Addendum to representation by Brockham Oil Watch

(Surrey County Council Planning Application MO/2018/0444 / SCC ref 2017/0215
Brockham Wellsite, Felton's Farm, Old School Lane, Brockham, Surrey RH3 7AU)

by

David K. Smythe

(Emeritus Professor of Geophysics, University of Glasgow)

La Fontenille*, *1, rue du Couchant*, *11120 Ventenac en Minervois*, *France

8 May 2018

1. Introduction

I have been asked by Brockham Oil Watch to provide technical comments concerning the subsurface operations by Angus Energy Limited (hereinafter the Applicant) at Brockham in support of its representation to Surrey County Council (SCC) on the proposed works. My expertise is summarised in Appendix 1.

2. Inadequacy of data and other information supplied to date

The Applicant has not provided SCC or the public with enough or adequate information for a reliable technical assessment of its proposals to be made. For example, the deviated welltrack of Brockham-X4Z remains confidential; the Well Proposal and Drilling Programme document dated 9 November 2016 is heavily redacted; there are conflicting versions of the Ordnance Survey grid coordinates for the surface positions of the Brockham wells; and a structure map (in time and depth) of the proposed Kimmeridgian prospect to be appraised has not been supplied.

More fundamentally, the existing database is not sufficiently robust to define the geological structures in sufficient detail. Figure 1 shows contours in depth of the Top Portland, coloured so that yellow through orange indicates a structural high, and green through blue indicates a low. The database for the contouring comprises the seismic lines shown in green, plus the group of wells drilled at Brockham in the upper-central part of the figure. The structure is a tilted block, faulted along its SE flank by what I call the Brockham Fault.

