

**Scientific and economic objections
to
unconventional drilling at
Broadford Bridge, West Sussex**

by

David Smythe

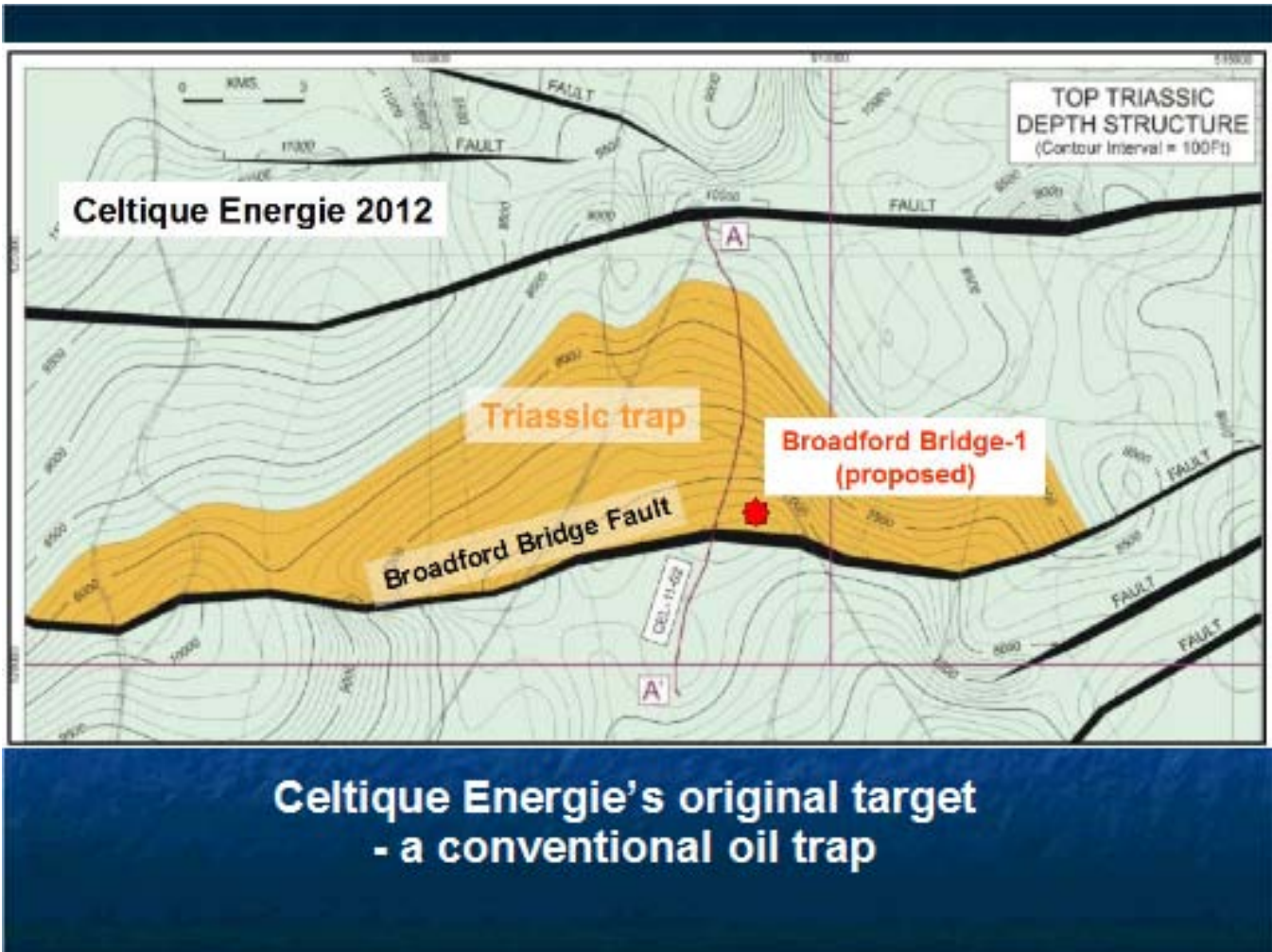
Emeritus Professor of Geophysics, University of Glasgow

Talk at Pulborough

April 2017

(version 1.1)

This is an annotated and referenced version of the talk I gave at Pulborough Village Hall on 30 April 2017.



**Celtique Energie's original target
- a conventional oil trap**

Celtique Energie's proposal at Broadford Bridge was to explore a potential conventional oil trap. The contour map is the structure of the top of the Sherwood Sandstone layer (of Triassic age, older and lying below the Jurassic Kimmeridge Clay), in feet below sea level. It was hoped that the oil would have accumulated in the very well-defined area - the trap - shown in orange. The trap is bounded to the south by an east-west fault shown as a thick black line, which I have called the Broadford Bridge Fault. The abrupt change in contour level across this fault is analogous to a cliff face on a topographic map, where all the contours are squashed together.

What do we mean by 'unconventional' ?

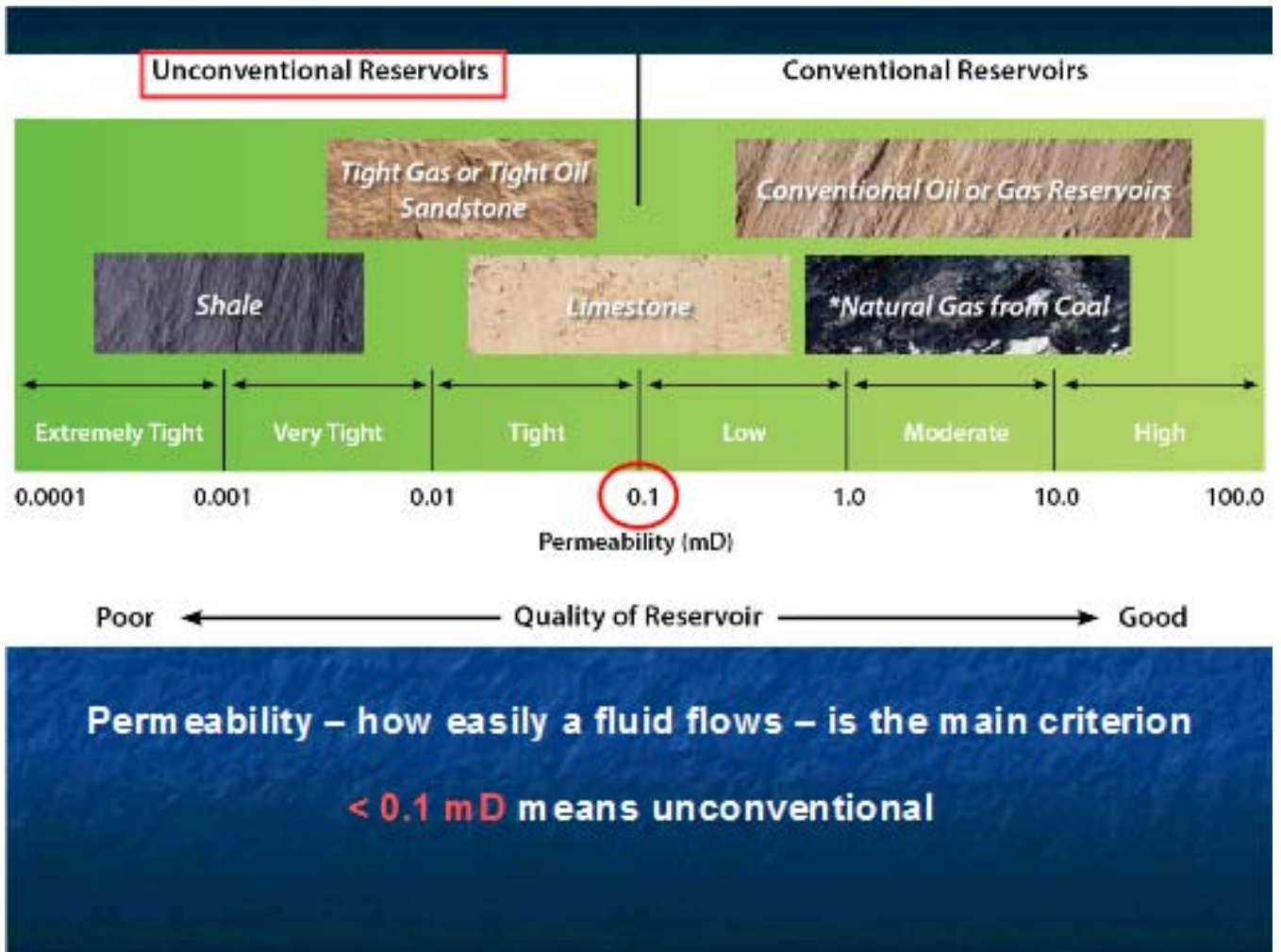
UK government:

Planning Practice Guidance (October 2014):

"Conventional hydrocarbons are oil and gas where the reservoir is sandstone or limestone.

Unconventional hydrocarbons refers to oil and gas which comes from sources such as shale or coal seams which act as the reservoirs."

