House of Lords Economic Affairs Select Committee
The economic impact on UK energy policy of shale gas and oil

Written evidence submitted by

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Summary

- The geology of the US shale basins is *fundamentally different* from western Europe.
- The UK shale basins are *heavily faulted*, from the shale layer right to the surface, in contrast to those of the USA.
- Pre-existing faults provide a potential *fast-track pathway* for fracking fluid and produced gas to escape upwards into drinking water aquifers and even to the surface
- This fault-leak problem associated with fracking has been *recognised in France and Germany*, but not in the UK.
- The current UK regulatory regime *is ill-equipped* to deal with this problem.
- Fracking for gas or oil should be banned in areas of complex faulted geology; in effect this means an *overall ban in the UK*.
- There will be no 'shale gas revolution' in the UK because in complex geology the *production process is uneconomic.*

Brief CV

1. I am a geophysicist and structural geologist with forty years' experience. I was with the British Geological Survey before taking up a new Chair of Geophysics at Glasgow University in 1988. I worked closely with the Department of Energy on oil and gas prospects during these years, and also prepared briefings for F&CO. At Glasgow I organised and led a complex multinational experiment near Murmansk in the USSR (now Russia) in the winter of 1992 to image the earth's crust at the world's deepest borehole, the aim being to characterise possible fluid layers.
2. I then worked on radioactive waste disposal, carrying out a large research contract for Nirex at Sellafield. This was the first-ever three-dimensional seismic image of a potential disposal site. But in the light of what I discovered about the complexity of the geology I appeared against Nirex as an expert witness at the Local Planning Inquiry of 1995-96.
3. I retired in 1998 following the closure of the earth science department at Glasgow. I pursue scientific research and occasionally consult for the oil and gas industry. In the last two years I submitted geological evidence to the DECC Managing Radioactive Waste Safely programme, and also delivered several public lectures in West Cumbria, showing why the geology of that entire region is unsuitable for siting a radioactive waste repository. This helped to persuade Cumbria County Council to withdraw from the MRWS process in January this year. I have also been studying the pertinent geology of shale gas basins in the USA, UK and France, with a view to understanding why the European experience will be different from that of the USA.
4. This submission is made in a personal capacity. I have no interests to declare. I am at the disposal of the committee to be examined as a witness. Numbered references in square brackets are available in a separate pdf document.

Why geological faults are crucial

5. The Royal Society report [1] into hydraulic fracturing ('fracking') concentrated on the risk of induced earthquakes. The problem of pre-existing faults was barely discussed, even though it was introduced as a subject for concern by the Geological Society of London.

6. Faults are roughly planar surfaces separating one block of rock which has been displaced relative to the other. They do not continue *ad infinitum*; as a rule of thumb the displacement (the 'throw') at the centre of a fault may be about one-tenth of the fault length in the vertical or horizontal dimension. The end of the fault (the tip) may grow as the fault moves. This normally happens in small jerks - such sudden displacements are earthquakes. The fault surface is composed of crushed rock, surrounded by fractured rock in the block on each side. Faults are important in our discussion, aside from causing earthquakes, because they can act as conduits for fluids.

7. Faults are mapped by field geologists. Identification at depth requires geophysical methods, of which imaging by the seismic reflection method is by far the best. Two-dimensional seismic profiles can image faults with a throw of about 30 m or more. So the 'resolution' - the finest detail that can be seen - is at least 30 m in length. The 3D seismic technique improves the resolution to the order of 4-5 m.

8. Faults are often missed even when a vertical well is drilled. This is because the drilling process grinds up the rock, which is identified only by the cuttings coming back up with the returning drilling fluid. So it is not surprising that a fault, which is characterised in detail by ground-up, crushed and fractured rock, often cannot be seen. Even if the well is cored, which involves the taking of a solid intact cylinder of rock from the inner zone of the drilling, faults can be difficult to recognise with certainty.

