Institution: Keele University

Unit of Assessment: UoA14 Geography and Environmental Studies

Title of case study: Seismic shift: the transformation of UK government policy on fracking

Period when the underpinning research was undertaken: 2003-2017

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Prof. Peter Styles	Professor of Geophysics Emeritus Professor	2008-2017 2017-present
Dr Ian Stimpson	SL in Geophysics	1987-present
Dr Nigel Cassidy	Reader in Geophysics	2001-2016
Dr Jamie Pringle	SL in Geoscience	2006-present
Dr Glenda Jones	Teaching Fellow	2018-present
Dr Rachel Westwood	Research Associate	2014-2017
Mr Samuel Toon	Research Associate	2001-2018

Period when the claimed impact occurred: 2014-2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact (indicative maximum 100 words)

Keele's research on fracking has guided UK government policy for shale gas extraction over the past decade, informing stakeholders on causes of fracking-related seismicity and identifying high-risk regions and procedures to mitigate risk. Recommendations from Keele's research led to the 'traffic light' system of magnitude limits, enforcing operators to conduct detailed surveys. In August 2019, the UK's largest fracking-induced earthquake triggered a 'red light' and suspension of fracking. The Oil and Gas Authority, based on Keele's research, concluded it is not currently possible to predict the probability of fracking-associated tremors, placing a moratorium on fracking in England from November 2019.

2. Underpinning research (indicative maximum 500 words)

Keele has a fifty-year history of developing theory, methods and applications used to characterise and monitor geotechnical, geological and geo-environmental problems. The Keele Applied and Environmental Geophysics (KAEG) group, in collaboration with the British Geological Survey (BGS), led research into 'induced' seismicity related to hydraulic fracturing (fracking). This led to the award of two EU Horizon 2020 programmes in 2015 (SHEER and EPOS), which underpin the development of a new open-source data platform (**3.1**).

Fracking can recover oil and gas from unconventional shale gas reservoirs with low permeability. The process sparked widespread concern from the British public, with 40% of respondents opposed to fracking in the Department for Business, Energy and Industrial Strategy (BEIS) public attitudes survey (2019, n=4224). 45% of these were concerned by increased earthquake risk.

Fracking generates networks of small fractures in impermeable rock, injecting a mix of water, sand and chemicals under high pressure, creating pathways along which hydrocarbons flow. This generates microseismic activity with magnitudes too small to be felt. However, if the injected fluid encounters a pre-stressed pre-existing geological fault, the change in fluid pressure can cause the fault to fail, inducing larger seismic events that can be felt over wider geographical areas, potentially damaging surface infrastructure (**3.2**). Critically, given that not all locations of natural faults are known in advance, it is currently not possible to accurately predict the probability of fracking-associated tremors.

In Spring 2011, a series of low-magnitude earthquakes, the largest of which registered 2.3 Local Magnitude (LM), occurred during fracking testing by Cuadrilla Resources at Preese Hall, Lancashire (**3.2**, **3.3**, **3.4**). KAEG, with BGS, installed seismometers to monitor induced seismic activity during fracking at the site, recording 50 earthquakes with similar waveforms to the initially detected earthquakes (**3.3**, **3.4**). The study concluded that earthquake activity resulted from direct fluid injection into a previously unidentified adjacent fault zone, reactivating it (**3.3**, **3.4**). The discovery that fracking can reactivate faults has been applied by UK government agencies to restrict development of fracking areas where known faults exist.

KAEG's work, with Durham and Newcastle universities, established a national baseline for anthropogenic earthquakes in the UK. The research found that from the mid-1980s to the 2000s detected anthropogenic earthquakes per year declined (**3.5**). Past levels of anthropogenic earthquakes in the UK have been high, with a concentration of coal mining-related earthquakes in Derbyshire, Nottinghamshire and Staffordshire coalfields (**3.5**). Mapping of subsurface faults in these coalfields is currently patchy, with the possibility of unknown faults that could be reactivated if fracking were to take place nearby (**3.2**, **3.5**).

KAEG has applied its expertise in geomechanical modelling to understand the level of stress changes caused by fracking and the influences these have upon geological structures, including faults (**3.6, 3.7**), indicating that minor changes of one parameter can markedly reduce/increase the risk of seismic events occurring on a pre-existing critical fault. A key recommendation made is that fracking operators complete detailed mapping of faults to fully understand the local geology prior to fracking, and that operations are monitored against guidelines (**3.3**, **3.6, 3.7**).