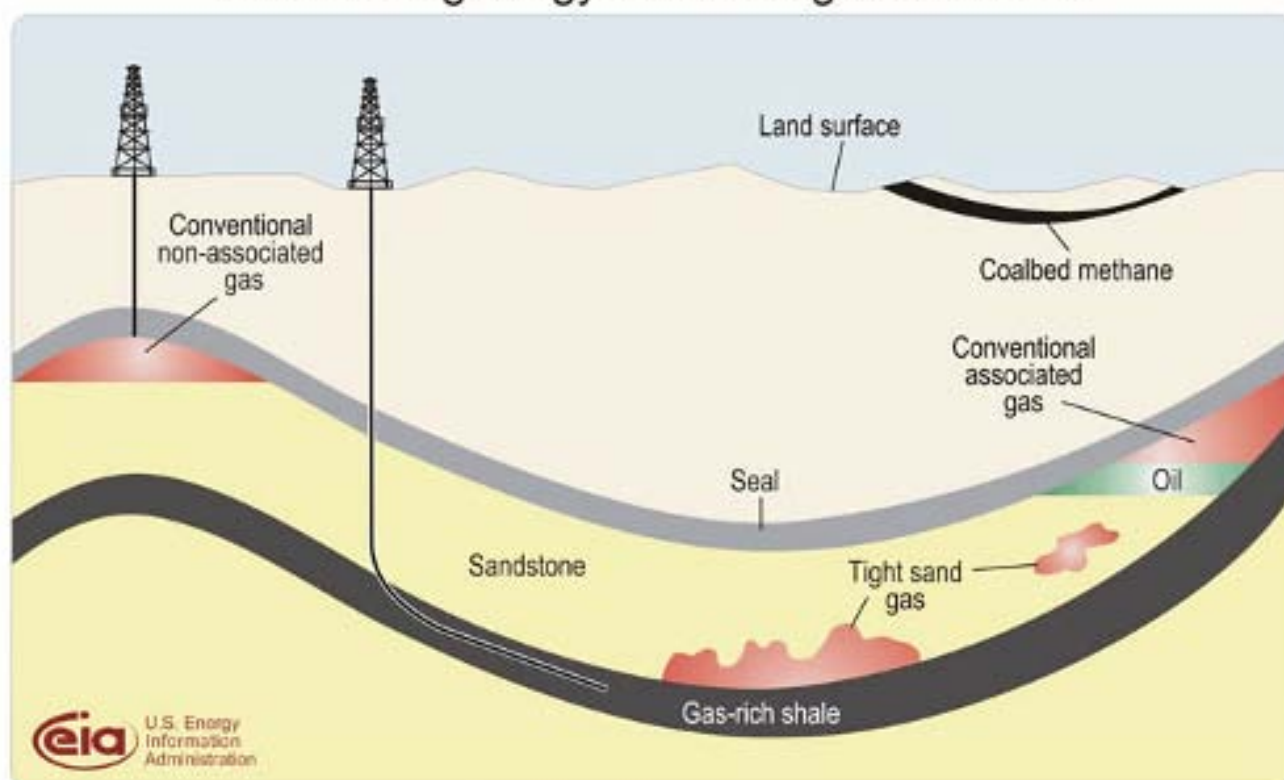
Councils are obliged to take into account this [Planning Practice Guidance](#). But the definitions given here, based on rock types, are over-simplistic. If a student had presented this as a definition (complete with bad grammar as shown above), in the days when I taught at Glasgow University, I would have failed them. Despite an FOI request, the government has been unable to supply me with a justification for these definitions.



This [diagram](#) from the [Canadian Society for Unconventional Resources](#) shows the generally accepted figure of 0.1 millidarcies (mD) as the criterion for discriminating between unconventional on the left and conventional on the right. A Darcy, or millidarcy, is the unit of permeability. Note that limestones and sandstones can be on either side of the 0.1 mD divide, demonstrating that the UK planning guidance definition is useless.

The spectrum is shown in logarithmic form; that is, each marked value along the scale is a factor of ten increasing to the right.

Schematic geology of natural gas resources



Well-defined vs. distributed resources

The traps shown at either side of this schematic cross-section are well-defined and concentrated. The oil and/or gas has flowed upwards from the source layer (shale) over a long period. It is trapped by a sealing layer of impermeable rock, the seal.

'Tight' sand gas is distributed in a diffuse way throughout the layer.

Source: US [Energy Information Administration](https://www.eia.gov) web page, The geology of natural gas resources.

Scientific definition of 'unconventional'

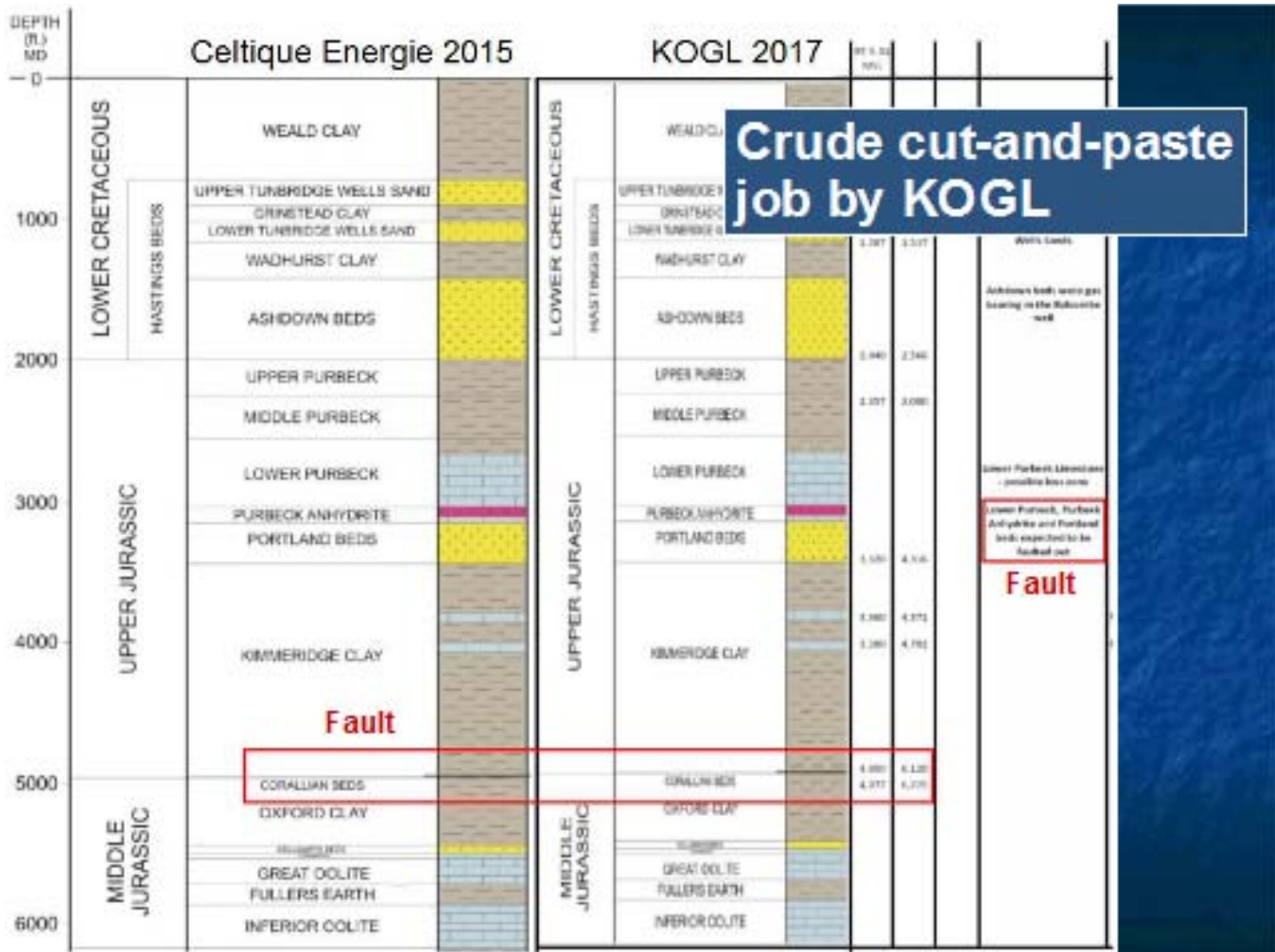
- **Permeability - < 0.1 mD**
- **Geological setting – ill-defined, spread-out**
- **Requires stimulation – to make oil/gas flow**

Sources consulted:

- Schlumberger
- Petrowiki
- Halliburton
- Canadian Society for Unconventional Resources
- US Dept of Energy
- US Energy Information Administration
- BP presentation to AAPG
- UK Onshore Oil & Gas
- Oil & Gas Journal
- British Geological Survey
- EU research documents

A generally acceptable definition of 'unconventional', culled from the sources listed, includes these three main criteria. Stimulation can include acidisation or fracking. The KOGIL Kimmeridge Limestone target is clearly unconventional.