9. <u>Permeability</u> is a general term applied to fluids (liquids and gases); it is a measure of how easily a fluid can flow through the medium. There are dozens of academic research groups and oil-industry service companies working on the problem of whether faults act as *conduits* or as *barriers* to fluid flow. The default position in the hydrocarbon industry is the conservative one, that <u>faults do not act as seals</u>; in other words, they are leaky (permeable) unless proved otherwise. In conventional oil or gas exploration, if a fault is wrongly judged to be a seal when in fact it is permeable, no damage is done, other than to the bank balances and share prices of companies and individuals. However, in the case of shale gas exploitation, the consequences of assuming that faults act as seals may be extremely damaging to the environment.

US shale basins

10. I have investigated the geological structure of the four principal shale gas basins in the USA: the Marcellus, Barnett, Eagle Ford and Woodford shales. In total these contain over half a million fracked wells. A Halliburton study [2], which has been widely quoted in support of the environmental safety of fracking, aims to show that the upward propagation of the new fractures created by fracking in these four basins is limited, and that, in all cases of the approximately 10,000 fracked wells used as a database, the highest fracture height lies well below the deepest water well in each county. Therefore Halliburton argues that fracking *per se* cannot affect near-surface groundwater resources. Halliburton also claims that its database includes areas of *"exceedingly complex geology"*.

11. I find that there are only about twenty wells out of half a million which lie within 1 km of a geological surface-breaking fault. So the Halliburton claim may apply to occasionally complex geological structure <u>at the level of the fracking</u>, but essentially *no pre-existing faults from the fracked levels extend up to the surface.*

12. The Royal Society report accepted uncritically the Halliburton study discussed above, as did a

DECC report [3]. This uncritical attitude towards an industry publication is surprising, given that:

- Halliburton has not published its database, which remains confidential
- The paper appears in a Society of Petroleum Engineers journal; as with conference abstracts, it is 'grey' literature, having been given only low-level peer review
- Wells are only located by county, and individual wells cannot be identified
- We do not know whether inconvenient results have been omitted
- We do not know how complete is the database
- There are no wells in areas where pre-existing faults break the surface.

13. Even if we accept Halliburton's main thesis at face value – that creation of new fractures by fracking has a natural upward limit above the horizontal wellbore of around 500 m, perhaps 1000 m at the most – the story is erroneous at several places:

- Plotting fluid flow by microseismic monitoring is incomplete. Microseismic events can jump 'silently' up a fault plane to another level [4]. Therefore microseismic activity does not record the passage of fracking fluid up a fault.
- Such leakage up faults can be a slow process [5], not necessarily occurring at the time of fracking.
- The authors argue that if faults were conduits all the gas would have leaked away by now. This is clearly false; the whole point of fracking is to release gas or oil which is trapped and therefore unable to migrate.

14. In conclusion, the Halliburton study is severely flawed, even when considered on its own terrain of US geology. It is certainly inapplicable to the UK.

UK shale basins

15. The crucial difference between the US and UK shale basins is that the latter are *pervaded by faults extending from the shale layer all the way to the surface*. Another fundamental difference is their basin dimensions, both vertically and horizontally. In general the UK shales are 5 to 50 times thicker than the US basins, but 10 to 100 times smaller in surface area. The Weald basin shale is 2 to 100 times smaller in area than the US shale basins, but between 3 and 8 times thicker than any of the US shales.

16. The depths at which fracking has taken place in the US, compared with the depth at which fracking either has or will be undertaken in the UK, are as follows:

- US shale basins: 1000-4300 m depth; 90% of wells greater than 1600 m depth
- UK Kimmeridge Limestone (tight oil, perhaps gas): 730 m (Balcombe), 1200 m (Wisborough Green)
- UK Bowland Shale, Lancs.: vertical well tested between 2300 and 2650 m approx.

17. Therefore the current Weald exploration is taking place at a much shallower depth than in the USA, with correspondingly thinner cover rocks above the fracked horizons.