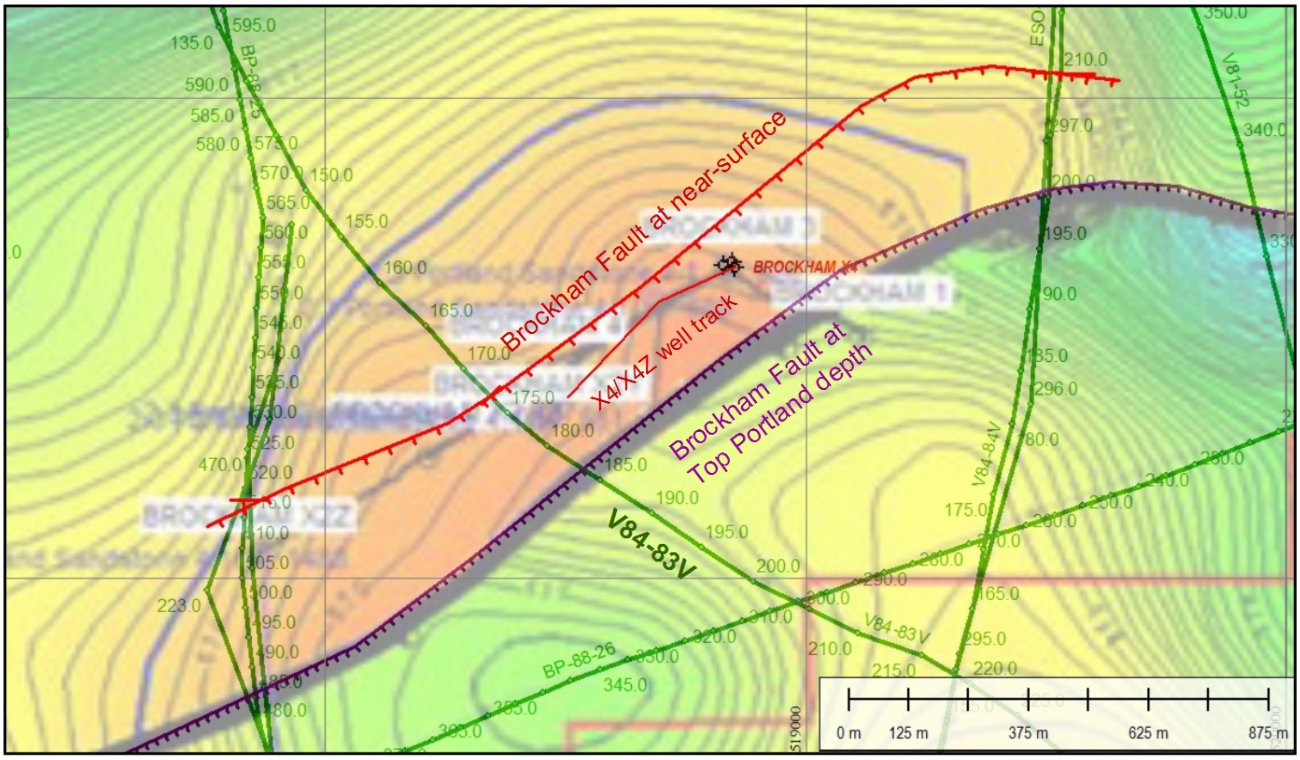


Figure 1. Structure contour map by the Applicant of the Brockham field at Top Portland (colours; orange high; green-blue low). Seismic lines used as the basis for the interpretation are shown in green; line V84-83V is shown below. The fault mapped at Top Portland (purple) is the same fault as mapped by myself near the surface (red line with teeth on the downthrown side).

The wells lie within the zone of the fault. The structure is constructed by interpolation, between two or three coincident N-S trending seismic lines on the west, through line V84-83V running NW-SE through the centre, and a pair of N-S line in the east. A tie-line shown running WSW-ENE at the bottom of the figure is somewhat inadequate as it lies on the downthrown side of the Brockham Fault.

No explanation has been offered as to why the south-westerly direction was chosen for the sidetrack well X4Z. The coverage of seismic data dates from 1984 or earlier. Reprocessing can only make marginal improvements to such vintage 2D data. Such coverage was barely adequate even in the era of drilling vertical wells, such as the Brockham-1 discovery well drilled by BP in 1987.

Figure 2 shows the various Brockham wells projected onto an E-W vertical plane, with a plan view shown as an inset. The scales are true (no vertical or horizontal exaggeration). The original BP well, Brockham-1, is depicted by the black line. Although it is slightly deviated to the SE, it is an essentially vertical well. The sidetrack X4Z is shown as a dashed green line coming off the donor well X4 at the 7 inch shoe; the welltrack will be curved as seen in the vertical section, but since only this point and the final point are available for plotting, it is depicted here as a straight line.

