UKOG Oil & Gas PLC

Application to Isle of Wight Council (ref. 20/00513/FUL)

to drill at Arreton, Isle of Wight:

Comments on the geology and hydrogeology

by

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SUMMARY

Arreton-1, drilled in 1952 by D'Arcy Petroleum (which later became BP) and nearby Arreton-2, drilled by British Gas in 1974, both proved that the Arreton anticlinal structure is 'dry' (no hydrocarbons) at any depth. Nevertheless, UKOG (hereinafter the Applicant) claims to have identified a "*discovery*" , which it wishes to follow up by applying for permission to drill a vertical well and a horizontal well originating at the surface at a new wellpad some 850 m WNW of the existing Arreton-2 well. No new evidence has been provided to substantiate this claim. No structural maps or seismic data have been presented to back up its 'calculations' (which amount to little more than guesswork) that the Portland Limestone, in particular, contains a substantial quantity of oil in place. The Applicant proposes to drill horizontally along the Portland, which has good porosity but probably very low permeability. It is difficult to see how any significant quantity of oil could be produced without resorting to unconventional stimulation techniques (fracking or matrix acidisation).

The application contains numerous inconsistencies regarding whether the directional drilling is towards the SW or to the SE. There may have been a change of strategy, but certain diagrams were never updated. The geology is far less certain than implied by the Applicant's cross-sections, and the 2D seismic coverage on which it is based is rather sparse and out-of-date. The complex Purbeck – Isle of Wight Fault zone runs E-W just to the north of the proposal. Accommodation faults splaying off this main structure are present, but hard to map. Drilling a well which is deviated from the vertical to the horizontal frequently leads to problems in cementing the gap between the production casing (a hollow steel tube) and the rockface of the hole, so that well integrity is compromised. Failure of well integrity may in the long term lead to leakage and contamination of the primary aquifer at the surface. The splay faults, unrecognised by the Applicant, may also connect the new wellbores to the Arreton-1 and -2 wells, which are now 68 and 46 years old, respectively, and which may have suffered loss of integrity through rusting of the casings. Drilling new wells near to these old wells constitutes a further environmental risk.

The Applicant has a proven poor track record of exploration in similar geological environments, involving severe technical problems with its wells, combined with exaggerated claims about future oil production which have proved to be illusory.

The possible short- or long-term risk to the primary aquifer at the surface, weighed against the very small chance of success of this application in the light of the existing knowledge of the Arreton structure, outweighs any finding in favour of the Applicant.

The Applicant has failed technically, and continues to fail, at two sites in the Weald, using essentially the same approach to that now proposed at Arreton, and in similar geology. On geological, hydrogeological and exploration grounds, the application should be refused.

1. Professor Smythe: relevant details from 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.

My professional qualifications are: BSc Geology (Glasgow 1970), PhD Geophysics (Glasgow 1987); I was made a Chartered Geologist in 1991, but am no longer registered as such.

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. In the 1990s I was closely involved in the search for a UK underground nuclear waste repository. I served on the BNFL Geological Review Panel from 1990 to 1991, to support BNFL's case for a Sellafield site for a Potential Repository Zone (PRZ), at the time when Nirex was investigating both Dounreay and Sellafield.

I was closely involved with Nirex at this epoch. I planned and conducted for Nirex an experimental 3D seismic reflection survey, which 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 only just emerging as an essential tool of the oil exploration industry.

I have published around 70 technical and scientific papers and reports (44 papers in the peer-reviewed literature). Since my retirement from the university in 1998 I have carried out private research, acted as a consultant to the oil industry, and maintained a professional interest in the geological problems raised by nuclear waste disposal, unconventional hydrocarbon exploration and coal-bed methane exploration.

At the BGS I worked closely with the Department of Energy (DEn) and occasionally advised the Foreign and Commonwealth Office.

I worked part-time as a consultant to the oil industry 2001-2011, mapping conventional prospects in the south of England and abroad. This included a period consulting for Norwest Energy in the area of the current application. This work frequently involved reprocessing existing 2D seismic data. I therefore have a profound understanding of the search for

hydrocarbons, and possess the necessary industry-standard software tools for processing and interpreting data.

I am probably the only person ever to sit on both sides of the table at PEDL award interviews. I was once invited to join the panel at which the DEn (the predecessor of the Oil and Gas Authority in hydrocarbon regulation) interviewed BP for a licence west of the UK. I sat on the regulatory side. Some 25 years later, during the period when I worked as an oil industry consultant, I sat at the other side of the table, successfully representing Norwest Energy for its onshore licences PEDL238 and PEDL239 in the south of England.

2. Declaration of interest, independence and non-liability

I have no interests to declare. This report was requested by Frack Free Isle of Wight. It has been prepared using my own resources, and has been submitted to the Isle of Wight Council *gratis*, in my own right.

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.

3. Previous exploration at Arreton

D'Arcy Exploration (the predecessor of BP) shot seismic lines in 1950, identified an E-W trending anticline (an elongated dome structure capable of hosting oil or gas), and drilled Arreton-1 in 1952. British Gas drilled Arreton-2 nearby in 1974 with the aim of exploring the deeper Permo-Triassic and Carboniferous within the same structure, not reached by Arreton-1. Both holes were dry, but with limited oil shows.

Brabant Petroleum (with British Gas, BP and latterly Wintershall as partners) operated the PL087 licence covering the whole of the Isle of Wight from 1974 to 1996. It concentrated on Sherwood Sandstone Group targets, but with disappointing results. On other reservoir possibilities, Brabant[1] concluded:

> *"The Isle of Wight is unusual in the context of other Southern England basins, in that the Sherwood constitutes virtually the sole reasonable reservoir target. The Bridport, Corallian and Portland sands are very poor to nonexistent here, while over the south of the island, the Mid Jurassic oolites are developed in their basinal Dorset facies, as evidenced by the tight and shaley section at Chessell."*

Black Rock Resources was granted PEDL98 including the Arreton area in 2001. Its proposed work programme[2] involved Kimmeridge Field analogues in the Cornbrash – Oxford Clay Interval. One contingent well was offered, but which was never drilled.

Norwest Energy obtained PEDL239, a licence split into an eastern and western parts, in 2008[3]. I was the geophysical consultant to Norwest between 2006 and 2011, working with a geological consultant. We concurred with the previous views of the Arreton area that the volume of any traps in the Jurassic was small, that the timing of oil migration was wrong to have filled the traps, and, of course, that the prospect had already been tested in 1952 and 1974. Norwest therefore concentrated its exploration on the Isle of Wight in the south-western sector, using the new tool of airborne full-tensor gravimetry to complement the seismic and well database, in addition to acquiring new 2D seismic data.

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[1] Brabant Petroleum Limited 1996. PL 087 – licence summary. Relinquishment report.

[2] Black Rock Resources (UK) Ltd 2000.Appendix B technical information on blocks applied for. National grid refs: SZ38, SZ48, SZ58 Location: Wilmingham-Arreton Area, Isle of Wight.

[3] NWE Southern Cross (UK) Pty Limited 2008. Petroleum geology and rationale to apply for Open blocks SZ28, SZ38, SZ48(b), SZ48(c), SZ47, SZ58(b), SZ57, and SZ68, in the Isle of Wight, UK 13th Licence Round. Powerpoint, February 2008.

