

Institution: Durham University
Unit of Assessment: Earth Systems and Environmental Sciences (UoA 7)
Title of case study: Safe Fracking: Understanding Environmental Risk and Influencing Government Policy
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>Durham research on hydraulic fracturing was an important part of the UK government's reasoning for lifting the ban on hydraulic fracturing to recover gas and oil from shale, which has an estimated commercial value in the UK of £1500 billion. We demonstrated that hydraulic fractures will not be tall enough to cause contamination of water supplies where there is a sufficient vertical separation (> 600 m) between the shale reservoir and the drinking water aquifer. Durham research has also provided critical data needed by national environment agencies setting regulations, oil and gas companies seeking permission from regulators to drill wells and for local communities that are objecting to hydraulic fracturing.</p>
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>[numbers] = references listed in Section 3</p> <p>Professor Richard Davies was appointed to a Chair in Durham Earth Sciences in 2006. He is presently Professor of Energy in Durham Energy Institute and Dean of Knowledge Exchange and Impact for Durham University. He has worked on natural hydraulic fracturing due to overpressure in many geological settings since 2002 (14 papers), including mud volcano systems. This led to three key papers on the Lusi mud volcano (Indonesia) which started to erupt on May 29th 2006 [1-3]. Davies coordinated an international team by leading the authorship of two papers and also two comments on other contradictory research. These all examined the role of hydraulic fracturing due to an influx of fluid into a gas exploration well versus the Yogyakarta earthquake (May 27th 2006) as triggers for the volcano. Our research concluded that hydraulic fracturing in the subsurface, caused by insufficient casing of a gas well was the trigger for the eruption.</p> <p>Investigating the role of hydraulic fracturing in the Lusi disaster and the engagement with non-specialists was an important precursor that led to research on hydraulic fracturing for the recovery of gas and oil from shale, a process known as 'fracking'. The technology involves drilling horizontal wells through low permeability shale and fracturing them using a pressurized fracking fluid which is mainly water, but with chemical additives. This increases gas flow rates so that commercial extraction is possible. In 2009-2010, around 20,000 shale gas wells were fracked by 9 companies in the USA alone. There have been significant environmental concerns surrounding the technology, with some academics, politicians, public organisations and NGOs accusing the oil and gas industry of polluting drinking water supplies with methane [4] and the chemicals in the fracking fluid. The aim of the key research [5] was to test this controversial hypothesis and to provide an evidence base for an initial safe vertical separation distance between shale reservoirs and aquifers.</p> <p>We measured the reported heights of thousands of upward propagating hydraulic fractures from several thousand fracking operations in the Marcellus, Barnett, Woodford, Eagleford and Niobrara shales (USA) mainly from published sources. We also measured 1170 natural hydraulic fractures imaged with three-dimensional seismic data offshore of West Africa [6] and mid-Norway where heights are no more than ~ 1106 m. Based on the empirical data, we derived probabilities that fractures, both natural and those from fracking, exceed a range of heights. The probability of a stimulated and natural hydraulic fracture extending vertically for distances > 350 m is ~ 1% and ~ 33% respectively. The maximum height of a stimulated fracture was 588 m. Therefore if fracking is carried out at depths of at least 600 m below the drinking water aquifer, the risk of contamination is extremely small as no fractures have been documented to extend to this distance. Conversely, if fracking is within this 600 m safe separation distance, then there is a real risk of contamination. We therefore recommended a 600 m safe separation distance.</p> <p>This is extremely important as an evidence base for decisions on the safe vertical separation</p>

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between stimulated hydraulic fracturing and rock strata not intended for penetration. The research provides a basis for policy decisions about fracking around the globe.

The key paper [5] and its impact were used as a pilot for a £0.79M consortium 'ReFINE' (Researching Fracking IN Europe), which was set up in 2012-13. It is led by Davies and is funded by NERC, Total, Chevron and Shell. Partners are DECC; Environment Agency; Joint Research Centre (EU); The Geological Society, London, the Bulgarian Geological Society and 3 other UK universities. Sir David King chairs its science board. [5] and other papers have been summarised in research-briefs for non-specialists and translated into 10 languages and video summaries (<http://www.refine.org.uk>).

For the key paper [5] the external co-authors' role was minor. They provided 2 out of the 8 datasets in the study and minor edits to the text.