Kimmeridge OGL's plans for Broadford Bridge

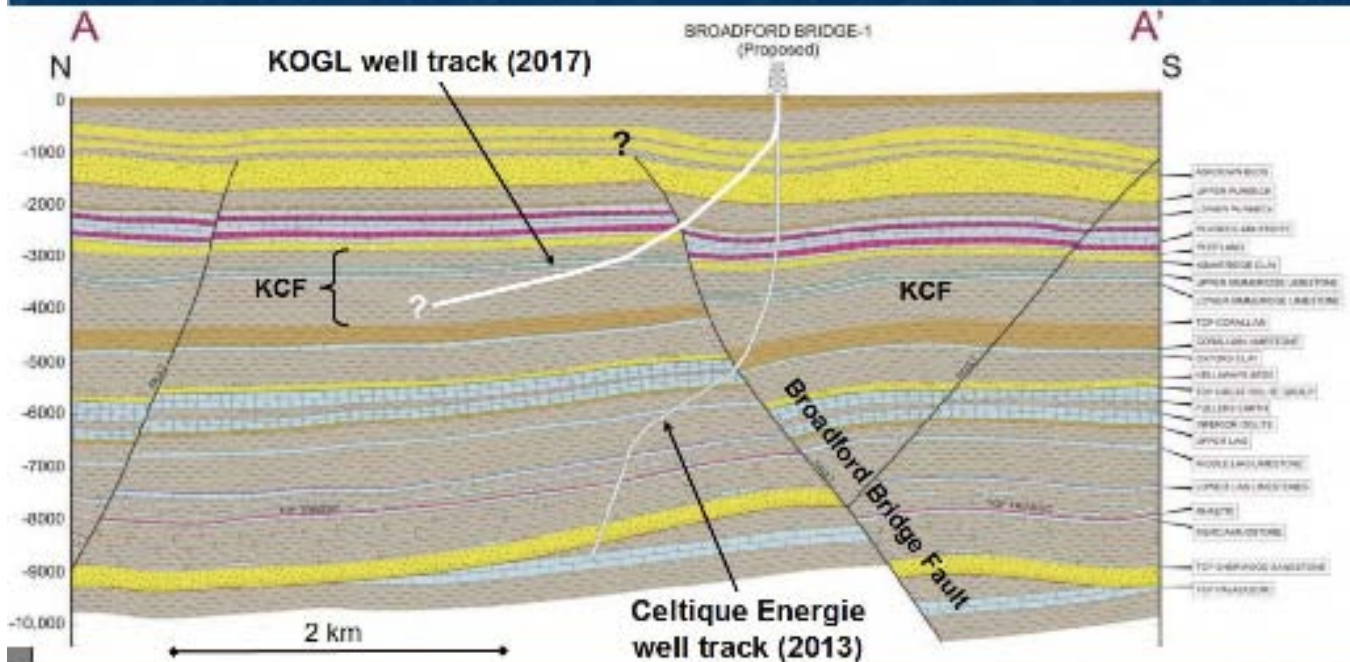


KOGL has simply copied the prognostic geological column from Celtique Energie's proposal on the left, and added slightly new depth figures and some notes on the right. This is highly misleading.

Celtique predicted that it would cross the Bradford Bridge Fault at about 5000 ft (scale at left-hand side), so that part of the geological succession is missing (lower red box). But KOGL plans to drill across the same fault at much shallower depth (note in red box on right). So geological layers should be missing from the right-hand column, instead of being a simple copy of the Celtique column on the left.

The proposal by KOGL as presented makes no geological sense, and should therefore be rejected.

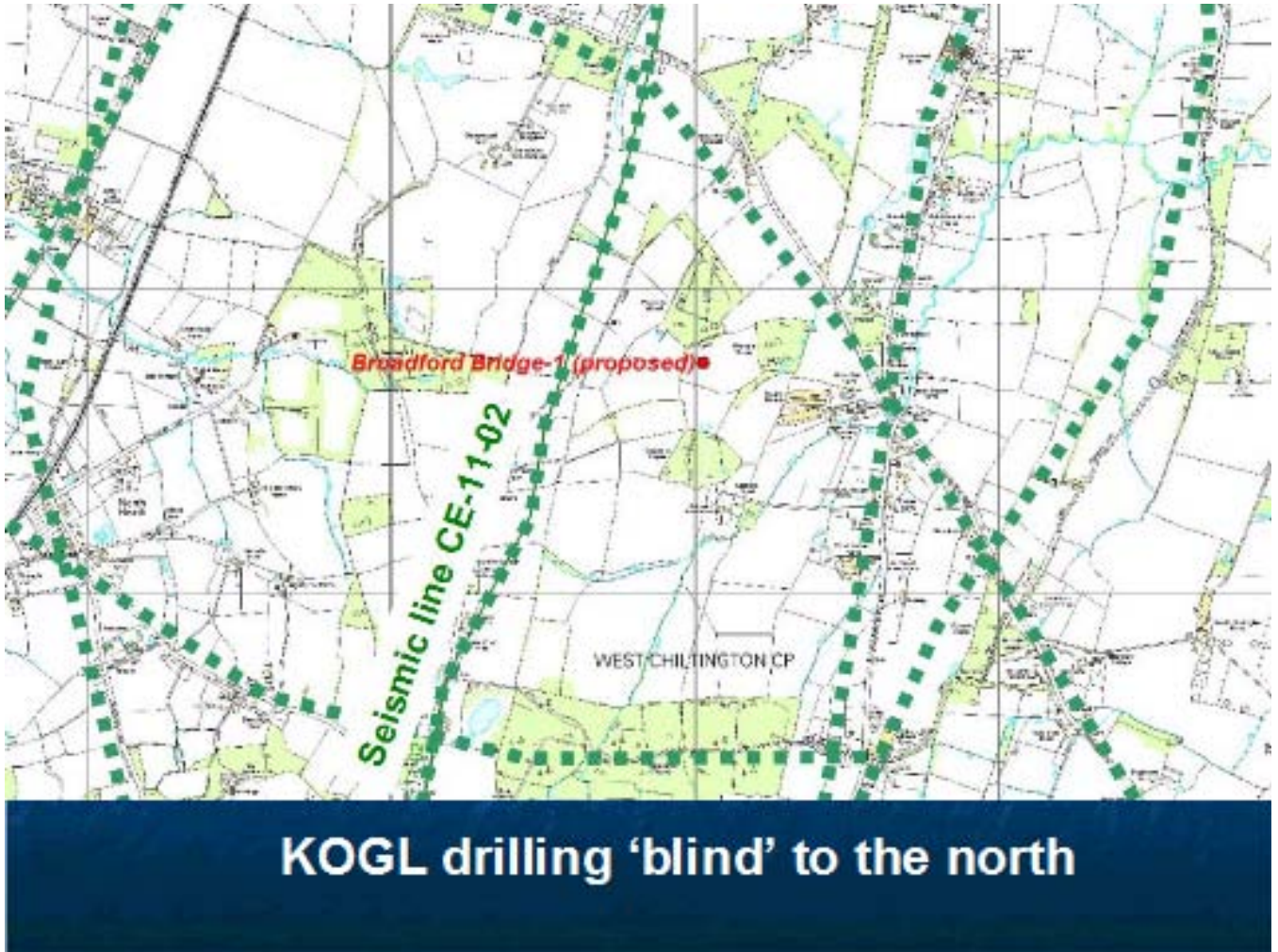
Geological cross-section interpretation



KOGL is now targeting the Kimmeridge shales

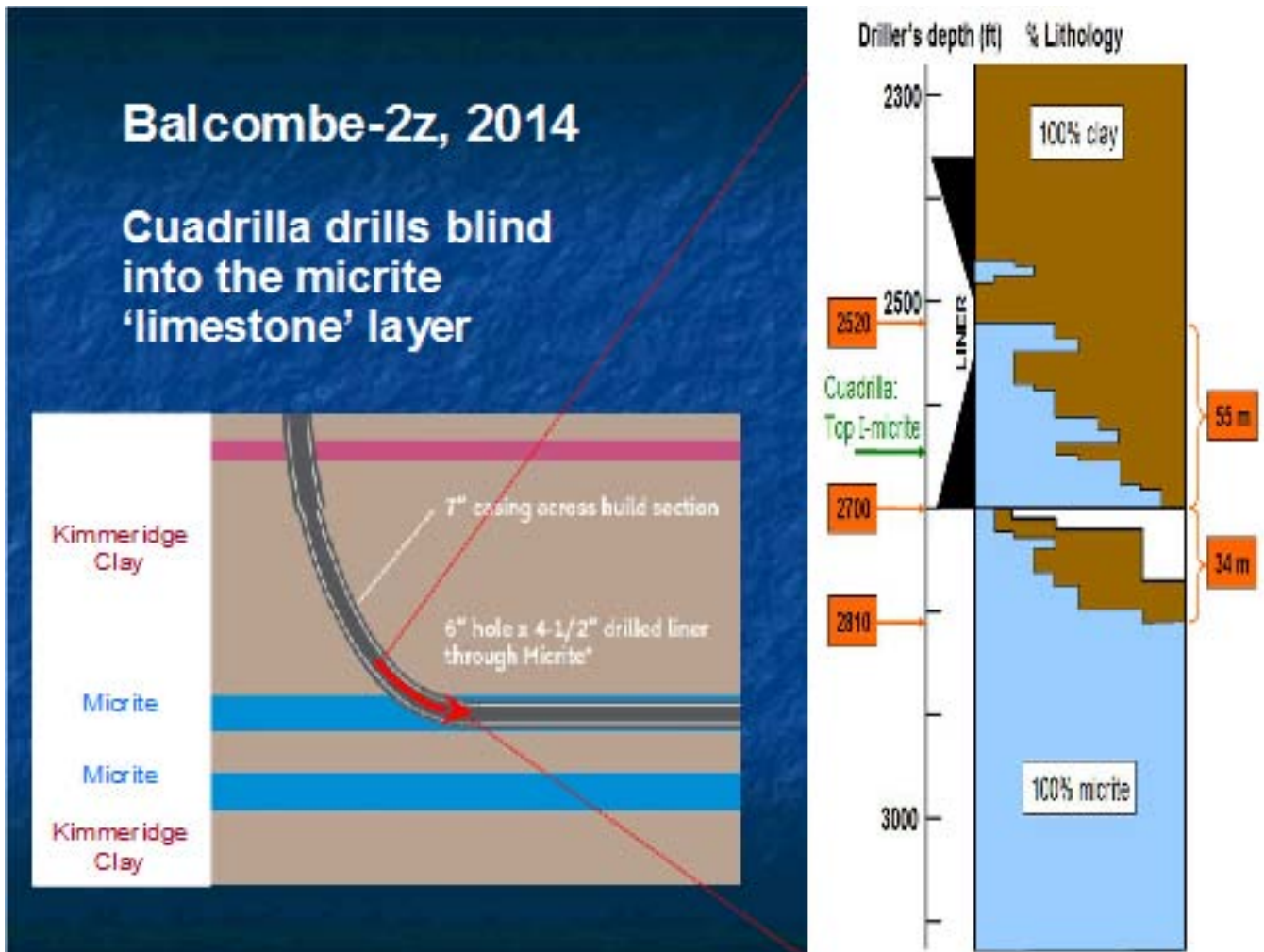
This is Celtique's prognosed geological cross-section, showing their proposed well track in grey. It deviates and crosses the fault at 5000 ft depth, then turns toward the vertical again to target the yellow Triassic sandstone layer.