Norwest commented on the Portland as follows[4]:

> *"Sands in the Purbeck/Portland sequence may be sealed by a combination of upper Purbeck shales and the Purbeck Anhydrite. … Migration paths are a big question in this region. … The most realistic source for this oil is that it migrated from mature source rocks south of Arreton. Arreton-2 had good oil shows in the lower Purbeck and recovered gas and oil cut mud from a test of a sandy limestone in the Portland."*

It should be noted that the search by Norwest in PEDL239, and its neighbouring licence PEDL238 in the Bournemouth area, was entirely for conventional hydrocarbons. But the various leads in both licences were considered too risky to develop, and Norwest relinquished both licences in 2014 without having drilled[5,6].

4. The Applicant's claim of a "*discovery*" at Arreton

The Applicant states[7]:

> *"Hydrocarbon exploration at Arreton commenced in 1952 with the drilling of the Arreton-1 borehole1. Initial appraisal confirmed the 'Arreton-1 Oil Discovery' within the Purbeck limestone, Portland limestone and the Inferior Oolitic limestone (the 'target formations') of the Wessex Basin where trapping structures within the rocks allow for the accumulation of hydrocarbon deposits. This was followed in 1974 with the drilling of a second exploratory borehole, Arreton-2 but there was no flowing of the reserves to surface at this time."*

On the contrary; the final report for Arreton-1[8] states in summary:

> *"Only very slight-traces of oil were encountered despite the moderate development of reservoir beds".*

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[4] NWE Mirrabooka (UK) Pty. Ltd. 2014. Licence PEDL239 Relinquishment Report. 10 July 2014.

[5] NWE Mirrabooka (UK) Pty Ltd 2014. Licence PEDL238 Relinquishment report.

[6] NWE Mirrabooka (UK) Pty Ltd 2014. Licence PEDL239 Relinquishment report.

[7] UK Oil & Gas plc. Arreton exploratory well site hydrocarbon exploration, testing and appraisal Environmental Statement. Doc. Ref. UKOG-A3-ES, 20 March 2020.

[8] MacLean, R.G. 1954. Geological completion report on Arreton No. 1 well Isle of Wight. D'Arcy Exploration Company Limited, 42 pp.

Furthermore, the Arreton-2 well completion report[9], written by British Gas in 1974, states that the well was abandoned on 6 June 1974 as a "*dry hole*". It concludes, under Hydrocarbon Indications, that:

> *"… good fluorescence, bright yellow, with good streaming cut (using chlorothene) was observed in the Purbeck/Portland Beds interval 2520' – 2670'. The zones of interest in the Purbeck Beds were relatively thin and sparse and were cored and tested, without hydrocarbon trace. The lower Portland beds, appear to have fair to good total porosity and the logs indicated that they merited testing. However, no production was achieved."*

The Xodus report[10] of 2016 commissioned by the Applicant states, regarding what had by now been mendaciously renamed by the Applicant as the 'Arreton Discovery':

> *"The Arreton-2 well, drilled in 1974, discovered several reservoirs including in the Portland Limestone, the Purbeck Limestone and the Inferior Oolite. Hydrocarbons were encountered in strong oil shows, a test was carried out but no hydrocarbons flowed to surface."*

The Applicant claims that the "*Arreton-2 (Oil discovery)*" had oil shows at the following five horizons (see, for example, the Environmental Statement, Appendix 5, 2D sections):

- Portland
- KL 4
- KL 3
- Corallian
- Oolite

But apart from the Portland show quoted above, the well completion report mentions only "*dead oil staining*" in the Corallian (with bitumen), Kellaways, Great Oolite, Upper Lias and Lower Lias (with bitumen). These indications do not constitute a "*discovery*". Although the

[9] Well completion report Arreton-2. UK Continental Shelf Well Records, DTI, 2002.

[10] Xodus Group 2016. Arreton Discovery, PEDL331, Onshore Isle of Wight Independent Review – Executive Summary. 27 January 2016.

two micrites (UKOG's KL4 and KL3) are clearly recognisable on the composite log, only the lower (KL3) is annotated, as "*Thin limestones, white, dark grey, microcrystalline*". There is no mention of hydrocarbon shows at either horizon. No cores were taken from which UKOG might have been able to establish oil shows that had somehow been missed by British Gas.

For the avoidance of doubt, no oil or gas shows were found in the Kimmeridgian of Chessell-1, Wilmingham-1, and Cowes-1. The Kimmeridgian is absent at Sandhills-1, -2, -2z, Bouldnor Copse-1, and Norton-1.

Therefore UKOG's claim of oil shows in these two Kimmeridgian micrites is false.

The Society of Petroleum Engineers[11] defines a discovery as follows:

> *"Discovered: The term applied to a petroleum accumulation/reservoir whose existence has been determined by its actual penetration by a well, which has also clearly demonstrated the existence of moveable petroleum by flow to the surface or at least some recovery of a sample of petroleum. Log and/or core data may suffice for proof of existence of moveable petroleum if an analogous reservoir is available for comparison."*

In contrast, a dry hole is as follows:

> *"A well found to be incapable of producing either oil or gas in sufficient quantities to justify completion as an oil or gas well."*

Lastly, the possible analogues for a shallow oil discovery hosted in the Portland in the Weald Basin are inappropriate, because in the Weald the Portland reservoir is a sandstone, not a limestone. In conclusion, there is no Arreton 'discovery'. The use of such a word is mendacious.

5. Geology around the proposed wells

The locations of Arreton-1 and Arreton-2 as presented on an Applicant's plan[12] appear to be accurate. However, on the BGS Isle of Wight Special Sheet[13], Arreton-1 is located 20 m west of its correct position, and Arreton-2 is 105 m east of its correct position. These errors are

[11] Glossary of Terms Used in Petroleum Reserves/Resources Definitions. https://www.spe.org/en/industry/terms-used-petroleum-reserves-resource-definitions/

[12] ES_APPENDIX_2_-_PLAN_2-2826879.pdf

[13] British Geological Survey 2013. Isle of Wight. England and Wales Special Sheet. 1: 50,000. Keyworth, Nottingham.

repeated in the UKOG inset maps, reproduced from the BGS Special Sheet, but should have been recognised and corrected by the Applicant.

In contrast to its other developments in the Weald at Horse Hill and Broadford Bridge, the Applicant has commendably provided a precise pair of plans showing the deviated paths of the two proposed wells[14]. However, the underlying geological basis for the wellpaths chosen is inadequate, and the wellbore plans conflict with other diagrams. No interpreted seismic data have been presented, nor have structure contour maps of the supposed prospects been produced. We have to rely on the following statement by Xodus[15], commissioned by UKOG in 2015 to review UKOG's interpretations and predictions:

> *"UKOG performed an interpretation of the available seismic and petrophysical data. Its interpretation of the well results is that a section of pay in the Portland has been missed and that the test results are unreliable.*
>
> *UKOG carried out an assessment of the Stock Tank Oil Initially In Place (STOIIP) volumes.*
>
> *Xodus has reviewed UKOG's seismic interpretation and the underlying Kingdom project, the well data, and related reports. Xodus independently derived the volume estimates assisted by a stochastic simulation software tool, REP, using an approach similar to that used by UKOG.*
>
> *Xodus concludes that the approach followed by UKOG to estimate the STOIIP is sound and is based on an adequate interpretation of the available data."*

One problem is that the geological cross-sections presented by UKOG, in lieu of more realistic data, give a misleading impression of certainty about the structure, whereas the geology around the Arreton wells depends on just two seismic profiles, one trending N-S, the other E-W.

The Applicant's calculations, independently checked by Xodus, require a volume of oil-bearing rock to be calculated. In the Arreton North Portland prospect, for example (Xodus, table E3),

[14] ES Appendix 5. Hydrogeological and flood risk assessment.