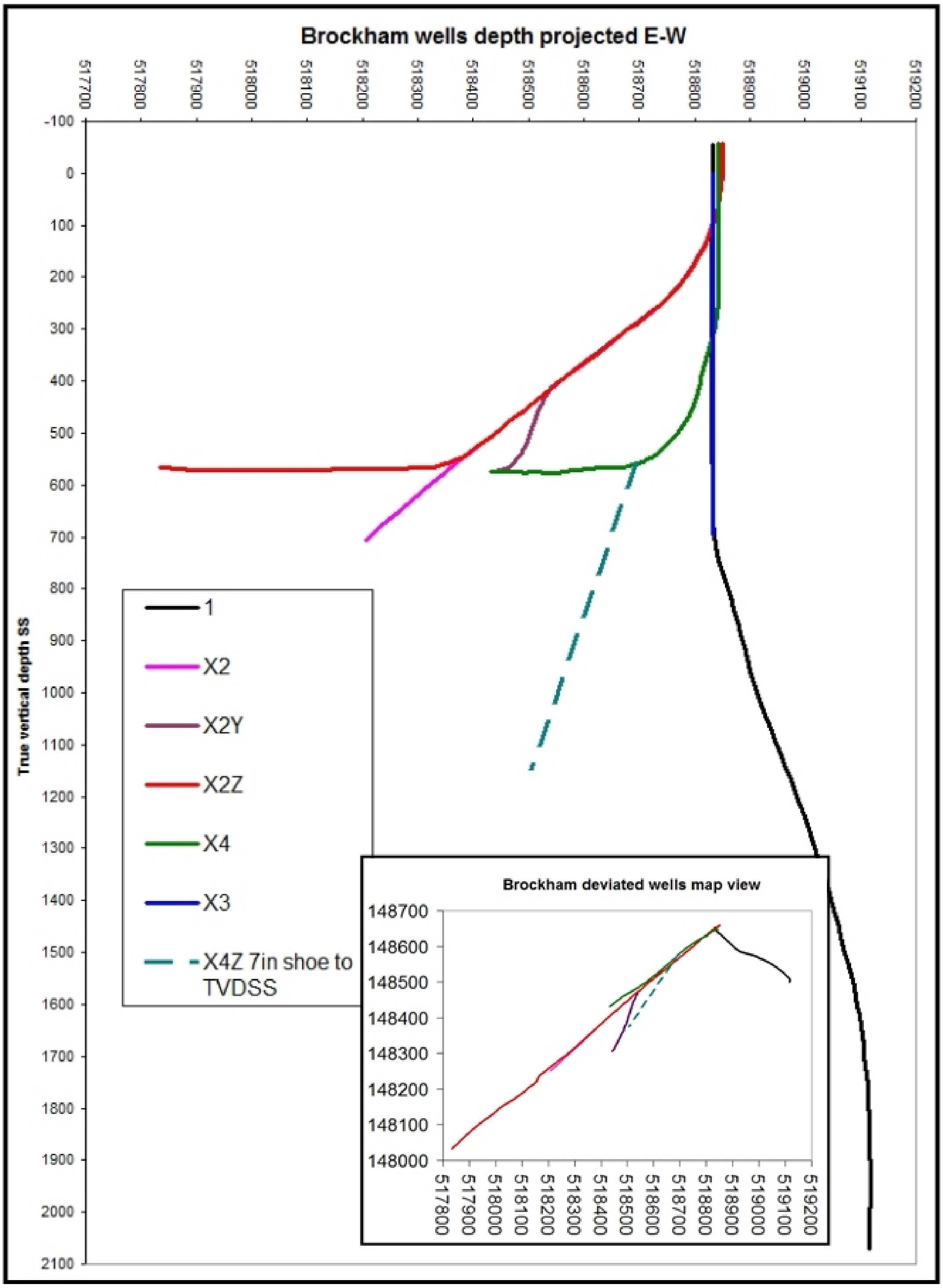


Figure 2. Vertical section running E-W showing the various Brockham wells (no vertical exaggeration). The inset is a plan view.

Figure 2 shows wells X2Z and X4 turning horizontal in a southwesterly direction along the Portland Sandstone at a depth of just under 600 m below sea level. The sidetrack X4Z takes a more southerly azimuth and turns vertical with increasing depth. It is likely to penetrate the Kimmeridgian micrites within 100 m or so of the adjacent Brockham Fault to the SE.

3. The proposed works; conventional or unconventional?

The appraisal of the Kimmeridge Clay Formation (KCF) is described ostensibly as a conventional resource appraisal. Appendix 2 provides a discussion of the difference between conventional and unconventional hydrocarbon resources, in the context of the current Weald oil prospecting in general, and the KCF in particular.

If the KCF were a conventional prospect it would comprise the following elements:

- The well-defined fault-bounded structure,
- The reservoir(s) of fractured micritic layers (semi-limestones or calcareous mudstones),
- The source of KCF shale below,
- The cap rock of KCF shale above.

However, this description is invalid, and, in any case, contradicted by the Applicant itself. The Waste Management Plan of May 2017 states (pp. 8-9):

> *"The new BRX4-Z sidetrack from the third well on the field offers the potential to produce from the Kimmeridge micrite limestones accessing oil from the Kimmeridge clay as a hybrid reservoir."*

The revelatory phrase here is "*hybrid reservoir*". The Applicant's Investor Presentation of January 2018 defines hybrid reservoirs (slide 9) as "*interbedded shale and limestone layers produced conventionally - without the need for fracking*". This definition is wrong and misleading. A hybrid reservoir is unconventional, but may include elements of a conventional trap such as a sandstone or limestone. Examples of hybrid shale reservoirs are discussed by Jarvie (2011), and include the Bakken play of North Dakota and the Niobrara of Colorado. Both these plays require fracking to increase the low permeability of the shale. The clastic and/or carbonate layers within the shale provide mechanically favourable targets for the fracking, but the vast bulk of the production comes from the fracked shale above and below.

In several of its published documents, including the one cited above, the Applicant discusses producing from the entire ~200 m of KCF. It asserts that this entire section is "*fractured*", and further asserts that fracking will not be required at Brockham. The proposed production from the entire 200 m section of KCF clearly conflicts with the definition of a conventional micrite reservoir prospect defined above, but, in contrast, compares closely to the unconventional (hybrid) Bakken and Niobrara plays of the USA.

A video presentation by the Applicant (A Walk Through Time: From Kimmeridge to Brockham, dated 23 January 2017) purports to demonstrate the natural fractures through which production will occur (sequence 03:10 to 03:30) by reference to the KCF outcrop at Kimmeridge Bay, Dorset. But as the sequence shows, the fractures within the limestone layers, each less than 1 m thick, are vertical, so it is difficult to see how lateral drainage of the reservoir can be achieved.

The use of an acid wash (only for wellbore cleaning) is mentioned in the Waste Management Plan (submitted to the EA for re-permitting). There is no mention of matrix acidisation, a method of enhancing permeability in unconventional plays by injection of acid under pressure into the formation. The word acid does not occur in the current planning application, nor in the Planning Statement. The Applicant asserts that fracking (in the sense of high volume hydraulic fracturing) will not be used. It is therefore difficult to see how the Applicant can achieve successful production from a geological sequence which elsewhere requires fracking and/or acidisation.