KOGL plans to drill a highly-deviated well, crossing the fault at around 2500 ft, and then penetrating very obliquely the Kimmeridge limestones within the Kimmeridge Clay Formation (KCF). This proposal has little or nothing in common with the original Celtique planning approval, except the use of the same pad.



Existing 2D seismic profile locations are shown by the dotted green lines. The wellpad is 500 m east of the Celtique seismic line CE-11-02, on which the geological interpretation is based. KOGL plans to drill northwards. There will therefore be inadequate control on the geology being drilled.

To the best of my knowledge such blind drilling has never occurred elsewhere abroad, except in the most simple cases of flat-lying geology with no faults. But in the UK it has already been attempted by Cuadrilla at Balcombe, with limited success.



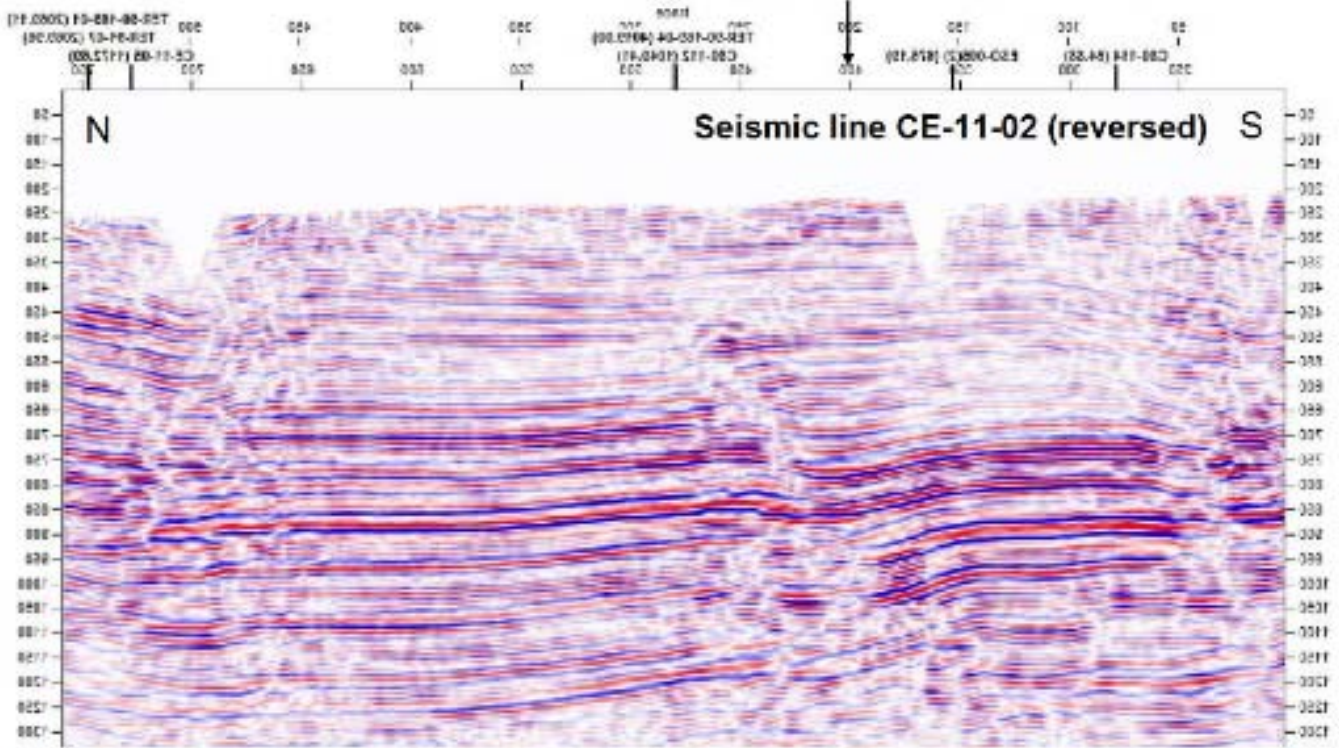
Cuadrilla drilled a horizontal well into the uppermost micrite (an impure, tight, muddy limestone) layer with its Balcome-2z well in 2014. The log of the portion of the curved wellpath as it 'lands' in the limestone (red arrow) is shown on the right, with the scale being driller's depth along the wellbore (NOT vertical depth).

The horizontal well was deviated to the west away from the vertical well Balcombe-2, and with no seismic control. Higher up, where the borehole is vertical, my prediction that Cuadrilla would drill through a fault unrecognised by it turned out to be correct.

The coloured column shows the proportion of rock type as seen in the drill cuttings. It is this evidence, plus a gamma-ray tool near the drill bit which helps to differentiate between limestone and shale, that tells the driller what layer the drillbit has reached. The cuttings became 90% micrite at 2700 ft, as the layer was entered. Drilling was then suspended, casing set, and a liner put in (the double black triangle symbol between 2370 and 2700 ft). The cement shoe was then drilled out as drilling recommenced. The cement cuttings are shown by the white lithology. But the drill bit appeared to be back in shale (brown), with a repeated transition to the micrite occurring over 34 m (110 ft).

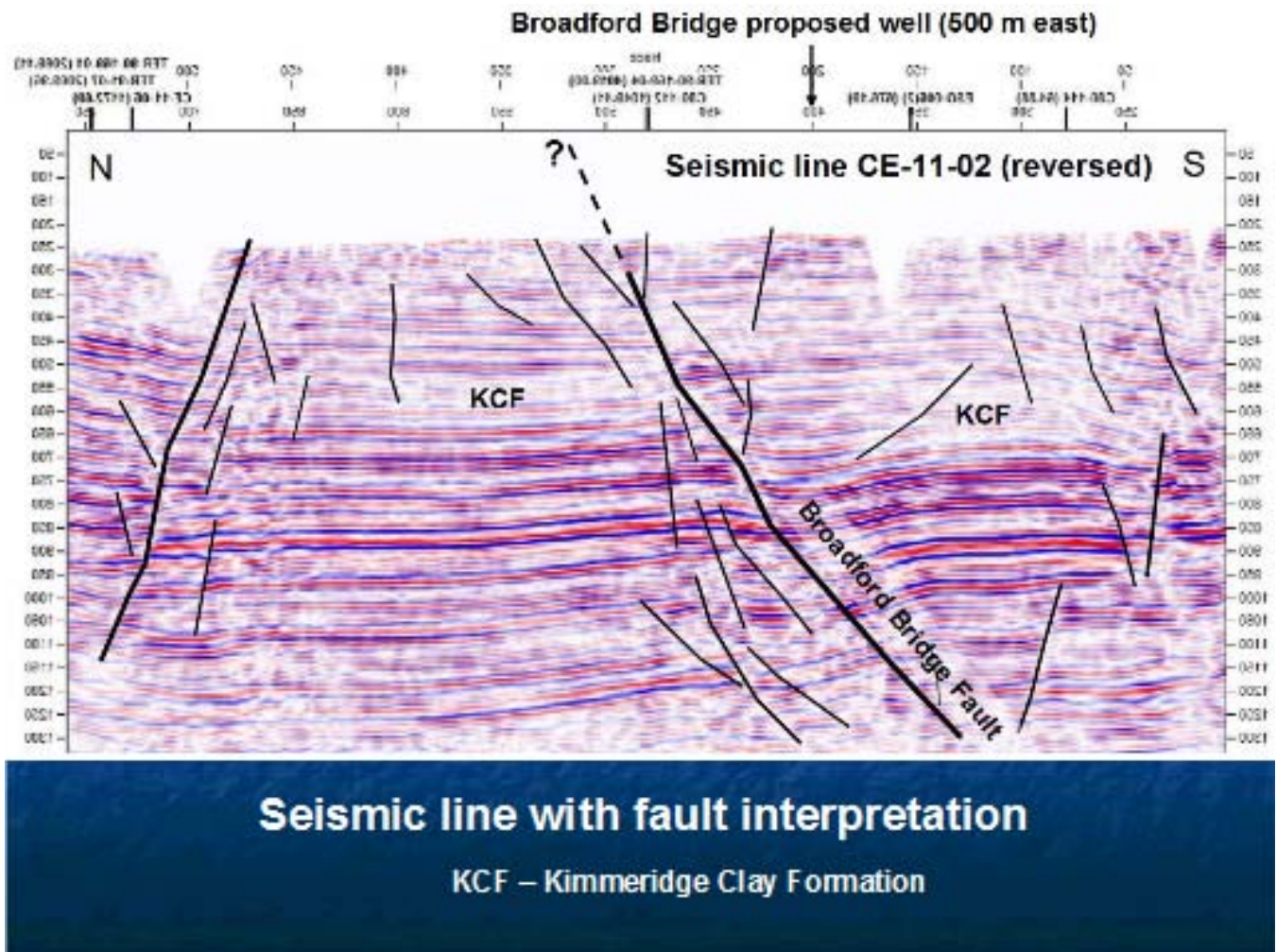
Cuadrilla has never explained this anomaly. The horizontal well stopped short of the original planned length. This episode illustrates the unreliability of blind drilling.