3. References to the research (indicative maximum of six references)

3.1 Orlecka-Sikora, B., Lasocki, S., Kocot, J., Szepieniec, T., Grasso, J. R., Garcia-Aristizabal, A., Schaming, M., Urban, P., Jones, G., Stimpson, I., Dineva, S., Sałek, P., Leptokaropoulos, K., Lizurek, G., Olszewska, D., Schmittbuhl, J., Kwiatek, G., Blanke, A., Saccarotti, G., Chodzińska, K., Rudziński, Ł., Dobrzycka, I., Mutke, G., Barański, A., Pierzyna, A., Kozlovskaya, E., Nevalainen, J., Kinscher, J., Sileny, J., Sterzel, M., Cielesta, S. and Fischer, T., 2020. An open data infrastructure for the study of anthropogenic hazards linked to georesource exploitation: **Nature Scientific Data**, 7, 89.

3.2 Styles, P., 2018. Fracking and Historic Coal Mining: Their relationship and should they coincide? **Report**, Keele University.

3.3 Green, C.A., Styles, P. and Baptie, B.J., 2012. Preese Hall shale gas fracturing review and recommendations for induced seismic mitigation. **Independent report** (a review for the Department of Energy & Climate Change).

3.4 Clarke, H., Eisner, L., Styles, P. and Turner, P., 2014. Felt seismicity associated with shale gas hydraulic fracturing: The first documented example in Europe. **Geophysical Research Letters**, 41(23), pp. 8308-8314. Doi.org/10.1002/2014GL062047.

3.5 Wilson, M.P., Davies, R.J., Foulger, G.R., Julian, B.R., Styles, P., Gluyas, J.G. and Almond, S., 2015. Anthropogenic earthquakes in the UK: A national baseline prior to shale exploitation. **Marine and Petroleum Geology**, 68, pp. 1-17. Doi.org/10.1016/j.marpetgeo.2015.08.023.

3.6 Westwood, R., Toon, S. and Cassidy, N.J., 2017. A sensitivity analysis of the effect of pumping parameters on hydraulic fracture networks and local stresses during shale gas operations. **Fuel**, 203, pp. 843-852. Doi.org/10.1016/j.fuel.2017.05.004.

3.7 Westwood, R.F., Toon, S.M., Styles, P. and Cassidy, N.J., 2017. Horizontal respect distance for hydraulic fracturing in the vicinity of existing faults in deep geological reservoirs: a review and modelling study. **Geomechanics and Geophysics for Geo-Energy and Geo-Resources**, 3(4), pp. 379-391. Doi.org/10.1007/s40948-018-0081-y.

Grants:
EU Horizon 2020: Understanding, preventing and mitigating the potential environmental impacts and risks of Shale Gas Exploration and Exploitation (SHEER) (2015-2018; €291,808).

EU Horizon 2020: European Plate Observing System: long-term plan to facilitate integrated use of data, data products, and facilities from distributed research infrastructures for solid Earth science in Europe (EPOS Implementation) (2015-2019; €162,275).

4. Details of the impact (indicative maximum 750 words)

KAEG has been involved in informing public debate and the government on fracking-induced seismic activity. KAEG's fracking research has been reported in numerous media outlets, with an international reach of >12 million, including reports in the US, Germany and Singapore, and extensive UK coverage by the BBC, Sky, LBC, the Guardian, Daily Express and Financial Times (**5.1**). KAEG expert opinion has been sought by several environmental groups, including Greenpeace (**5.2**), and local community action groups such as 'Frack Free United' and 'Residents Action on Fylde Fracking' (**5.1**). KAEG has worked with policymakers, raising awareness, informing understanding of geologically vulnerable areas, and how fracking-induced earthquakes are triggered. The research (**3.2-3.7**) has been applied to guidelines and policy regulating the UK fracking industry.

Advising the UK government and developing fracking policy

Over the past decade, KAEG has advised the UK government on how fracking-related earthquakes are caused, high-risk areas where fracking should be avoided, and procedures needed to minimise the risk of fracking-induced earthquakes (see **3.2**).