4. Appraisal or production?

The Applicant is asking for a period of three years for appraisal. This is untenable, given that appraisal normally takes six months, and normally less. The Applicant has further stated in its March 2018 annual report:

> *"These activities from the Group's conventional reservoirs at Brockham and Lidsey will be complemented by the testing of the Balcombe-2z well and the first commercial production from the Kimmeridge layers at Brockham (Brockham -X4Z) in 2018."*

It therefore appears that the Applicant is asking for an artificially extended period of 'appraisal', under cover of which it intends to start production.

5. Faulting

Figure 3 shows a portion of the original version of seismic line V84-83V. I have not used the reprocessed version, available in figure 5.6 of the Exodus report, because the quality of reproduction of the latter is poor. However, there appears to be no significant difference between the two versions. I overlaid the latter version with its fault interpretation on the original version in order to position the faults shown in Figure 3.

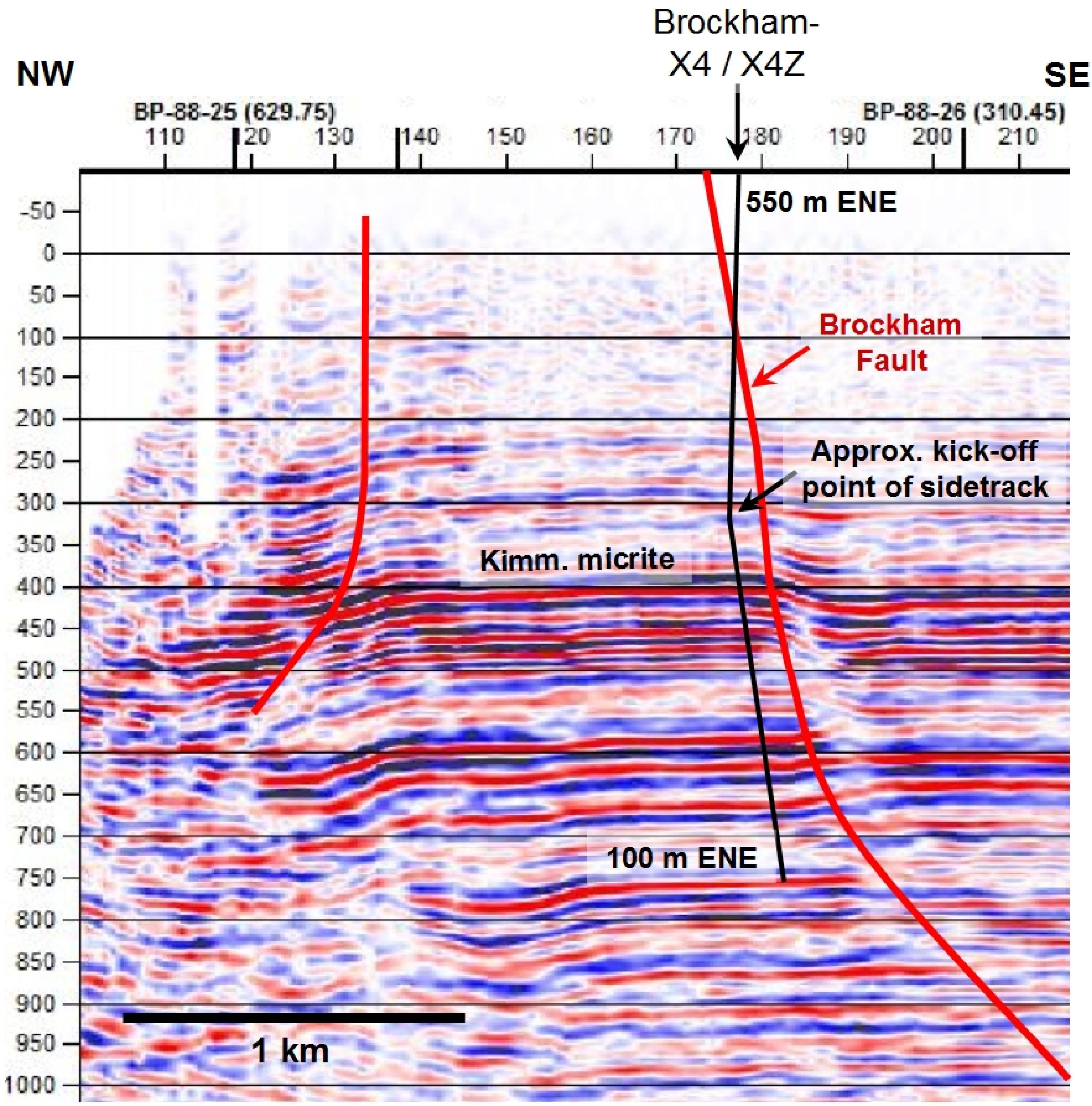


Figure 3. Seismic section V84-83V (original version, courtesy of the UK Onshore Geophysical Library) showing the Applicant's interpreted faults (red) and the Brockham-X4/X4Z well projected SW, from 550 m NE (near surface) to 100 m NE of the seismic section at the well bottom.