[15] Xodus Advisory 2016. Arreton Discovery, PEDL331, Onshore Isle of Wight. Independent Review – Executive Summary UK Oil & Gas Investments PLC.

there is estimated to be between 0.5 and 7.6 million barrels of oil (worst and best cases, respectively), with a so-called Chance of Success of 69%, which is defined as "*the probability of discovering hydrocarbons in sufficient quantity for them to be tested to the surface*". The exercise is a good example of the computing adage 'Garbage in – garbage out'.

This absurdly optimistic confirmation by Xodus is based on UKOG's belief, quoted by Xodus, that "*a section of pay* [the oil-bearing zone] *in the Portland has been missed and that the test results are unreliable*". But oil in place, in the pore spaces of the rock (having good *porosity*), does not mean that the oil can be extracted. This requires that the rock also be *permeable*, and on this question the Applicant is silent. If the permeability is low, as implied by the previous drilling, then the only feasible way to extract the resource is by using unconventional methods – fracking and/or acidisation. But the Applicant has explicitly ruled out fracking, and any acidisation, it is claimed, will be restricted to wellbore washing.

Figure 1 shows a map of the available seismic data in the context of the Applicant's drilling proposals. Duplicate data, and the very old analog single-fold BP surveys from 1950, have been omitted. There are dip lines running across the geological structure in a N-S direction spaced at 2.3 – 3 km, and a strike line made up of two survey lines running E-W past the Arreton wells.

The two existing Arreton wells are shown, with the deviated proposed Arreton-3z shown in red passing nearby in a south-easterly direction (according to the well plan). The shorter red wellbore is the slightly deviated Arreton-3.

The Applicant's geological profile (ES Appendix 5, fig. 5) is shown in Figure 2. Segment AB runs SE-NW. The interpretation is based on the two seismic lines GC86-V442 and BP-357, tied in to Arreton-2. Segment BC runs S-N, and is based on seismic line BP-353, which is offset some 450 m to the east. This line is the key line for the Arreton structure.

Figure 2 gives a misleading impression of precision in the understanding of the geology, but this is far from the case, as can be seen in Figure 3.

The original version of BP-353 (Figure 3, left-hand panel) shows an apparently clear anticlinal structure. The Portland horizon is marked in crimson. Just north of this structure the data become very poor, due to the steep dips to the north and the high-velocity Chalk at outcrop. This is indicated by the yellow bracket. The location of the main Purbeck-IOW Fault zone is poorly defined. The OGA reprocessed and released a new version of BP-353 in 2016 (too late

for the Applicant to make use of). This new 'migrated' version should be better than the old, but the poor data zone is still present. The anticlinal structure has now disappeared. This illustrates the uncertainty in the geological interpretation in the vicinity of the major fault structure, and in turn calls into question the reliability of the oil-in-place calculations proferred by the Applicant.

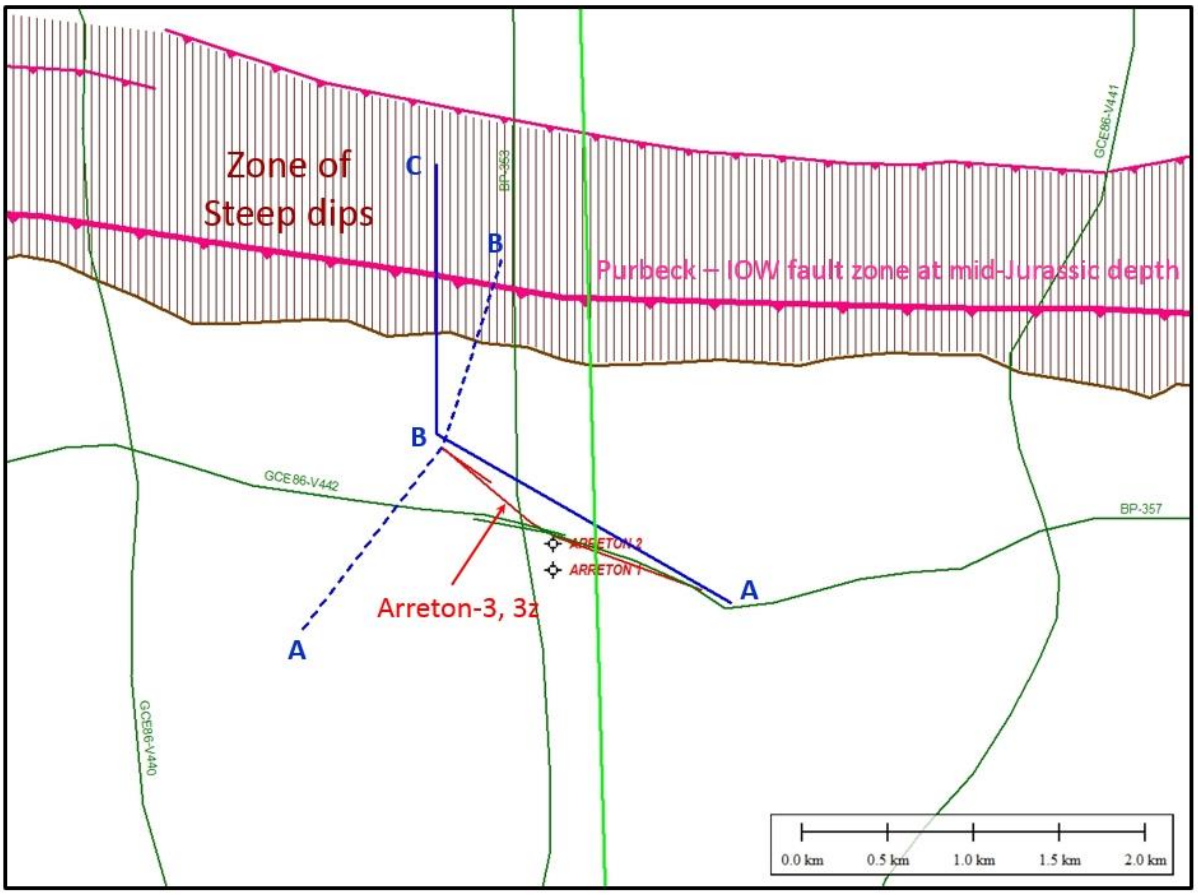

Figure 1. Map of the Arreton area showing seismic reflection data (green), the Applicant's geological cross-sections (blue), and the proposed Arreton-3 and -3z welltracks (red). The location of the BGS geological profile is shown in light green.