Following fracking-related seismic activity at Preese Hall, Lancashire, the UK government reviewed regulations and, in 2012, introduced a traffic light system (**5.3**). Ed Davey, then Energy Secretary, stated, "This was a key decision – based on the best science available – and after extensive consultation. Indeed, I insisted on consulting on the report itself and its recommendations to promote as much transparency as possible." (**5.2**). The system put in place a series of checks to monitor seismicity, requiring drilling to stop for 18 hours in the event of tremors >0.5ML, a standard recommended to government in a 2012 report co-authored by Prof. Styles (**5.2, 5.4**). Further recommendations have also been implemented, including the requirement of operators to conduct local geological studies, including mapping faults and fully understand local geology, to assess whether fracking could reactivate existing faults (**5.5 5.6**). The Oil and Gas Authority (OGA) also makes an independent assessment of the likelihood of seismic activity based upon recommended geological studies (**5.6**).

On 22nd May 2018, Prof. Styles' report (**3.2**) was launched in the House of Lords in an event hosted by Baroness Lynne Featherstone, who commented, "This report asks some serious questions of the Government and the fracking industry. Ministers must take heed and listen to the growing weight of evidence on fracking and, at the bare minimum, implement a moratorium on fracking in coal mining areas and review fracking across the UK" (**5.7**). On the same day, an Early Day Motion (EDM) on fracking in former coalfield areas was presented to the House of Commons by John Mann, supported by 19 MPs. The EDM draws upon **3.2**, highlighting 'the risk of earthquakes posed

by fracking beneath coal-mined areas where mining-induced seismicity has already occurred' (**5.8**). It calls on 'the Secretary of State for Communities and Local Government' to adopt Prof. Styles' best-practice recommendation that planning applications for any fracking site include all available, high-resolution, carefully mapped datasets and incorporate these in the 'National Planning Policy Framework', and further calls on 'the Government and local authorities to place a moratorium on fracking-related activities in coalfield areas' (**5.8**). The report was cited in the House of Commons Housing, Communities and Local Government Committee (2nd July 2018), in a report titled 'Planning guidance on fracking 2017–19' (**5.9**). In this, the committee recommends that the government assesses fracking guidance and responds to its findings that fracking in former coal mining areas could reactivate old or unknown faults (**5.9**).

In August 2019, fracking began at Preston New Road 2 (PNR2), Lancashire, after agreeing a Hydraulic Fracture Plan with fracking operator Cuadrilla (**5.3**). The plan proposed using mitigation measures recommended in **3.3**, including the traffic light system, to undertake geological surveys of the area and monitor seismic activity (**5.3**). Fracking commenced at the site on 15th August; a series of seismic events were recorded including red-light events that resulted in fracking being paused. On 26th August, the UK's largest fracking-induced earthquake occurred, measuring 2.9ML, which was widely felt across the region with cosmetic damage to some buildings (**5.3**). Based upon the measures proposed in **3.3**, OGA suspended operations. In an interim OGA report in November 2019 (**5.3**), based upon the seismic data and traffic light monitoring system at PNR2, it was concluded that it is not possible with current technology to accurately predict the probability of fracking-associated tremors. Based on this, the government put a moratorium on fracking in England (**5.4**, **5.10**). Business and Energy Secretary Andrea Leadsom MP said, "In the UK, we have been led by the best available scientific evidence...after reviewing the OGA's report into recent seismic activity at Preston New Road, it is clear that we cannot rule out future unacceptable impacts on the local community" (**5.10**).

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1 Spreadsheet of media coverage.

5.2 Greenpeace (7 May 2018) Unearthed online magazine, Do the UK's fracking miniquakes matter?

5.3 Oil and Gas Authority (2019) Interim report of the scientific analysis of data gathered from Cuadrilla's operations at Preston New Road.

5.4 Testimonial from Helena Charlton, Deputy Director, Oil and Gas Exploration and Production, at Department Business, Energy and Industrial Strategy.

5.5 Department for the Environment and Climate Change (2014) Fracking UK shale: understanding earthquake risk.

5.6 Department for Business, Energy & Industrial Strategy, 12 March 2019, Guidance on fracking: developing shale gas in the UK.

5.7 Oil change international, 22 May 2018, 'Fracking "Could Cause Earthquakes On Up To Half Of Land Licensed In UK"'.

5.8 House of Commons Early Day Motions, 22 May 2018, Fracking in the former coalfield area.

5.9 House of Commons Housing, Communities and Local Government Committee Planning guidance on fracking Eighth Report of Session 2017–19.

5.10 Department for Business, Energy & Industrial Strategy, 2 November 2019, Press Release 'Government ends support for fracking'.