The principal fault of interest is the field-bounding fault downthrowing to the south. I have marked the approximate location of Brockham-X4 (the donor well) and its sidetrack X4Z on the map of Figure 1, projected SW (at an azimuth of 232°) onto the plane of the seismic section of Figure 3. The projection distance is 550 m at or near the surface, diminishing to about 100 m at the bottom of the well. The top of the Kimmeridgian micrites is clearly marked by a strong reflector; this is a regional characteristic of the micrites.

The final depth of the well is shown only approximately in Figure 3 because the vertical scale of the seismic section is in two-way travel time, not depth. Interconversion between these two scales requires a knowledge of the velocity-depth profile, which has not been made available.

The well penetrates the Brockham Fault at a shallow depth, and after slight deviations it ends at around 200 m from the fault, but within about 100 m of the fault at the micrite level. There it may therefore lie within the damage zone of the fault - the zone on either side of which the surrounding rock is fractured. This may be intentional on the part of the Applicant, because vertically upwards from the micrites, along the northern flank of the fault, there will be a zone of fracturing which will enhance oil flow. My analysis of the nearby Horse Hill-1 so-called Kimmeridgian 'discovery' by UK Oil & Gas Ltd (the 'Gatwick Gusher') shows that the reason for the temporary high oil flow at Horse Hill-1 was probably because the well was drilled about 60 m north of a fault, and well within the damage zone of that fault.

6. Discussion

I concur with the facts stated in the submission by Brockham Oil Watch concerning the Applicant's track record. It is evident that the Applicant has behaved in the past in an untrustworthy manner in the matter of regulation. I believe that the current application is a continuation of this mendacious approach to planning, for the following reasons:

- The KCF is an **unconventional play**, contrary to the Applicant's assertions,
- The so-called **appraisal**, lasting three years, may be a cover for moving into production without asking for the necessary extra planning consent,
- The drilling and testing of the KCF so near to a **major fault** may be an attempt to emulate the Horse Hill-1 results,
- If so, any **flow from the KCF** will be due to proximity to a fault, and will therefore not be diagnostic of the wider KCF,
- The arguments that **stimulation** of the KCF, whether by acidisation or by fracking, will not be necessary are incredible, because they run counter to the known geomechanical properties

of the KCF, and because they conflict with the extensive experience of similar unconventional plays in the USA.

- There is an **environmental risk** in drilling close to a fault, because if any kind of stimulation is applied the fault zone may become permeable and therefore be a 'fast track' to the near-surface environment.

7. Conclusions

The move from **conventional production** of the Portland Sandstone into **unconventional appraisal** of the Kimmeridge Clay Formation (KCF) is a fundamental change in exploration and production strategy, and is not covered by the existing permits. The Applicant is misleading SCC, the public and its investors by insisting that all its activities, including the appraisal of the KCF, are conventional in nature.

The Applicant had to obtain a fresh Field Development Plan from the OGA, and should be required to make a fresh planning application to SCC. This new application should contain far more detail and justification of its proposals than the sketchy outlines provided to date. Therefore the application should be refused.

8. Reference

Jarvie, D.M. 2011. Unconventional Oil Petroleum Systems: Shales and Shale Hybrids. Society of Petroleum Engineers Search and Discovery Article #80131.

APPENDIX 1

A1.1 Relevant personal details from my CV

I am Emeritus Professor of Geophysics in the University of Glasgow. Although I am now a French resident I remain a British citizen, and take an active interest in UK, French and foreign affairs, as well as in various facets of scientific research.

Prior to my taking up the Chair of Geophysics at the University of Glasgow in 1988 I was employed by the British Geological Survey (BGS) in Edinburgh from 1973 to 1987. I was a research scientist, rising to the post of Principal Scientific Officer. My work in the BGS from 1973 to 1986 was funded by the UK Department of Energy as part of a Commissioned Research programme on the geology of the offshore UK region. I also gave geological advice to the Foreign & Commonwealth Office on matters pertaining to UK territorial claims offshore. This was during the exciting phase of early discoveries and development of the North Sea. I led a team of seismic interpreters working mainly on the prospectivity of the western margins of the UK, using the industry seismic and well data supplied to the Department of Energy. As a result I became the UK's leading expert on the deep geology of the continental margin west of the British Isles. Although our interpretation groups in the BGS were never able to commission our own wildcat wells, we had many 'virtual successes', where our independent interpretations were confirmed by subsequent drilling, and where the industry operator was proved spectacularly off-course.