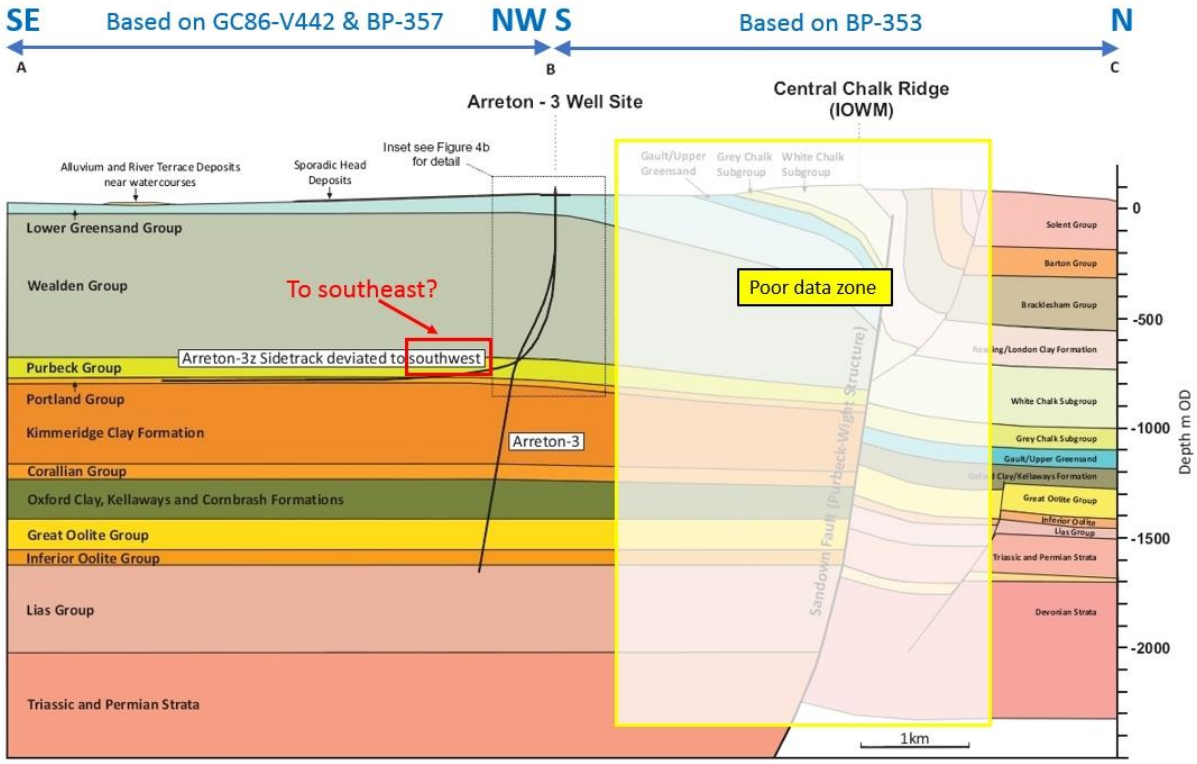

Figure 2. The Applicant's geological cross-section ABC (solid blue line in Figure 1), annotated for reference to seismic data. The zone of poor seismic data, and hence of unreliable interpretation is shown by the partially obscuring rectangle.

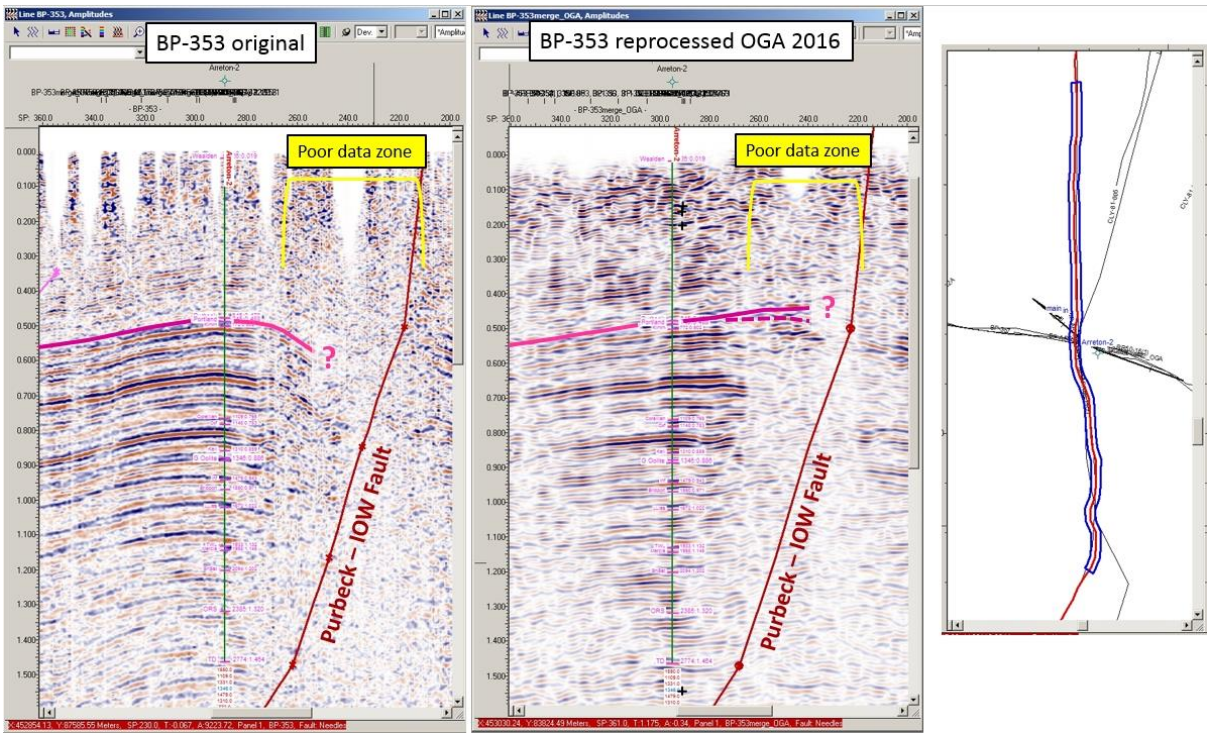

Figure 3. Two versions of dip line BP-353 through Arreton-2. Location map is shown on the right with the displayed portion of BP-353 (red) highlighted in blue, and proposed Arreton-3 and -3z shown in black.

Another geological cross-section is presented by the Applicant (ES Appendix 5, fig. 5B). It is located in Figure 1 above as the blue dashed line AB, and reproduced in Figure 4.

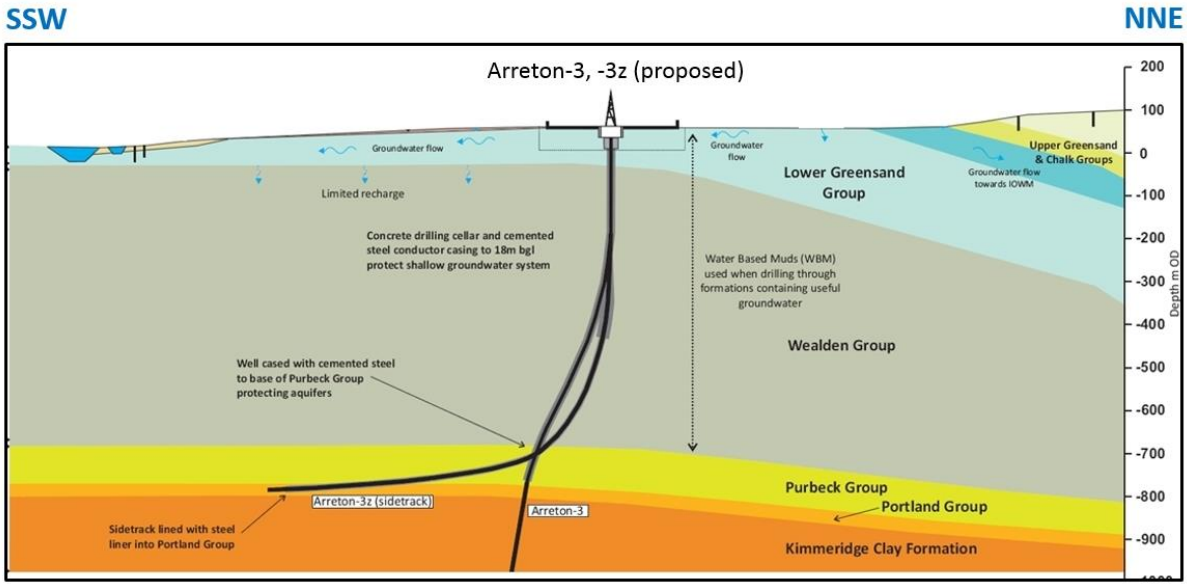

Figure 4. Geological cross-section from ES Appendix 5, figure 5B, cropped and relabelled.

