomings related to their implementation and interpretation

A full paper on the framework is currently undergoing minor revision for publication in *Seismological Research Letters* –would be very grateful for additional feedback!