In the 1990s I was closely involved in the search for a UK underground nuclear waste repository, and conducted for Nirex (the nuclear waste disposal agency) an experimental 3D seismic reflection survey. This took place in 1994. The survey encompassed the volume of the proposed rock characterisation facility (RCF) – a deep underground laboratory planned as a precursor to actual waste disposal. This was a double world 'first' – the first ever 3D seismic survey of such a site, and the first academic group to use this method, which at the time was just emerging as an essential tool of the oil exploration industry.

Since my retirement from the university in 1998 I have carried out private research, acted as a consultant to the oil industry for conventional exploration (2002-2011), and maintained an interest in the geological problems raised by nuclear waste disposal, shale gas exploration and coal-bed methane exploration. My tools for this work are up-to-date; I have my own licence for ProMAX 3D (seismic data processing), and currently hold on loan industry-owned licences for SMT Kingdom (seismic and well interpretation) and ModelVision (gravity/magnetic modelling including tensor fields).

A1.2 Declaration of interest, independence and non-liability

I have no interests to declare. This document was requested by Brockham Oil Watch, and has been provided *pro bono publico*. I am not connected to, nor am I a member of, any activist group, political party, or other organisation. I am solely responsible for the contents of this submission. It is supplied in good faith, but I can accept no liability resulting from any errors or omissions.

For the avoidance of doubt, my legal dispute with the University of Glasgow (2016-2018) has been settled amicably, and the Secretary of the University has stated (5 January 2018) :

> *"I have no reason to doubt your integrity as a scientific researcher, and hope that you will continue to be as productive in your research as you have been since your retirement in 1998."*

He has also confirmed that I am free to continue to use the title of Emeritus Professor of Geophysics without hindrance. I remain a member of the College of Science and Engineering, but not attached to any specific school or group within the University, and the views expressed are my own.

[end of Appendix 1]

APPENDIX 2

THE DEFINITION OF CONVENTIONAL AND UNCONVENTIONAL HYDROCARBON RESOURCES

A2.1 National planning practice guidance

The Minerals section of Planning Practice Guidance, published on 17 October 2014, states:

> *"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."*

This attempt to define the difference between conventional and unconventional hydrocarbons conflates the mineral itself ("*hydrocarbons*") with the process ("*comes from*") and the supposed source or reservoir rock. But the difference between the two terms is fundamentally one of resource extraction method. The guidance fails to recognise this point.

The definition is unsound for the following reasons:

1. It uses overly-simplistic rock types to differentiate between the two resources - "*sandstone*", "*limestone*", "*shale*", "*coal seams*" - without defining them properly. Such nomenclature is too black and white; in practice, there are gradations between end-member rock types; for example, geologists can describe a muddy sandstone, a sandy limestone, or a sand-prone shale. The end-members themselves, for example, 100% pure limestone, are rather rare in nature.

2. There is no mention of the geological context within which any of these rock types occur, for example, basin position, trap geometry, layer thickness, etc., nor the source where the hydrocarbons have been generated. Figure A2.1, from the US Energy Information Administration, illustrates the various geological settings in which natural gas resources occur. The diagram is similar for oil.