Figure 4 shows Arreton-3z deviated to the SSW. In conjunction with the label (highlighted in red in Figure 2 above), this suggests that the deviation direction is to the SW or SSW; but this conflicts with the wellbore target plans, which show deviations to the SE. It appears that the Applicant may have originally proposed to deviate both wells to the SW, and later altered its plans, but failed to correct or re-draw its figures 5A and 5B. The Applicant needs to correct this ambiguity.

6. Complex faulting in and around the main Purbeck – IOW Fault

The Applicant has based its figure 5A (see Figure 2 above) on the BGS cross-section no. 4 accompanying the Isle of Wight Special Sheet. The northern part (segment BC) of the Applicant's figure is 900 m west of the BGS cross-section, the location of which is shown by the light green line in Figure 1. Figure 5 shows a detail from the BGS cross-section. The intersection of the proposed Arreton-3z (assuming that the south-easterly wellbore plans are indeed the latest and valid versions) is shown by the red disk on the Portland horizon at 750.8 m below sea level.

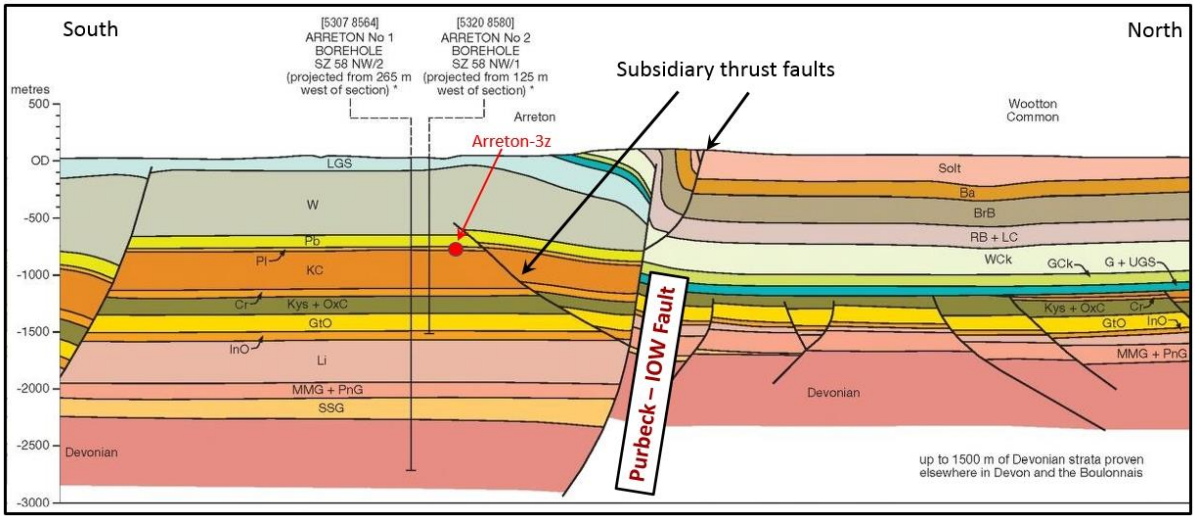

Figure 5. BGS cross-section near Arreton wells. The proposed Arreton-3z intersects the section at the red disk. Contains BGS data © Crown copyright and database right (2020). A BGS/EDINA supplied service.

The BGS cross-section shows, somewhat schematically, two subsidiary thrust faults splaying off the main Purbeck – IOW Fault zone. One of the two subsidiary faults lies about 200 m or less above the horizontal leg of Arreton-3z, and presumably intersects it either to the west or to the east. The Applicant has failed to take this into consideration.

However, the subsidiary thrusting shown in Figure 5 may only be schematic. But its existence was anticipated by Norwest interpretations made between 2007 and 2010, before the Arreton area was excluded from further detailed exploration. Figure 6 shows a preliminary interpretation of BP-353 submitted with the application by Norwest for PEDL239 (ref. 3). Such small-scale pervasive thrusting has to be postulated to accommodate strain around the main Purbeck – IOW Fault during the period of overthrusting to the north on this main fault in the Tertiary.

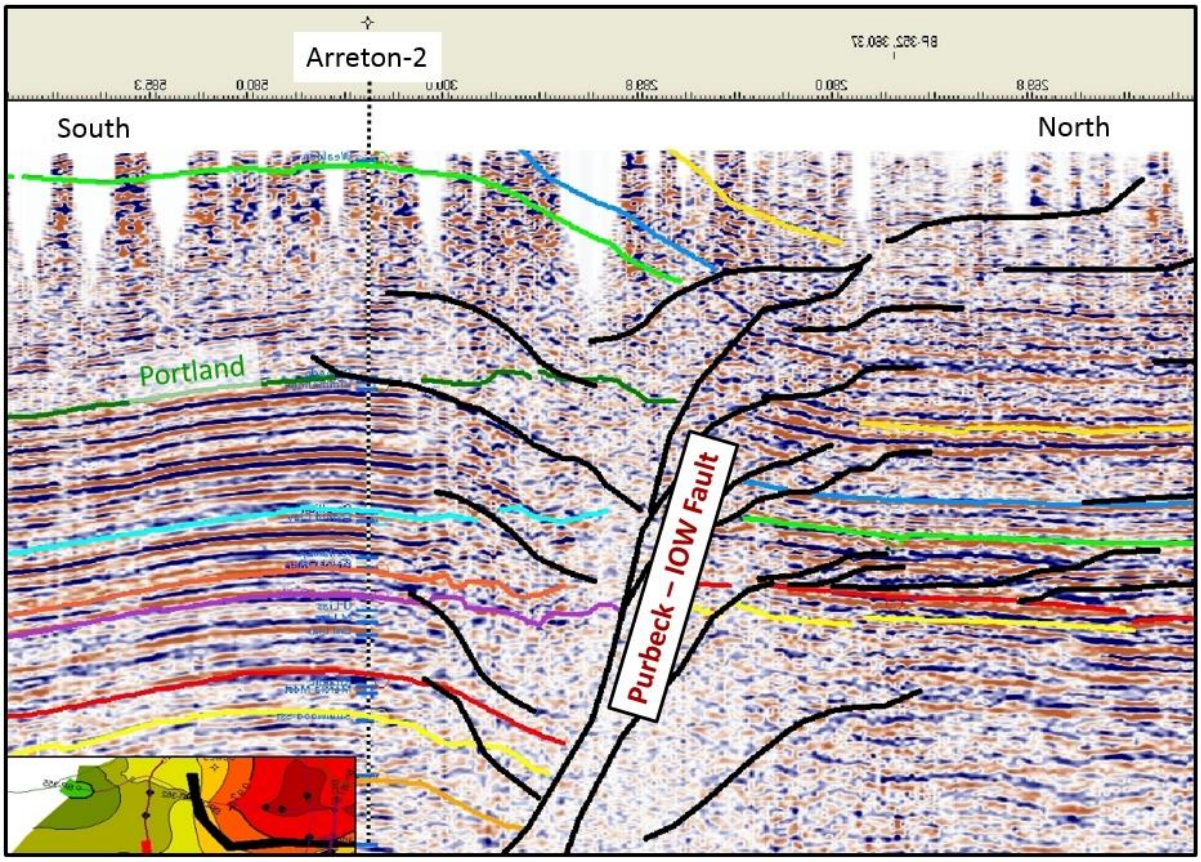

Figure 6. Preliminary interpretation of BP-353 by Norwest in 2008, mirrored to put south on the left. Faulting is shown in black. Many splay faults (black) branch off the main Purbeck – IOW Fault. The Portland is marked in green.

