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Interactive comment on "Hydraulic fracturing in thick shale basins: problems in identifying faults in the Bowland and Weald Basins, UK" *by* David K. Smythe

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Reply to "Hydraulic fracturing in thick shale basins: problems in identifying faults in the Bowland and Weald Basins, UK"

I would like to address three specific issues in response to points made by Smythe (2016)

A. The position of the fault with respect to the Preese Hall-1 well bore

B. The origin of the casing deformation at Preese hall-1

C. Balcombe-2 faulting

A. Smythe (2016) argues that the faulthich appears to be responsible for the tremors at Preese Hall-1, actually crosses the well bore. This so-called 're-interpretation' does not use the 3D seismic data or well bore image data, but merely re-positions the trace of the fault on Figure 4 from the Clarke et al. (2014). One could have the impression that this is merely a device in order to provide a platform to expound his views regarding the hydrogeological risks of hydraulic fracturing in the Bowland Basin. Our contention is that, in fact, all of the evidence collected to date supports the observation that the wellbore was within 300m of a fault but does not intersect it (Clarke et al. op cit). The evidence is as follows:

1) The stratigraphy encountered within the Preese Hall wellbore correlates near to identically with both the Thistleton-1 and Grange Hill-1 wellbores. This applies both to the detailed wireline log correlation between these wells but also the specific ammonoid biozone have been identified over the crucial interval. These observations indicate that there is no missing or repeated sections. All three wellbores correlate strongly with each other in the shale section and have no signs of significant faulting, see figure 1. 2) The image log collected within the Preese Hall wellbore has no indications of faulting at the depth Smythe suggests, (de Pater, C. J., and S. Baisch, 2011). This image log is of high quality and resolution. It provides the most direct evidence of what faulting actually occurs within the wellbore. This poses the question of why such data, which is publically available, and the evidence it provides has been omitted from this submitted article. 3) In considering the fault interpreted by Smythe that has been redrafted on the original 3D seismic image Smythe states that this is a consistent fault interpretation with the hypocentre focal mechanism provided in the Clarke et al paper. While the uncertainty of the inverted source mechanism is significant, low dipping planes are inconsistent with observed amplitudes as illustrated in Appendix S2 of Clarke et al. When considering the Smythe fault plane one might assume the azimuth of his redrafted fault to be consistent with the focal mechanism, the dip of the fault interpreted by Smythe is approximately 30o from horizontal, but Appendix S2 of Clarke et al shows that a fault interpretation with given dip would result in larger misfit

than the 60-70o dipping planes. While it is certainly possible to reconsider picks of P- or S-waves (as suggested by in SC2 of Westway) one must bear in mind that picking is subjective and unless picked very unusually the new picks are unlikely to result in low dipping plane fitting the observed data. So they are in fact not compatible observations and disprove the redrafting interpretation. 4) It is also the case that in the current strike slip stress environment the fault Smythe has redrafted would have a much reduced slip tendency and considered less critically stressed than the Clarke et al interpretation and therefore not as likely, if at all possible to have failed given the Preese Hall 1 stimulation operations, in the current stress regime. 5) Westway (SC2, 2016) suggest alternative location of the hypocentre resulting from a velocity model. As pointed out by Verdon (2016, SC7) there is a large uncertainty in the location. Considering that Clarke et al estimated uncertainty relative to the velocity model 150m and 250m in horizontal and vertical directions, respectively, the differences in locations seem to be within these uncertainties. To conclude, the location of the weak aftershock may fit spatially within the uncertainty of a shallow dipping plane, but the observed amplitude do not.

The obvious question that should be posed when assuming a fault intersects the well bore would be why it is not the case that the hypocenteral location for the seismic event does not occur also where Smythe proposes a fault intersects the wellbore. This is to say if the fault were to intersect the Preese Hall wellbore, it would be the point that would experience the highest fluid volume entry, and experience the largest reduction in effective normal stress. Therefore being the most obvious point to have failed and provide a hypocentral location at the wellbore, not c.300m away as observed. Instead the hypocentre is distant from the wellbore and consistent with the fault interpretation provided in the Clarke et al 2014 paper. For these reasons the redrafted fault provided by Smythe should be ignored and the original Clarke et al fault consider the most appropriate interpretation at this point in time.

B. With regard to the casing deformation which Smythe attempts to use as an argument for a fault crossing the wellbore, a more robust mechanism for this deformation

is bedding parallel slip as outlined in the geomechanical study of Preese Hall 1, (de Pater, C. J., and S. Baisch, 2011). It should be noted that the deformation occurred over a section of the wellbore and not in a unique plane as would be expected if it was caused by a unique plane such as a fault (T. Keiser, 2014). Wellbore deformation over a broad section is known and documented to have been caused by bedding parallel slip globally (M. Dusseaul et al, 2001) and does not require seismic activity to be associated. The author should refer to why his argument is counter to that of currently held and accepted understanding of such observations and mechanical causes.