3. There is no mention of the physical properties of the rock types, such as permeability and porosity.

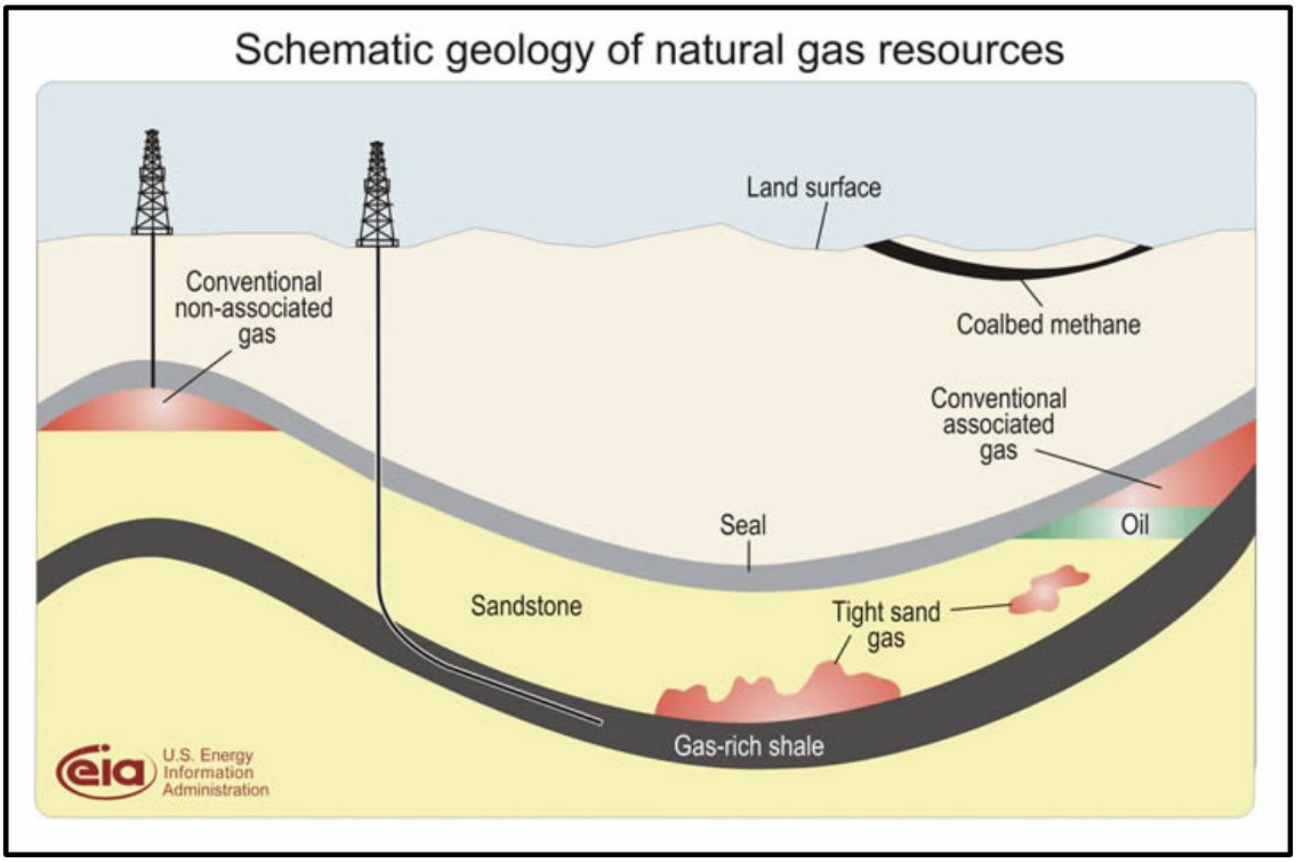
4. It omits mention of the physical and chemical properties of the "hydrocarbons" themselves, e.g. viscosity, API gravity (oil), or alkane (gas).

5. It omits to mention the processes by which the hydrocarbon is extracted, in particular the difference between hydrocarbons which are extracted from the rock with little or no treatment, versus those requiring extensive treatment to make them flow - e.g. steam heating, acidising, or hydraulic fracturing, or whatever forms of reservoir stimulation.

6. There is no mention of the economic aspects of the production process.

Figure A2.1. Schematic geology of gas resources, from US Energy Information Administration.

A2.2 Other definitions



There is no universally agreed definition of the difference between conventional and unconventional hydrocarbon mineral extraction; various versions in the scientific and technical literature emphasize different aspects mentioned in points 1-6 above. However, all reasonable definitions that I am aware of include, either implicitly or explicitly, the permeability of the host rock.

The figure of 0.1 mD (milliDarcies) for the host rock is generally agreed to differentiate between the two extraction procedures, although the Society for Petroleum and Coal Science and Technology of Germany defines a higher value of 0.6 mD. Given the vast range of possible permeabilities and the limited precision in estimating permeability, the scale is usually presented in logarithmic form, so that units (decades) on the scale are 0.001, 0.01, 0.1, 1, 10 ... mD and so on. Figure A2.2 illustrates the permeability spectrum. Below 0.1 mD the process required to extract the hydrocarbons is unconventional, whereas above that value it is considered to be conventional. Note that the measured range of Kimmeridge Clay micrites unambiguously falls into the unconventional area of the spectrum. A version of this diagram has been adopted by the Oil and Gas Authority (OGA) and published on its website in June 2017.