Similar thrust-faults are shown on the better-quality dip lines GCE86-V440 and GCE86-V441 lying on either side of BP-353 (Figure 1). The significance of this faulting is discussed below.

7. Faults and wellbores as contamination pathways

Failure of wellbore sealing

The Applicant intends to drill a deviated well, landing horizontally in the Portland, stating[14]:

> *"The annulus between the drilled borehole wall and the steel casings will be filled with cement grout from the base of the Purbeck Group to the surface. The sealed casings will prevent groundwater movement between different geological formations and stop potentially polluting formation water or hydrocarbons in the deeper formations (Portland Group, Kimmeridge Clay Formation and formations below) migrating upwards to shallower groundwater systems."*

But the assumption that sealing the casing-rockface annulus with cement will "*prevent*" potential pollution is unfounded. Recent research highlights the particular problem of

cementing the wellbore, that is, sealing the annulus between the outer drilled rockface and the inner steel casing. Dusseault et al. (2014) have noted[16]:

> *"Failure to adequately displace drilling mud during the initial construction of the wellbore may result in the development of microannuli, channels and generally poor cement quality ...*
>
> *So, mud-contaminated cement slurry may result in undesirable behavior. ...*
>
> *Eccentric casing placement, as illustrated in Figure 3.4,* [reproduced below as the inset to Figure 7] *is a critical factor contributing to inadequate mud removal in deviated wellbores. A difference in annular space thickness on the two sides of the casing makes displacing the drilling mud and placing the cement slurry more difficult, especially when the interior casing is in direct contact with the exterior casing or the rock wall over a considerable distance. Residual mud may be left behind in the thinner annulus (contact zone) because turbulent displacement will be inhibited and the cement slurry will preferentially flow up the wider side of the annulus ... In Figure 3.3, the effects of an eccentric casing are observed to be particularly detrimental to full mud removal in the deviated part of the borehole. Note on the thinner side of the annulus, the microannulus is much more significant than on the wider side of the annulus."*

Figure 7 shows a schematic cross-section through the deviated well. The inset shows the original figure from Dussealt et al.[16]. The annulus is the space between the casing and the bare rockface, which is supposed to be sealed with cement (brown). But in going round the bend from vertical to horizontal (Figure 7 inset, upper right) the casing will tend to rest on the outside of the bend, leaving a narrow annulus on one side which is very difficult to fill with cement.

The Applicant will furthermore be drilling at a very shallow angle through a sequence of limestones in the Purbeck and Portland Groups, interbedded with arenaceous rocks. The carbonates will be particularly at risk of wellbore washout, and in the lower part of the highly deviated wellbore this problem may be very difficult to resolve. Washouts are drilled zones where the hole is widened through crumbling of the rock.

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[16] Dusseault, M. B., Jackson, R.E. and MacDonald, D. 2014. Towards a road map for mitigating the rates and occurrences of long-term wellbore leakage. Department of Earth and Environmental Sciences, University of Waterloo, 22 May 2014.

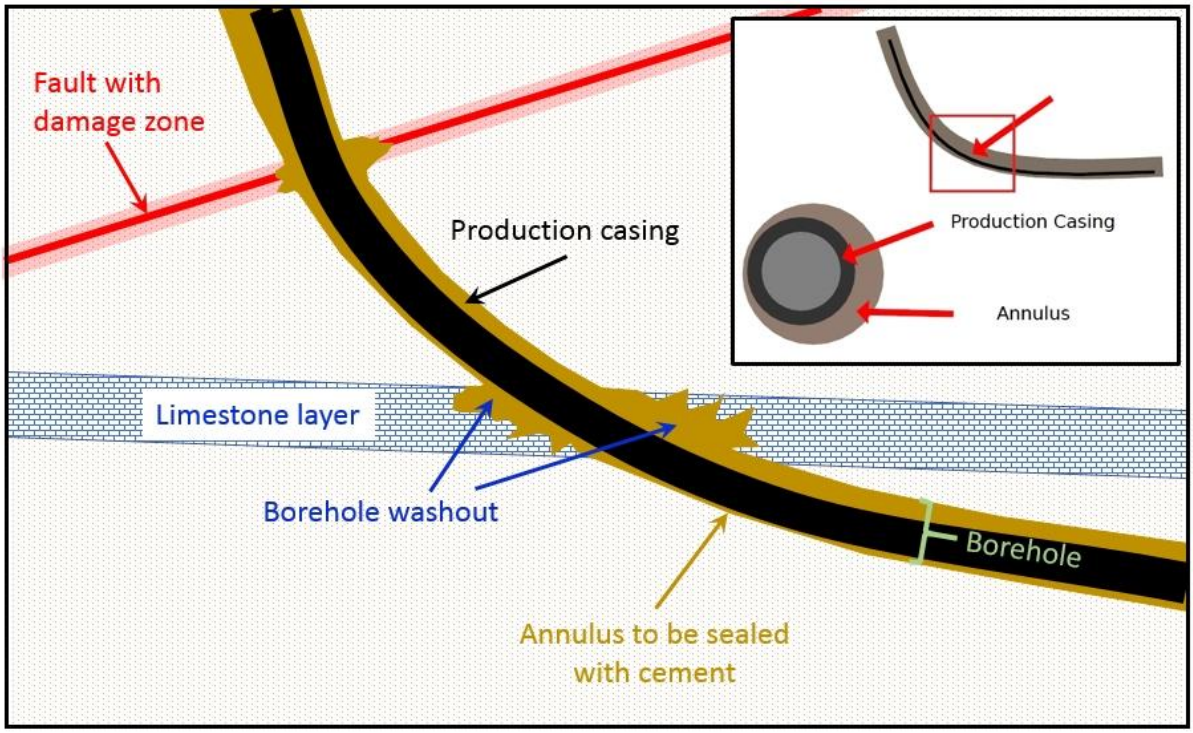

Figure 7. Wellbore washout and excentric positioning of production casing. The latter problem is shown in the inset, from Dusseault et al. (2014) fig. 3.4, showing excentric casing in a deviated wellbore. Cement is shown in brown, casing in black. The main diagram also shows washout both in a representative limestone layer and in passing through a fault.

Washouts also arise in drilling through a fault, in which the damage zone on either side of the fault crumbles and causes the hole to collapse. The hole will in consequence be difficult to seal. These very problems arose when the Applicant drilled the inclined Broadford Bridge-1 well, and was forced to sidetrack into Broadford Bridge-1z to try to circumvent the washout.

In summary, the combination of drilling at a shallow angle through varied lithologies and across faults leads to washouts; in addition the eccentric positioning of the casing going round the bend leads to incomplete cement sealing. In consequence a passage for polluting fluids is created both up the outside of the casing and *via* faults.