Broadford Bridge proposed well (500 m east)



Seismic line 500 m west of, and parallel to, proposed deviated well

The geology is inferred from 2D seismic reflection images like this one, lying 500 m west of the proposed drill site. It is akin to a geological cross-section, except that the vertical scale is in milliseconds of down-and-back reflection time, not depth.



I have added fault interpretation to the raw seismic data, with thicker lines indicating bigger faults. The main Broadford Bridge Fault may extend up to the surface, but has not been mapped at outcrop (i.e. at the surface), and, as can be seen, there is no seismic image shallower than 250 ms (about 300 m depth below sea level).

The big faults have smaller faults beside them, either parallel to or merging with the main fault.

KOGL plans to drill obliquely into the Kimmeridge Clay Formation (KCF) on the north side of the Broadford Bridge Fault. The micrite limestone layers are too thin to show up on the seismic image.

Even if the drilling were to be carried out along the vertical plane of this section, it can be seen that there are many uncertainties in identifying both the faults and the geological layering. For KOGL to drill 500 m away from this line is irresponsible.

Definition of fracking

Irrational UK definition of fracking of wells by water use

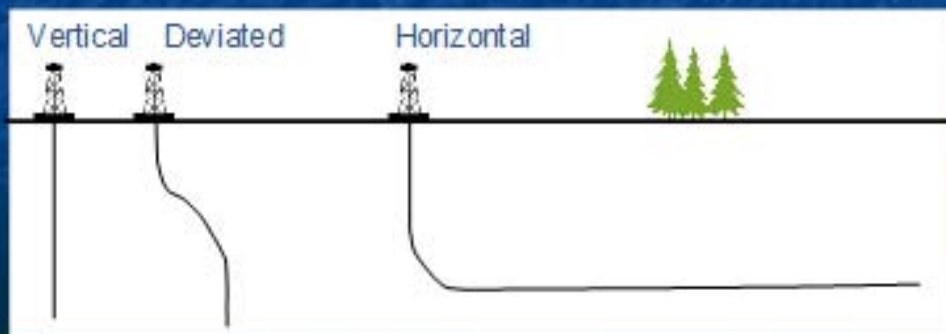
UK government:

- Less than 1000 cu. m per stage
- OR
- Less than 10,000 cu.m in total

Deliberately (?) conflates water and geothermal wells with fossil fuel wells

No justification for figures chosen

Solution - separate horizontal wells from others



The Infrastructure Act 2015, [Section 50, supplementary para. 4B to Section 4A](#) defines fracking as follows:

(1) “Associated hydraulic fracturing” means hydraulic fracturing of shale or strata encased in shale which—

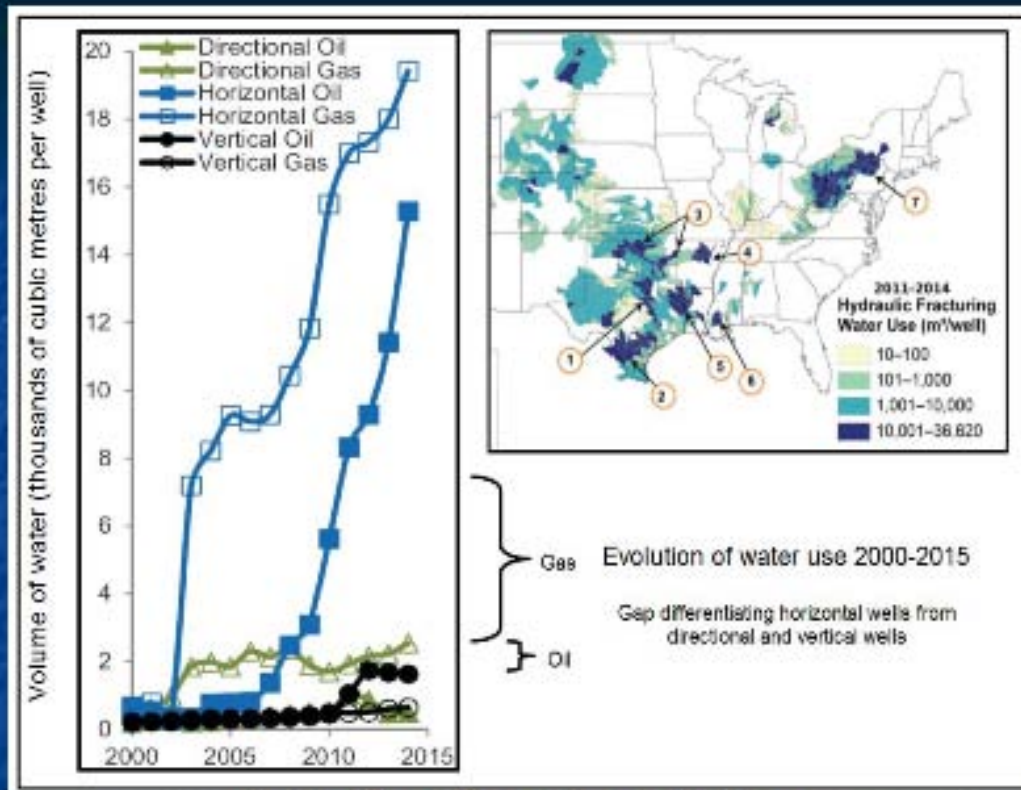
(a) is carried out in connection with the use of the relevant well to search or bore for or get petroleum, and

(b) involves, or is expected to involve, the injection of—

(i) more than 1,000 cubic metres of fluid at each stage, or expected stage, of the hydraulic fracturing, or

(ii) more than 10,000 cubic metres of fluid in total.

This definition has little or no foundation in evidence or logic. If volume of water is to be used as the criterion, the answer is to separate horizontal wells from deviated or vertical wells. This is what has been done in the USA.