Migration of fluids up faults and through overlying rock

18. The US oil industry advises that faults, sometimes present at the fracking level, are to be avoided if possible, because they reduce the effectiveness of the fracking treatment. Furthermore, re-activated faults are usually conduits to fluid flow [6]. But the problem of environmental contamination by fugitive methane and/or fracking fluids reaching the surface rarely arises in the

USA, because there are essentially no faults which extend from the fracking level up to the surface.

19. Controversy over contamination in the USA due to fracking operations has therefore concentrated on the problem of faulty well construction, which can lead to fugitive methane emissions. In the scientific literature there are industry-sponsored papers purporting to show that methane emissions are 'natural' (pre-dating the advent of drilling, and/or negligible). One example of this is a newly-published paper [7] purporting to show low methane emissions – but the sites, pre-selected by the industry, are confidential. This has been immediately criticised on the ground that other independent studies report methane emissions ten to twenty times higher [8].

20. An equally recent (non-industry) study of drinking water wells in Pennsylvania [9] shows that elevated (including dangerous) methane levels correlate with nearness to well sites, at a probability level of well under 1% (i.e. the chances of this correlation being by random chance), *and* the characteristic signature of the methane shows that it originates in the fracked Marcellus Shale, and is not a shallow biogenic product. In the Pennsylvania study area there are no geological faults breaking the surface. Even if the source of the methane leak is due to poor drilling techniques, the interesting fact remains that fugitive methane is not found just at some wellbores, but also up to several kilometres away. This suggests that the cover rocks above the Marcellus Shale, which here is at depths of 1500 to 2100 m, do not make a perfect seal.

21. How much rock is required above a fracked zone to seal it? In the East Irish Sea Basin at least 600 m of Mercia Mudstone Group is required for it to be an effective hydrocarbon seal [10] although the same rocks make a good cap for the Wytch Farm oilfield in Dorset. In the Wirral, natural gas seaps [11] either passed up through 1500 m of mudstones and sandstones (poorly and very permeable, respectively), or else *via* faults.

22. In short, there is no perfect cap-rock seal. If fracking takes place on an industrial scale over large areas, it is likely that in areas of complex geology fugitive methane and perhaps fracking fluid will eventually contaminate aquifers. This contrasts with onshore UK oil and gas fields, which are only a few square kilometres in area.

The UK regulatory regime (onshore)

23. I have sat on both sides of the table at DECC interviews for licence awards. The applicant's technical proposals are heard politely, but the decision on whether or not to award the licence is based essentially on how much funding will be committed. This is a robust system, widely used elsewhere, and leaves the detail of the geological prospects to the licensee.

24. In my view the weakest point of the regulatory process concerns the Environment Agency, which is asked by the planning authority to comment on planning applications. This reduces to commenting on the applicant's Environmental Statement (ES), meaning that the EA is dependent upon information furnished by the applicant. It is a reactive rather than a proactive system. The EA is ill-equipped to cope with the new demands of unconventional hydrocarbon exploration. Two geological examples illustrate this weakness:

25. The EA response to Celtique Energie's current ES for West Sussex County Council is weak:

> *"The content of the reports are satisfactory and we agree with the conclusions and recommendations. As stated in the reports, the site lies on a non-productive aquifer and the risk to water resources is low."*

26. My analysis [12] shows that the geology of Celtique's ES is misleading in places. The seal is *ineffective*, even with 1200 m of overlying rock, and therefore a contamination risk. In addition, an attempt to drill a water well some 500 m NE of the proposed site found saline water at 39 m depth. This commonly suggests a fluid connection to depths of at least 500 m, where saline water is to be found.