There is a large literature on the problem of wellbore leakage, whether in the short or long term. The review by Davies et al. (2014)[17] covers both conventional and unconventional drilling worldwide, and with emphasis on the UK. It was criticised by Thorogood and Younger

[17] Davies, R.J., Almond, S., Ward, R.S., Jackson, R.B., Adams, C., Worrall, F., Herringshaw, L.G., Gluyas, J.G., Whitehead, M.A., 2014. Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation. Marine and Petroleum Geology 56, 239–254. https://doi.org/10.1016/j.marpetgeo.2014.03.001

(2014)[18]. This critique was rebutted in turn by Davies et al. (2015)[19]. Davies et al. (2014) studied 2152 hydrocarbon wells in the onshore UK. They estimate that between 50 and 100 of these wells are 'orphan', in that the current owners cannot be identified.

Davies et al. (2014) state:

> *"In the UK there have been a small number of reported pollution incidents associated with active wells and none with inactive abandoned wells. This could therefore indicate that pollution is not a common event, but one should bear in mind that monitoring of abandoned wells does not take place in the UK (or any other jurisdiction that we know of) and less visible pollutants such as methane leaks are unlikely to be reported. It is possible that well integrity failure may be more widespread than the presently limited data show."*

They conclude:

> *"Only 2 wells in the UK have recorded well integrity failure (Hatfield Blowout and Singleton Oil Field) but this figure is based only on data that were publicly available or accessible through UK Environment Agency and only out of the minority of UK wells which were active."*

In summary, the review does not suggest that the long-term monitoring of hydrocarbon wells by the Environment Agency, or any other government agency, is robust. This failing should be of special concern in an environmentally sensitive district like the Isle of Wight, where the geology is a great deal more complex and subtle than the Applicant seems to appreciate. In addition, the Applicant has not provided any evidence that it even understands this problem, still less how it proposes to deal with it.

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[18] Thorogood, J.L., Younger, P.L., 2015. Discussion of "Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation" by R.J. Davies, S. Almond, R.S., Ward, R.B. Jackson, C. Adams, F. Worrall, L.G. Herringshaw, J.G. Gluyas and M.A. Whitehead. (Marine and Petroleum Geology 2014). Marine and Petroleum Geology 59, 671–673. https://doi.org/10.1016/j.marpetgeo.2014.07.011

[19] Davies, R.J., Almond, S., Ward, R.S., Jackson, R.B., Adams, C., Worrall, F., Herringshaw, L.G., Gluyas, J.G., Whitehead, M.A., 2015. Reply: "Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation." Marine and Petroleum Geology 59, 674–675. https://doi.org/10.1016/j.marpetgeo.2014.07.014

Faults as pathways for contamination

The faulting south of the main Purbeck – IOW Fault zone, even if not mappable in detail, explains in principle why there is no oil accumulation within the Arreton structure at any level – even presupposing that oil had migrated into the structure after it was created by overthrusting from the south in the mid Tertiary. It should be remembered that the oil shows at several horizons, proved in the two existing Arreton wells, merely indicate that oil had once been there, and has passed by on its way elsewhere. Further indirect evidence against any accumulation being present is the complete absence of oil seeps anywhere on the Isle of Wight, even though oil and gas seeps are frequent both on the mainland nearby and offshore. Oil seeps are an indicator of oil present at depth. Dr Ian West has compiled a comprehensive field guide to these phenomena[20] in southern England.

Empirical evidence for faults acting as pathways for fluid migration includes the recently developed direct imaging of the migration of gas from hydrocarbon reservoirs seen on high-quality 3D seismic surveys[21].

Faults frequently act as pathways for fluids, not only permitting oil and gas to migrate upwards, but also acting as potential pathways for contaminating products of hydrocarbon exploitation. So despite the Applicant's assurance that production casing will be set all the way down to the Portland in the Arreton-3z horizontal well, there will still exist the possibility of passage of polluting fluids up the outside of the casing, particularly at the bend in the casing from vertical to horizontal where it is practically impossible to cement the casing to the bedrock. This risk is exacerbated by the possible intersection of the wellbore with pre-existing faults, often at low angles, as shown in Figure 6.

Figure 8 shows the proposed welltrack for Arreton-3z superimposed on seismic line BP-357, which it follows horizontally at the Portland horizon from near Arreton-2.

[20] West, Ian. 2016. Petroleum geology – south of England. The Portland – Isle of Wight Basin. http://www.southampton.ac.uk/~imw/Petroleum-South-Portland-Wight-Basin.htm

[21] Aminzadeh, F., Berge, T. B., and Connolly, D. L. 2013. Hydrocarbon seepage: from source to surface, Geophysical Developments Series no. 16, Society of Exploration Geophysicists and American Association of Petroleum Geologists, Tulsa, Oklahoma, 244 pp.