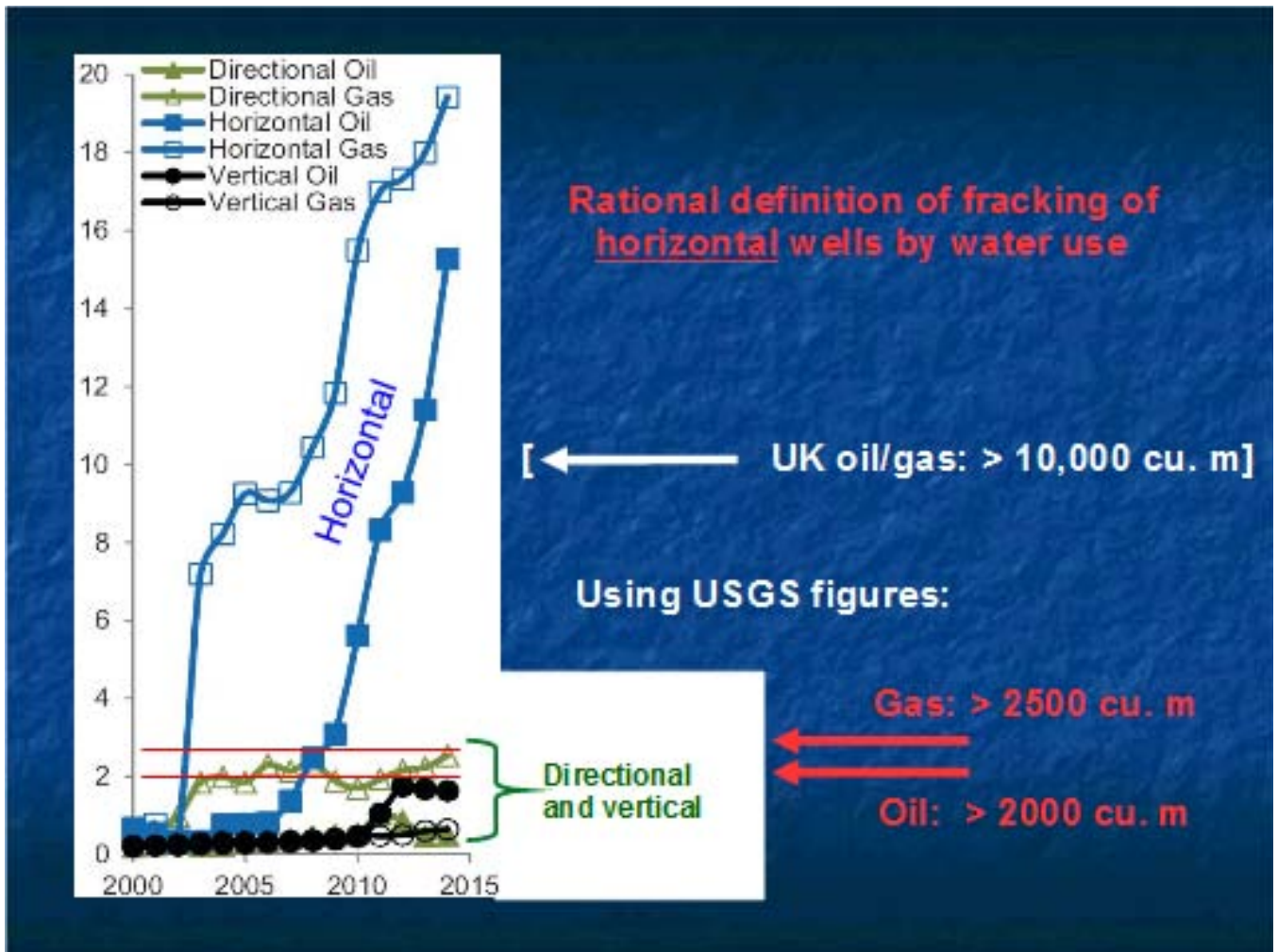


A scientific, evidence-based definition:
US Geological Survey study of 263,859 fracked wells

Annual median values of water volume (cubic metres per well)

A [recent study by the USGS](#) measured water volume use in 263,589 fracked oil and gas wells in the US. The wells were categorised as vertical, deviated (directional) or horizontal. The horizontal wells can be identified as being unconventional shale wells. The water use of these wells has increased over time as the horizontal part of these wells has increased.

A unique volume measure can be derived from these data to separate horizontal fracked wells from the others. This also reliably separates the high volume hydraulically fractured (HVHF) wells, which are for unconventional hydrocarbons, from the other categories, which may include water or geothermal wells.



The water volume use in directional and vertical wells has stabilised over time since about 2003. For oil wells, a figure of 2000 cu. m separates these wells from horizontal fracked wells, for all the data. The corresponding figure for gas wells is 2500 cu. m.

Below these threshold figures the fracking will not have been for high-volume horizontal fracking (HVHF) – for the simple reasons that the volumes are low and the wells are not horizontal. Above the threshold, the wells are indeed HVHF.

Therefore a rational criterion based on water use for defining fracking of high-volume unconventional fracked wells (HVHF wells) from the others would be 2500 cu. m (or even 2000 cu. m, in the case of oil wells). There is no rational justification for the UK government's figure of 10,000 cu. m, which seems to have been arbitrarily picked as a number halfway between the current volumes used for horizontal fracking and the non-horizontal fracked wells. So, for example, if horizontal fracking water use were to increase to 50,000 cu. m per well, does that mean that the definition of fracking for hydrocarbons should be redefined to 25,000 cu. m?

It has been pointed out by [Gilfillan and Haszeldine](#), two Edinburgh University academics, that the current UK definition of 10,000 cu. m per well would mean that Preese Hall-1 in Lancashire, the only UK well to date whose shale has been fracked, would not even count as a fracked well.

Economics

(1) The fantasy

Government and press listen

to:

Breitling Energy Corp CEO
Chris Faulkner, "the Frack
Master"



Lord Ridley



Cuadrilla CEO Francis Egan
(speaking to HoL economic affairs committee)

"30,000 wells a year in US"

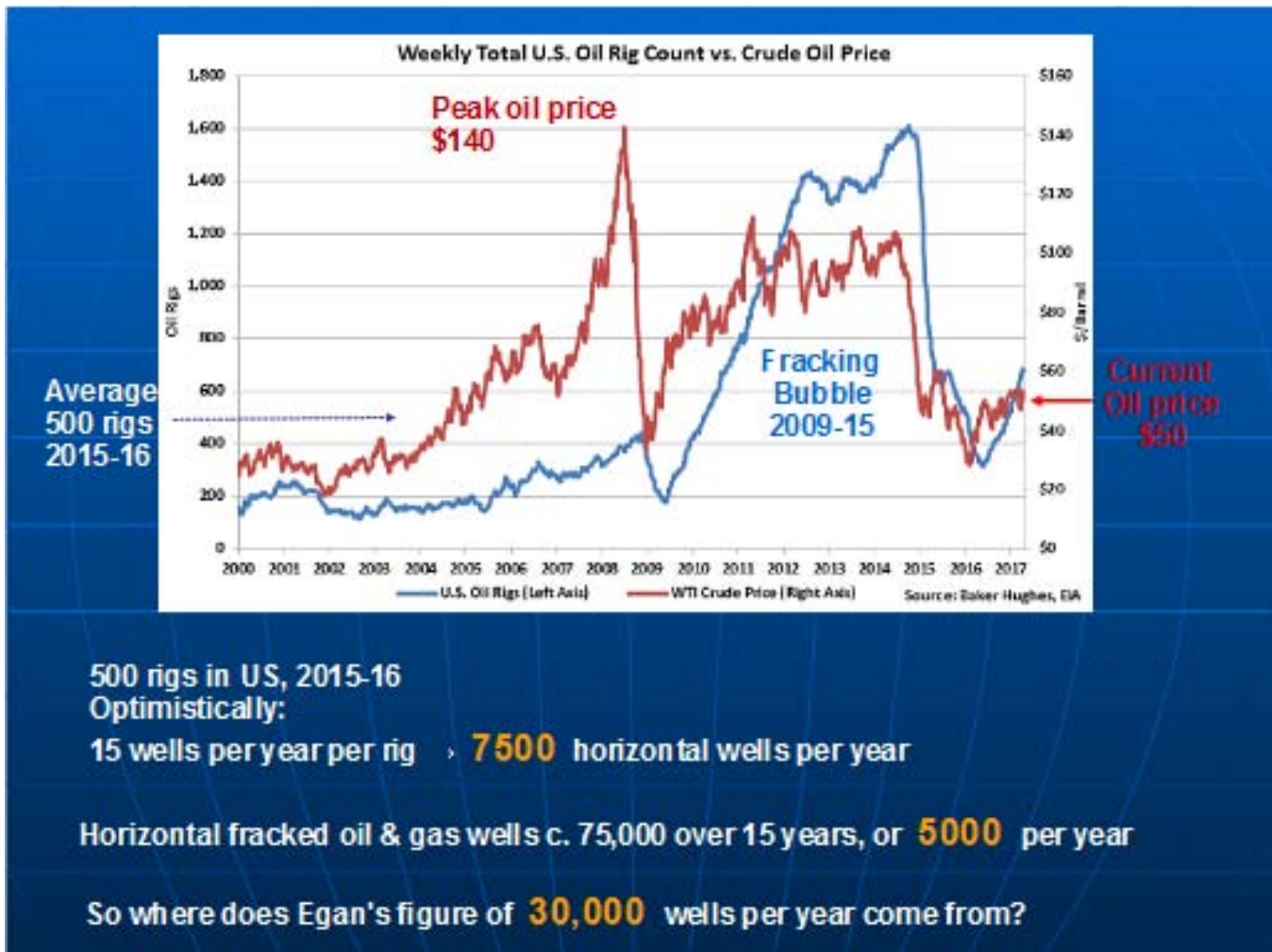


The UK government appears to listen to charlatans, crooks and others with an agenda, when informing itself about shale gas and oil.

Christopher Faulkner, self-styled 'Frack Master' and CEO of Breitling Energy, appeared several times in the UK, promoting the [benefits of shale production](#). But in July 2016 he and others were [charged with fraud](#) by the Securities and Exchange Commission of the USA. Faulkner is currently being held without bail in a Texas prison.

'Lord' (aka 'Viscount') Matt Ridley has a PhD in chemistry, and therefore seems to feel that he is qualified to pronounce as a scientist on matters like [anthropogenic global warming](#) and [shale fracking](#). Why? Is it because he has an inherited title? Is it because his family [extracts opencast coal](#) in Northumbria?