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

[number of citations, Google Scholar]

= references included in REF submission

* = authors that are not academics at Durham University

† = students at Durham University

[1] Davies, R.J., Swarbrick, R.E., Evans, R.J.* & Huuse, M.,* 2007, Birth of a mud volcano: East Java, 29 May 2006. *GSA Today*, 17, 4-9. doi: 10.1130/GSAT01702A.1 [92]

[2] Davies, R.J., Brumm M,* Manga M,* Rubiandini, R.,* Swarbrick, R.E., & Tingay, M.,* 2008, The East Java mud volcano (2006 to present): An earthquake or drilling trigger? *Earth and Planetary Science Letters* 272, 627–638. doi:10.1016/j.epsl.2008.05.029 [54]#

[3] Tingay, M.,* Heidbach, O.,* Davies, R.J., & Swarbrick, R.E., 2008, Triggering of the Lusi mud eruption: Earthquake versus drilling initiation. *Geology* 36, 639-642. doi:10.1130/G24697A.1 [25]

[4] Davies, R.J., 2011, Methane contamination of drinking water caused by hydraulic fracturing remains unproven *PNAS* 2011 108 (43) E871. doi: 10.1073/pnas.1113299108 [9]

[5] Davies, R.J., Mathias, S.A., Moss, J.,* Hustoft, S.,* & Newport, L.,† 2012, Hydraulic Fractures: How Far Can They Go? *Marine and Petroleum Geology*, 37, 1-6. doi:10.1016/j.marpetgeo.2012.04.001 [13]

[6] Davies, R.J., & Clark A.L.† 2010, Methane recycling between hydrate and critically pressured stratigraphic traps, offshore Mauritania, *Geology*. 38, 963-966. doi:10.1130/G31058.1 [3]#

Quality of Research:

Papers 1&2 have 10-15 citations per year. Refs 2-4&6 were published in *Geology* and *Earth and Planetary Science Letters*. These journals publish papers of international significance for a wide readership and in 2013 have Impact Factors of 4.1 and 4.3 respectively. Refs 2&6 are submitted as research outputs for REF 2014. Ref 1 led to global news coverage including articles in the journals *Science* and *Nature*.

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

[numbers] = research outputs listed in Section 3 or corroboration sources listed in Section 5.

The key paper [5] was published online on 23rd April 2012. A press release was issued on the same day and the research results were widely reported in the international press. Davies discussed the results with the Senior Geophysicist at DECC - Department of Energy and Climate Change) and presented to a wider DECC audience in London on 25th April 2012. On 27th Nov 2012 Davies gave evidence to the Energy and Climate Select Committee on shale gas, chaired by Rt. Hon. Tim Yeo MP. The impact of the research has been in four main areas:

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(1) **Policy:** On 13th Dec 2012 the government announced its decision to lift the ban on fracking. In a Radio 5 Live interview on the same day, John Hayes (Minister of State for Energy at the time) twice referred to the Durham study as providing evidence that contamination could not occur if fracking were to commence in Lancashire, UK. During the 6 min radio piece [7], John Hayes said *'the claim that the water used in fracking gets into the aquifer was categorically refuted by the Durham University study'*.

A month later on Jan 16th 2013, Hayes gave evidence to the Energy and Climate Change Select Committee who were sitting to consider 'The Impact of Shale Gas on Energy Markets'. The transcript of oral evidence and Parliamentary video record show that the questions and answers moved onto the how shale gas could benefit communities financially. Rt. Hon. Tim Yeo MP (Chair) asked about ways of *'kick-starting the whole [shale gas exploitation] process'*. John Hayes responded *'I think the issue of benefit and incentive is one that needs to be considered closely'* then he added *'In addition, one might say more information and more understanding—clearly the Royal Society of Engineers' report has been helpful, the Durham University study has been helpful, and, as things move on, I suspect provision of more information will lead to a greater degree of engagement'* [8].

The radio interview prompted Davies to ask a senior DECC official how the research had been used in government. In his email to us (Jan 17th 2013) [9], he states: *'the study was included in a briefing to ministers, including John Hayes and 'it was also referenced in the Royal Society and Royal Academy of Engineering report on fracking, and the DECC Chief Scientist discussed it with John Hayes'*.