C. Considering figure 8b, for which I cannot find a reference, Smythe has misinterpreted the formation evaluation log from Balcombe 2. Central to his argument is the interpretation of this log showing a normal fault with downthrown to the east and using this interpretation to strongly suggest a hydrogeological risk. However the Smythe interpretation has no supportive evidence and indicates poor understanding of drilling processes. The apparent repeat section referred to in figure 8b is due to drilling out the cement shoe following the installation of the liner in the top of I micrite (reference Cuadrilla planning application). As this cement shoe is drilled out into formation, there is increasingly less cement returned and increasingly more formation cuttings returned until drilling of the shoe is complete and 100% of formation is returned via the drill bit. This is a fundamental drilling observation and provides no evidence towards any fault. As such the Smythe interpretation should be rejected. It should also be noted for completeness that the bedding dip is not zero but 3 degrees from horizontal which is available from information in the Balcombe 1 wellbore.

Smythe refers to his own blog written about the Cuadrilla Balcombe operation here (www.davidsmythe.org/fracking/cuadrilla%20sussex%20critique%20V2.0.pdf) which he uses as evidence to support that his conclusions are true to his predictions with regard to fault interpretations. However along with the previous unequivocal argument regarding drilling returns and there not being a fault, other predictions made by Smythe within this document are also contradicted by this submitted publication. D. The central theme of the Smythe manuscript proposes that faults intersected by hydraulic fractures may form conduits through which fluids can potentially pollute ground water. He also argues that monitoring of fracture-fault interactions in not possible through seismic monitoring. Frieberg et al. (2014) and BGOC (2012) show detailed studies in Ohio, USA and Bristish Colombia, Canada, where hydraulic fractures intersected pre-existing faults and induced seismicity below the injection intervals. Such observations are consistent with the location of seismicity below injection at Preese Hall as published by Clarke et al (2014) and suggest that when hydraulic fractures intersects pre-existing fault sthe fluids penetrate to greater depths. Futrthermore, Zoback (2007) shows that fluid conductive faults are usually faults favourably stressed for shear failure. Such faults when lubricated often create shear events which are detectable by seismic monitoring. Hence, the proposed seismic monitoring prevents not only the induced seismicity but also fracturing into large pre-existing faults and is considered adequate and best practice. Comments regarding operator competence would be more appropriately directed to the regulator of these activities. The opinion Smythe states on the regulatory system in the UK is also counter to that which is widely held; that UK oil and gas regulation is viewed as a global exempla (Royal Society, 2012).

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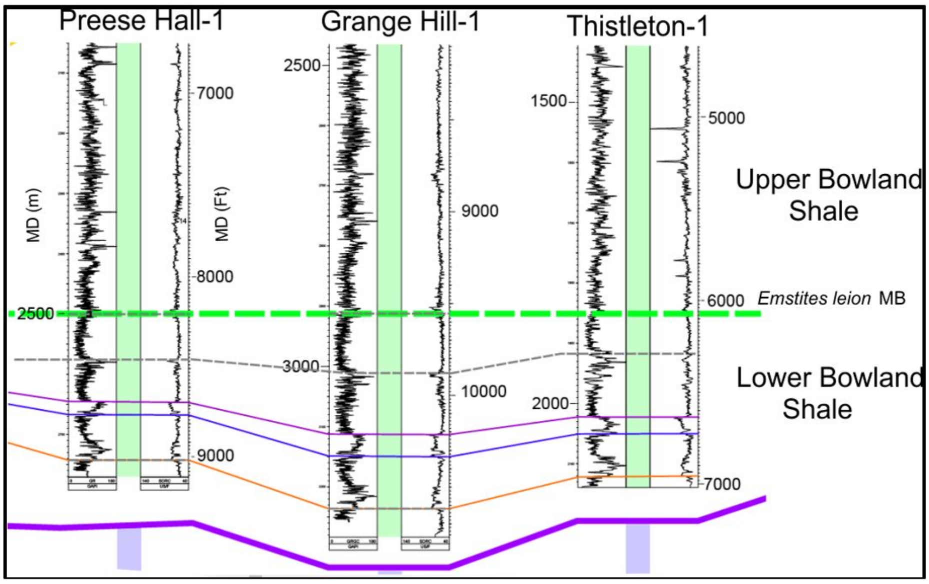
Preese Hall-1
Grange Hill-1
Thistleton-1
MD (m)
MD (Ft)
7000
8000
9000
2500
2500
3000
9000
10000
1500
2000
5000
6000
7000
Upper Bowland
Shale
Emstites leion MB
Lower Bowland
Shale

Fig. 1.