Francis Egan, CEO of Cuadrilla, clearly has a right to put his views on fracking to government. But [his evidence is misleading](#) - whether by design or simple ignorance, I do not know. He stated that 30,000 wells a year are drilled in the US, or 120,000 over 4 years, the same time it has taken the UK to frack one vertical well. This figure is completely wrong, as demonstrated in the next slide.



Here I show how Egan's figure is completely wrong. The blue graph is the [Baker-Hughes rig count](#). This is a measure of drilling activity onshore in the US. During 2015-16, the last year of Egan's statement dated October 2016, there were about 500 active rigs. If we assume, optimistically, that each rig drilled 15 wells, that makes a total of 7500. Alternatively, over the lifetime of the shale industry around 75,000 wells have been drilled, or an average of 5000 a year. So where does Egan's figure of 30,000 per year come from? Is he deliberately misleading the House of Lords economic affairs committee?

The red curve shows the oil price since 2000 (WTI = West Texas Intermediate, an onshore US oil price indicator). The current price is around \$50 per barrel.

Chesapeake Energy Biggest shale gas player in US

Founder and ex-CEO
Aubrey McClendon



One of the biggest shale players in the US is [Chesapeake Energy](#). Its founder and former CEO, Aubrey McClendon, [apparently committed suicide](#) by [driving himself into a motorway bridge](#), the day after being charged with rigging bids for oil and gas drilling rights. He had previously been ousted from the Chesapeake board for cheating on his Chesapeake investments. McClendon left behind debts of between \$455M and \$1 billion. Chesapeake has also been accused of [cheating on landowner due royalty gas payments](#) by 'logic-defying' expense charges.

Is this the kind of rampant capitalism and so-called 'wealth creation' that we want to see in the UK?

Government also listens to: UK Onshore Oil and Gas group (UKOOG):

100 drilling pads, each with 40 horizontal (lateral) wells in a full-scale UK unconventional industry.


But for drilling and completing one well it estimates:

*" - a few weeks to prepare the site
- eight to twelve weeks to drill the well
- one to three months of completion activities including between one and seven days of stimulation."*

UKOOG then concludes:

*"This initial three- to five-month investment has the potential to deliver a well that will produce oil or natural gas for **20 to 40 years, or more.**"*

The UK Onshore Oil and Gas group (UKOOG, not to be confused with UKOG) has issued highly optimistic and misleading figures about a putative UK shale industry in full production mode. In particular, the claim that an unconventional well will produce oil or gas for "20 to 40 years, or more", is wrong. The error in this figure (another 'alternative fact' put about by the UK shale industry) is demonstrated below.



Economics

(2) The reality



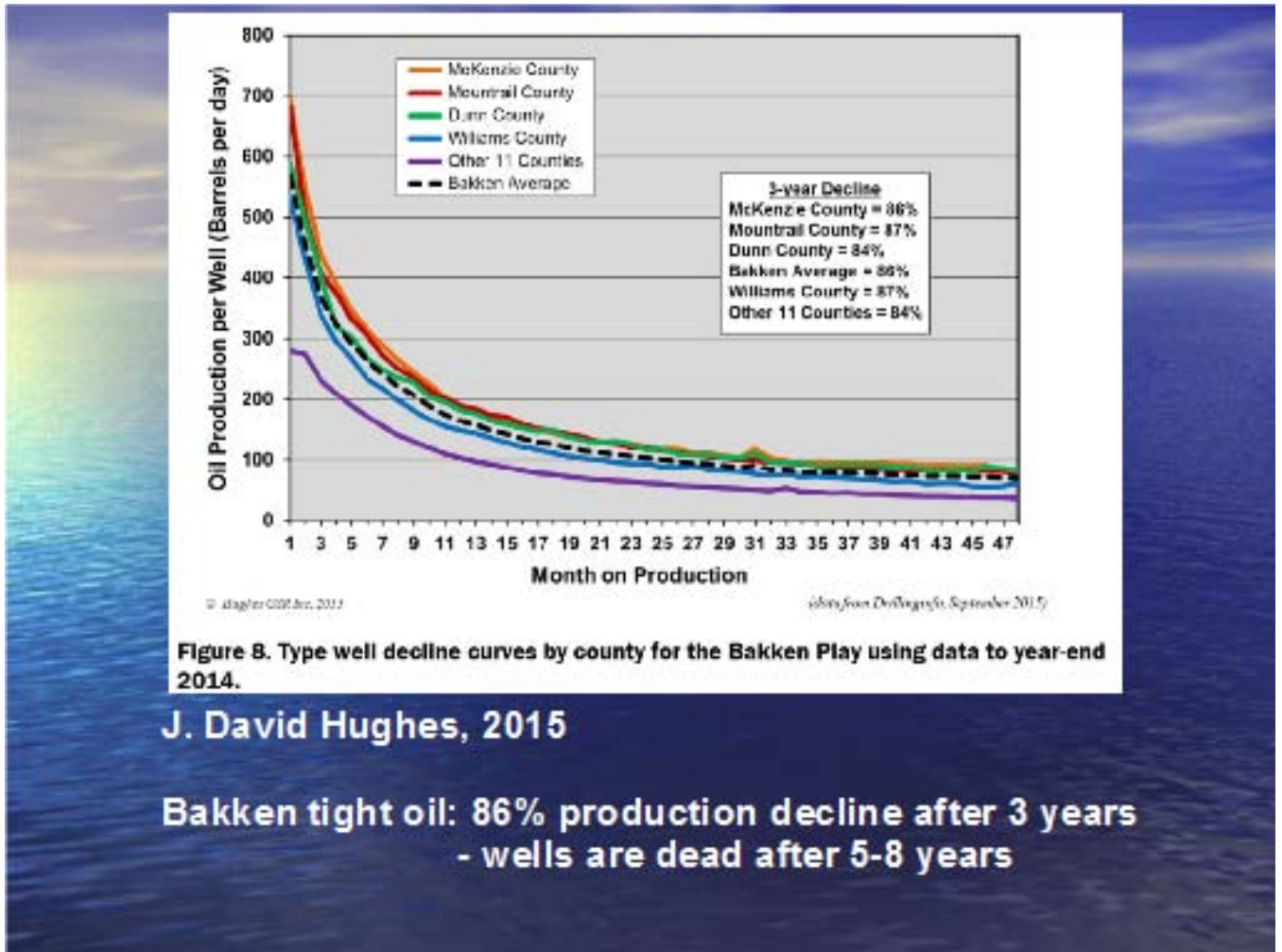
Bakken tight oil of North Dakota
- analogous to Kimmeridge Clay,
where a thin limestone is fracked

February 2017



The proposed Kimmeridge shale play in the Weald is analogous to the Bakken play, found in North Dakota, Montana, and into Canada (yellow play area circled in red), in that a thin limestone will be targeted. The Bakken is about six times larger in area than the Weald, and very sparsely inhabited. The limestone in both areas, being brittle, has natural fractures which make it a good candidate for fracking. The fracks will extend upwards and downwards into the shale above and below. There is no intention (nor is there the ability) to confine fracking just to a 20-30 m thick limestone layer.

A respected oil industry commentator, Art Berman, said in February 2017 that the [Bakken is nearing its end](#). Mr Berman used to write for the [Oil & Gas Journal](#), the leading hard-copy industry magazine, but was sacked in 2009 after writing too many articles critical of the US shale industry.



David Hughes has produced [several evidence-based reports](#) on the economic realities of shale gas and oil production. Here are his 'decline' curves for the Bakken. The average across several counties is the black dotted line. The curves show that most of the production from an unconventional well occurs in the first 18-24 months. The wells are effectively dead after 5-8 years.

Such steep decline curves are common to all unconventional wells, and there is no reason to believe that UK wells will be any different. The UKOOG figure of 20 to 40 years is therefore misleading by a factor of 4 to 8.



June 2016

Art Berman
Energy specialist & keynote speaker

Menu

« Permian Basin Break-Even Price is \$61: The Best of a Bad Lot

Posted in The Permian Basin on June 24, 2016

The lowest break-even price for Permian Basin tight oil plays is about \$40 per barrel (Table 1), that puts Permian plays among the lowest cost significant supply sources in the world. Although that is good news for U.S. tight oil plays, there is a dark side to the story.

Just because tight oil is low cost compared to other expensive sources of oil doesn't mean that it is cheap. We are in a recession and need oil prices...

The troubling reality is that the rate of oil production has declined since the 1970s. That is very bad news for the global economy. Those who believe that technology is always the answer need to think about that.

Although that may, Permian Basin tight oil plays, are the best of a bad, expensive lot.

NB: today's oil price: \$50

Permian Basin tight oil of West Texas

- mixed conventional and unconventional

Art Berman considers that the Permian Basin of West Texas and New Mexico is the [nearest thing to a financially viable shale industry](#), or “*the best of a bad lot*”. The Permian Basin hydrocarbon play started life 50 years ago as a conventional play, but within the last decade extraction has turned to using unconventional methods. Note that the average break-even price of \$61 is still over \$10 higher than the current price of West Texas Intermediate crude oil. So even here money is being lost.