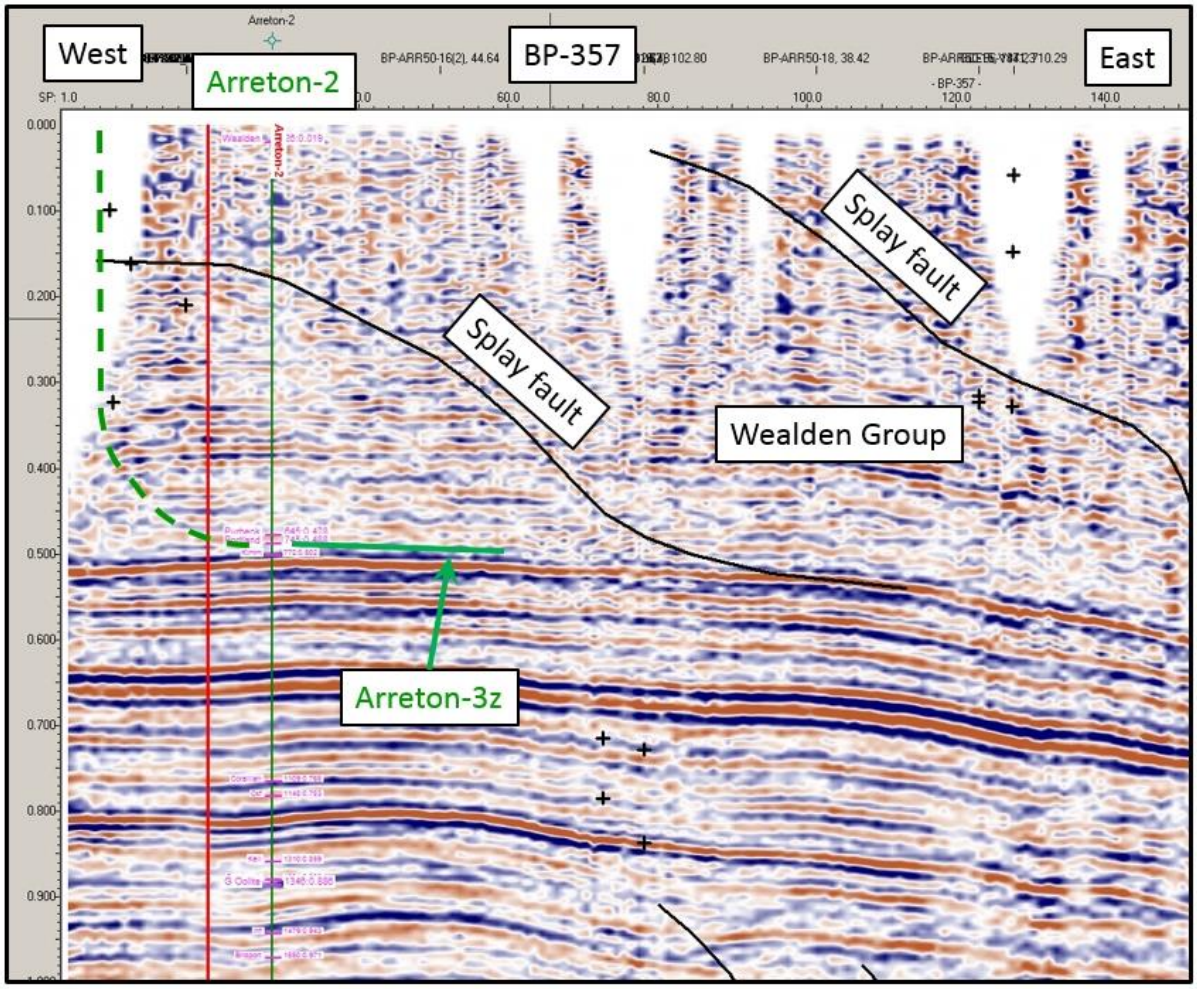

Figure 8. Track of proposed wellbore Arreton-3z on seismic line BP-357. It runs horizontally (solid green line) at 750.8 m depth east of Arreton-2, along the seismic line at the Portland horizon. To the west, the projection from the north, of up to 350 m of the vertical part of Arreton-3z, is shown by the green dashed line.

Two splay faults, of the same type as seen on Figure 6, are shown intersecting the section at an oblique angle. These were originally interpreted by the Norwest geological interpreter in c. 2009, not by myself, but have merely been adjusted slightly. Such faults originate and die out in bedding planes. Many more of them may exist, but are too subtle, or of too small an amplitude, to be seen on 2D seismic data, particularly on data that are 30 to 40 years old like the sections shown herein. Such faults are likely to be a hazard if encountered when drilling obliquely and near-horizontally. Drilling horizontally to follow the Portland, which is only 27 m thick, is possible using measurement while drilling techniques as long as there are no faults, but a small fault of the order of 20 m in vertical displacement is below the resolution of the seismic data, and may put the drillbit out of the limestone. So drilling the Portland is not as straightforward as the Applicant asserts.

Conclusion on contamination pathways

The proposed well pad site lies inside a Zone 3 Groundwater Source Protection Zone. Protection of this resource is vital. On hydrogeological risk the Applicant concludes[14]:

> *"Based on the proposed well design and well management procedures, it is very unlikely that there will be any migration of fluids or hydrocarbons from the wellbore into any of the formations penetrated by the Arreton- 3 well or Arreton- 3z sidetrack as a result of well casing failure. It is also very unlikely that fault structures will provide a pathway for the migration of fluids of hydrocarbons in this geological setting."*

This conclusion is complacent and unsound. I have pointed out the risk of wellbore sealing failure, and the existence of pervasive unrecognised faults. A further possible pathway for pollution, the old Arreton wells, is considered but dismissed by the Applicant[14]:

> *"Historic exploration wells Arreton-1 and Arreton-2 are located approximately 1km to the southeast of the Site and the planned trajectory for the sidetrack well will pass north of these locations. These wells are plugged and abandoned. UKOG has access to historic well records and will ensure through professional well design and planning that no interaction is possible between the new and historic wells."*

The Arreton-1 and -2 wells are 68 and 46 years old, respectively. It is likely that the steel casings will by now have partially rusted, leading to loss of well integrity, so that a potential pathway to the surface is created. Even though the planned wellbores lie north of these old abandoned wells, there could be a contaminant pathway linking the new wellbores to the old wellbores *via* low-angle faults, as outlined in Figures 6-8 above.

8. Track record of the Applicant

It is crucial that the Applicant has a robust knowledge of faulting in and around its prospects, in order that the risks of such contaminant migration be well understood. But it is clear from the evidence made public that the Applicant does not possess this knowledge, nor is it willing to undertake a 3D seismic survey before drilling, which would resolve many of the geological difficulties.

The Applicant has encountered severe technical problems at two sites in the Weald. The root of the problems at both sites lies in pressing ahead with inclined drilling before undertaking adequate geological studies. Its horizontal well Horse Hill-2z into the Portland Sandstone at Horse Hill is currently producing excessive water. Its attempt to drill at a shallow inclination through a fault zone at Broadford Bridge ended in failure when the original borehole ended in formation washout, and the company had to drill a parallel sidetrack, while claiming the existence of no less than five micrites in the Kimmeridgian – hallucination rather than geological observation. I explained three years ago how drilling through a fault at an angle at Broadford Bridge could have encountered the same micrite twice over[22]. In contrast, the BGS recognises only two micrites, and locally three, in the Weald Basin[23].

There is no reason to justify the Applicant being given the opportunity on the Isle of Wight to repeat its technical failures in the Weald.

[22] Smythe, D. 2017. Analysis of UKOG drilling results at Broadford Bridge. Frackland. 11 December 2017. http://www.davidsmythe.org/frackland/?p=468

[23] Andrews, I. J. 2014. The Jurassic shales of the Weald Basin: geology and shale oil and shale gas resource estimation, British Geological Survey for Department of Energy and Climate Change, London, UK, https://www.gov.uk/government/publications/bgs-weald-basin-jurassic-shale-reports

9. Conclusions

The Applicant has:

- Misled the Council over its so-called Arreton "*discovery*", which is, in fact, a doubly-confirmed dry oil ex-prospect at all levels down to the Triassic Sherwood Sandstone.
- Exaggerated the size of the supposed oil "*discovery*", repeating the manner of its grossly exaggerated claims about the quantity of oil in the Weald at Horse Hill (Gatwick, Surrey) and elsewhere.
- Failed to explain why the various previous negative results of exploration at Arreton were somehow mistaken.
- Added the two Kimmeridge micrites to its list of oil shows, whereas there is no evidence whatsoever for such shows either at Arreton or anywhere else on the Isle of Wight.
- Provided conflicting information about the direction of the well tracks proposed.
- Failed to appreciate the significance of the complex faulting in the area of the proposed wells.
- Failed to provide any background information on the supposed geological structure to be explored, leaving open the suspicion that unconventional targets are being sought.
- Been evasive about whether unconventional methods, including acidisation, will be required to produce commercial quantities of oil from the Portland
- Failed to consider the environmental risks of drilling at a low inclination, with concomitant likely poor cementing of production casing to the rockface.
- Failed to consider that drilling near to the old Arreton wells, which by now are rusting away underground, provides another contaminant pathway to the near-surface aquifers.
- Failed technically, and continues to fail, at two sites in the Weald, using essentially the same approach to that now proposed at Arreton.

The Applicant needs to correct the severe errors in its proposals, and must also provide a great deal of further information on why it considers that there is a likelihood of oil in commercially extractable quantities at Arreton, given the long prior history of negative results. This information needs to include interpreted seismic data, structural maps, and reinterpretations of the oil geochemistry. The failure to provide such information to date

leaves a strong impression that the Applicant is more interested in using Arreton to play the stock market, than in seriously trying to produce oil.

If the Applicant wishes to pursue its Arreton proposal, the old Arreton wells need first to be re-accessed so that their integrity can be checked; alternatively, new wellpaths should be sited at least 1 km away from these old wells. Given the doubt about the very existence of the Arreton structure, a 3D seismic survey should be undertaken in advance of any drilling, so that a full and accurate 3D geological image of the volume to be drilled can be acquired. If this study produces favourable results, it could restore some faith in the seriousness of the Applicant's intentions towards conventional exploration, and form the basis of a new application.

In conclusion, in view of the inadequacies in the Applicant's proposals, and the hydrogeological risks that they entail, **I recommend that the Council should reject the application.**