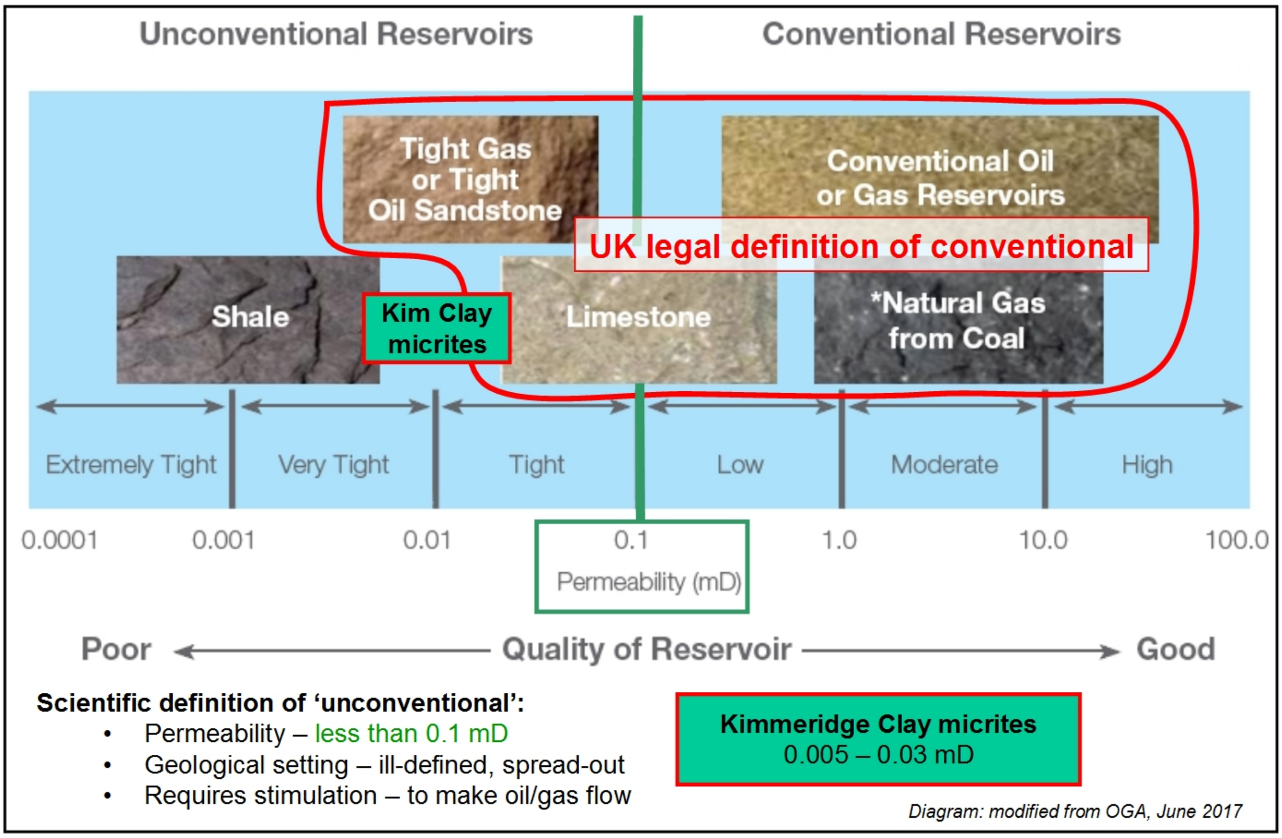


Figure A2.2. Spectrum of permeabilities used to differentiate between unconventional and conventional reservoirs (Canadian Society for Unconventional Resources). The UK legal definition is outlined in red. The Kimmeridge Clay micrite range of permeabilities has been added (green box).

Next in importance to a quantitative definition using permeability comes the geological setting in which the hydrocarbon-bearing rock occurs. Thus conventional resources are found in finite and well-defined traps, whereas unconventional gas or oil is distributed throughout a widespread layer with no clear-cut boundaries.

Along with the two criteria above, the process of extracting the hydrocarbons is important. It is variously described as fracking, acidising, massive stimulation, additional extraction or conversion technology, or assertive recovery solution. Although different in detail, what they all have in common is the aim of making the hydrocarbon flow when it would otherwise not do so.

A2.3 Discussion and conclusion

No definitions of which I am aware (see list below) regard so-called "*sandstone*" or "*limestone*" reservoirs as automatically conventional, as has been simplistically defined by the national Planning Practice Guidance. On the contrary, many sandstone and limestone reservoirs are called 'tight', meaning that unconventional extraction methods are required.

Given the unscientific and imprecise nature of the Planning Practice Guidance definition, SCC should ignore it as being unsound, and follow instead the permeability-based definition endorsed by the OGA.

[end of Appendix 2]