Capital investment

Cuadrilla drilling rig

Capital cost: \$40 million

Onsite staff (24 hour operation):
20 in 2 shifts



The fracking 'spread' on a drill pad

Capital cost: \$50 million

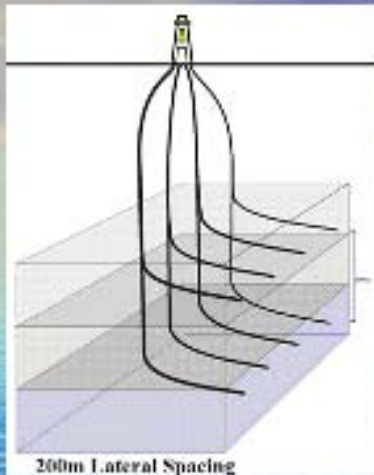
Staff: 90-100 technicians

NB. U S equipment not homologated for UK roads

The capital expenditure which would be required for a viable UK shale industry is frequently overlooked. One heavy-duty onshore drilling rig suitable for horizontal drilling costs in the order of \$40M.

The 'spread', or fleet of vehicles and ancillary equipment required for 'completion' of the well, including fracking, [costs in the order of \\$50M](#). Note that US equipment cannot simply be imported for UK use, because the vehicles are too wide, and with too great a turning circle, for the UK road network.

Thick shales in UK - different from US



Stacked laterals in Bowland Shale

Diagram misleading:

40-well pad requires 40 separate wells

One UK 40-well pad:

Drilling time: 22 days x 40 = 880 days

Completion (fracking): 1 well per day = 40 days

Total time 920 days + other work: say 1000 days or **c. 3 years**

A fundamental geological difference between the US and UK shale basins is that the shales in the latter are very much thicker. This could allow for stacked horizontal drilling, all from one pad. However, the diagram is misleading in implying that the laterals each branch off from a common vertical well. In fact each well has to be drilled separately from the surface, although the wellheads can be spaced just a few metres apart.

The drilling and completion of one putative 40-well pad would require that the drilling rig be on site for around three years.

UKOOG full shale production pipe-dream

50 pads over 6-10 years would require:

	\$M
50 rigs @ \$40M	2000

(Say) 20 completion spreads @ \$50M	1000
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- \$3 billion capital investment

Staff:

2000 completion technicians

1000 rig engineers

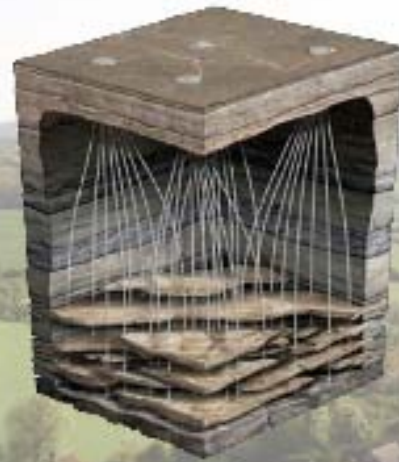
Using UKOOG's fantasy figures, assuming that 50 pads are being drilled simultaneously, will take between six and ten years, plus the subsequent completion; this will require an upfront capital investment of some \$3 billion.

The expert staff required would have to be imported from the US. Naturally, engineers from Texas or Pennsylvania will have to be paid a premium to relocate to (say) Blackpool, so staff costs will be far higher than they are in the US. Former North Sea oil engineers could be re-trained, but most of them have probably retired by now. There is no indigenous UK skill base for wellsite completion with fracking.

In short, a UK shale industry can never be developed in any kind of realistic time-frame to serve as a so-called bridge to renewable energy sources. The personnel training and capital investment should be logically applied directly to developing renewables as fast as possible.

**Can be produced with
low visual impact**

- 12-24 wells in 4-6 acre site
- Wells and pumps below ground level
- Control production to reduce initial road tanker impact
- Can be located in brown field sites and away from villages, houses, small roads



UKOG diagram misleading:

Cannot frack vertical/deviated wells efficiently

This UKOG diagram misleadingly implies that multi-well pads will direct the deviated wells vertically through the Kimmeridge Clay Formation. But production fracking (as opposed to test fracking, as at Preese Hall-1 in Lancashire) requires that the wellbore be horizontal, and aligned at right-angles to the maximum principal tectonic stress direction. This stress direction is horizontal, and directed north-south or NNW-SSE in the UK. The fracks created then be aligned in vertical planes, parallel to the maximum principal stress. They cannot be created by vertical wells, as suggested here.

Shale well profit/loss

US gas wells: 2007- mid 2014

Historic income (gas sales)
Drilling cost: 46,000 @ \$7-8M
Royalties, leases, interest

\$ billion

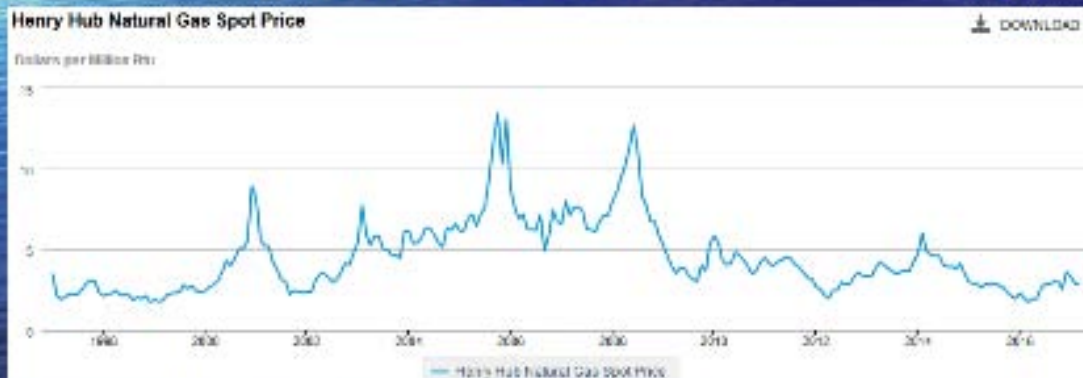
215

322-368

?

Debt (W S J, end 2015)

> 200



I have tried to quantify the economically disastrous shale gas bubble in the US, after reading an [article](#) at the end of 2015 which quoted the *Wall Street Journal* as saying that the onshore US shale industry (NB excluding the majors Chevron and ExxonMobil) was carrying debts of more than \$200 billion.

One can take the [official monthly gas production figures](#) from the Energy Information Administration, and multiply each by the [historic Henry Hub gas price](#) for each month. The Henry Hub is a gas pipeline distribution point in Louisiana, where gas price is valued. From 2007 to mid-2014 the total raw gas sale value amounts to \$215 billion.

But the historic raw drilling cost for the approximately 46,000 horizontal gas wells, at \$7M to \$8M per well, is more than \$100 billion higher, of the order of \$350 billion. This figure excludes royalty payments (typically one-eighth, or 12.5%), lease costs, interest payments, and so on.

Most of these wells are now over five years old. Because of the high decline rate of fracked wells, little additional income can be expected from existing wells. Therefore it cannot be argued that the investment has been made, and that significant income has yet to be generated.

These figures do not add up to a viable industry. It has been a bubble, or Ponzi scheme, wherein new drilling (to keep up the high initial rate of production) is financed by pulling in new investment in the form of junk bonds. Greedy investors are (or have been) attracted by the annual dividend of around 6%, but they will never get back their capital.

Conclusions

UKOG plans for Broadford Bridge disingenuous

- Fracking will be required to produce Kimmeridge Clay oil
- Irresponsible to drill through faulted zones (pollution risk)
- No 3D seismic – drilling blind

Government

- mendaciously defines 'unconventional' and 'fracking'
- influenced by free market ideologues / fraudsters
- toothless, ineffective regulation

Lessons from the US

- fracking has been an economic disaster (Ponzi scheme)
- UK shale production costs will be double that of the US
- It will never take off in the UK without govt subsidy

Reliable countries can supply UK with LNG while 23 million gas users switch to renewables over next 10-15 years

UK shale gas/oil – polluting, expensive

The UKOG / KOGI plans for Broadford Bridge are disingenuous. A fresh planning application is required. More seismic surveys, and preferably in the form of 3D, must be obtained before such drilling is permitted. There is a real risk of polluting aquifers because of the evident technical inadequacies of the developer.

The UK government, apparently influenced by free-market ideologues like Matt Ridley, and taken in by American shale industry fraudsters, is mendaciously defining the words 'unconventional' and 'fracking' in ways that benefit industry. These definitions, which make a mockery of evidence-based science, can, and should, be challenged legally.

We should learn from the 15-year history of the shale industry in the US that a UK shale industry will never be economic. The high-volume hydraulic fracturing (HVHF) method for shale was devised in the era when the price of oil was \$80 or more. In the UK the costs of such an industry will be double those of the US, so it will never be economically viable - unless of course the government decides to subsidise it.

I accept that we cannot expect the 23 million UK households who heat their homes by gas to switch energy supplies overnight. But while such a changeover takes place over the next 10-15 years, liquid natural gas can be imported from stable countries such as Qatar, Nigeria, Norway, and the USA.

In conclusion, my advice to local objectors is to keep delaying, challenging and otherwise obstructing the advance of the shale industry by all legal means, not least by lobbying your MPs with the facts. Perhaps within just a year or two from now the misguided investors in this nascent industry will pull the plug, and we can all relax.