The evidence shows the research was a key part of the scientific case that the UK government used to justify the lifting of the ban and allay public concerns. The commercial value of this decision is difficult to quantify precisely, but if it leads to large-scale exploitation of shale gas, it will likely run into billions or tens of billions of pounds.

Davies has also presented the research results across Europe (London, Brussels, Poland, Ukraine, Romania, Bulgaria and Lithuania) including five meetings with the Bulgarian government's '42nd Bulgarian National Assembly Sub-Committee on Shale gas'. This is tasked with analyzing and discussing good practices and legislative solutions to regulate activities relating to exploration and extraction of mineral resources while protecting the environment. Bulgaria presently has a ban on fracking in place. The Manager of the Global Technology Centre at Chevron, one of the world's leading integrated energy companies, said *'The paper and engagement of Richard Davies has helped promote a dispassionate, objective, fact-based approach to concerns expressed regarding shale gas development to a sceptical public and media. This will be critical to inform regulation and enable social license to operate for natural gas from shale which has an important potential role to play in the UK and EU energy mix in the decades to come.'*

(2) **Awareness of risk for local communities.** In May 2012, concerns came to a head in the Sussex Village of Balcombe (population 1,765) over proposals by Cuadrilla to carry out fracking for shale gas and oil in the area. The Balcombe community pointed out to Charles Hendry (Minister of State for Energy at the time) and to the Head of Licensing, Exploration and Development at DECC [10] that the separation distance was less than 600 m and this was grounds to not allow fracking at this site. This triggered a series of internal government emails between DECC and the Environment Agency on its policy with regard to aquifers.

(3) **Process and practice:** For shale gas wells where the separation distance between water aquifers and the fracking is greater than 600 m, the study has been used as supporting evidence for safe drilling [11&12]. Approval documents for the drilling of 34 shale gas wells in Garfield county, Colorado, USA have cited the research. The commercial significance is that a shale gas well costs approximately £4 million and 34 wells therefore cost a total of £136 million, with the inevitable impact of job creation and allowing for the exploitation of shale in this state, which in turn generates revenue.

(4) **Protection of the environment:** The study has been used by the Natural Resources Defence Council to influence the USA Environmental protection agency, who are developing policy on fracking. The UK's Environment Agency uses the research to identify areas where it may need to acquire more detailed information and expertise [12], particularly if it is required to regulate future onshore unconventional gas operations in England and Wales. In the EU, the research has been cited in a report prepared for the Directorate General (DG) Environment (40 Directorates-General make up the European Commission), which recommended that a safe separation distance for fracking should be adopted. It states '*For example, based on Davies et al. (2012) an appropriate vertical separation between shale gas extraction and aquifer may be considered to be 600 metres*' [14].

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

[7] Recording of Radio 5 Live interview with John Hayes, 13th Dec 2012.

[8] House of Commons, Energy and Climate Change Select Committee Report 'The Impact of Shale Gas on Energy Markets 26th April 2013

<http://www.publications.parliament.uk/pa/cm201213/cmselect/cmenergy/c785-iii/c785iii.pdf> (see page 31).

[9] Email from DECC (Department of Energy and Climate Change) 17th Jan 2013

[10] Freedom of Information (FOI) request made by Greenpeace provides the internal communication between DECC and Charles Hendry.

<https://www.documentcloud.org/documents/482162-rishale.html>

[11] U.S. Department of the Interior, Bureau of Land Management 2012, Environmental Assessment (see page 76)

http://www.blm.gov/pgdata/etc/medialib/blm/co/information/nepa/glenwood_springs_field/2012_documents.Par.89190.File.dat/DOI-BLM-CO-N040-2012-0076-EA.pdf

[12] U.S. Department of the Interior, Bureau of Land Management 2012, Environmental Assessment. (see page 17)

http://www.blm.gov/pgdata/etc/medialib/blm/co/information/nepa/glenwood_springs_field/2012_documents.Par.89190.File.dat/DOI-BLM-CO-N040-2012-0009-EA.pdf

[13] UK Environment Agency, 2012. Monitoring and control of fugitive methane from unconventional gas operations. <http://cdn.environment-agency.gov.uk/scho0812buwk-e-e.pdf>

[14] Report by AEA for European Commission DG Environment (see page 160) -

<http://ec.europa.eu/environment/integration/energy/pdf/fracking%20study.pdf>

Other sources of corroboration:

Manager of the Global Technology Centre at Chevron