27. Greenpark (now Dart) Energy's ES for Becklees Farm coal bed methane development (Cumbria) states:

> *"The site is situated over an area of Triassic and Permian Sandstones which act as a major aquifer. However, because there is a layer of overlying drift, the Environment Agency have designated the local groundwater as having a low vulnerability to potential pollution because of the protective properties of the overlying drift."*

28. The site is located where the major aquifer is overlain by a mere 5 m of 'overlying drift' (post-glacial till) [13]. The only conceivable explanation for the EA approval is that it was narrowly considering the risk of pollution from spills at the surface possibly penetrating down to the aquifer. It evidently did not consider upward migration of pollutants from depth into the aquifer, *via* the drill bore and/or faults.

29. The EA appears to have insufficient in-house expertise to respond to planning applications in this area. But instead of strengthening the expertise, government is planning a 15% staff job cut. The EA states, furthermore, that from February next permits will be issued within 1-2 weeks. It is difficult to see how this haste can be reconciled with *"taking into account the views of local communities, environmental organisations and other stakeholders"* [14].

30. The current regime is, in effect, one of self-regulation.

Critique of some current unconventional operations

31. I am unimpressed by the technical competence of some shale gas/oil and CBM operators who hold current UK exploration licences, as viewed through the prism of their planning application documents. Some of my findings are discussed and/or published in more detail elsewhere [15]; here is a summary:

32. Cuadrilla licence PEDL244 (Balcombe, West Sussex):

- Licence boundary on application map out of place by up to 1200 m
- No account taken of the BGS surface geology maps showing faults surrounding the drill location
- Poor subsurface structural interpretation due to omission of the BGS fault dataset
- Lateral (horizontal) drilling at Balcombe was done 'in the dark' (no seismic image).

33. Celtique licence PEDL234 – proposed drilling near Wisborough Green, West Sussex:

- No effective sealing (cap rock) layer
- Misleading description of regional groundwater flow
- New 2D seismic data acquired, but no 3D, necessary for lateral drilling
- Saline water in water well drilled 500 m NE of proposed drillsite not mentioned.

34. Dart Energy PEDL133 - proposed CBM development at Airth, Stirlingshire:

- Inappropriate geological cross-sections supplied in ES (both outside area of proposal)
- Five major faults omitted from these cross-sections
- Misleading and very incomplete discussion justifying faults as barriers to fluid flow
- Internally inconsistent maps of a major fault (>300 m throw; biggest in whole region)
- This fault unaccountably absent over development location, but present either side
- Misleading discussion of sealing cap rocks above coal formations
- No 3D seismic survey.

35. Cuadrilla licence PEDL165 (Lancashire):

- Interpretations based on poor-quality reprocessed 2D seismic data
- Classification of faults into two types A and B is unjustifiable
- Interpretation (late 2011) of major Thistleton Fault wrong, and mismatches BGS maps
- Explanation of seismicity and future magnitude mitigation steps depends on this wrong interpretation.

36. My overall impression of the work done to date is that it is frequently hurried and based upon poor-quality data and interpretations. The most serious failing is that the faulting which pervades all these licensed areas has not properly been taken into account. Equally serious is the fact that the companies seem to be getting away with presenting such work.

Discussion and conclusions

37. France has confirmed its ban on fracking while in Germany it seems probable that the new coalition government will adopt a moratorium on fracking pending further investigation of health and environmental issues. In large part, these decisions have been based on unacceptable local environmental risks due to complex geology.

38. Chevron has withdrawn from Poland, citing over-complex geology. On the purely commercial front, US industry is reporting that fault zones should be avoided because fracking becomes inefficient – simply too much energy and fracking fluid is wasted sending it up faults.

39. New methods have been tested for fracking without using water, including propane gas as the proppant fluid, and electric shocks. Total concludes that the latter is a failure. The use of propane (in liquid form under high pressure) will mitigate water consumption, but introduces new dangers and does not solve the fault-leak or insecure cap-rock problems which can lead to aquifer contamination.

40. In view of the local environmental risks due to complex geology, together with the likely concomitant uneconomic nature of fracking in the UK, I therefore see no sound reason for the UK to continue to promote shale gas.

[signed]

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