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 (doi: http://dx.doi.org/10.1016/j.marpetgeo.2014.03.001)).

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Davies *et al.* present an interesting collation of data and anecdotal information on the integrity of oil and gas wells from around the world. The overwhelming majority of the cases reviewed relate to *conventional* oil and gas reservoirs which were over-pressured prior to exploitation, and in some cases remained so after the end of economic production of hydrocarbons. As the title of the paper suggests, in its final sections Davies *et al.* attempt to draw lessons from these observations for future *unconventional* oil and gas wells in the onshore UK environment. This involves rather drastic extrapolation from over-pressured to under-pressured reservoir environments, seasoned with a liberal dose of hydrogeological over-simplification, which in our view leads to dangerously misleading conclusions.

The fundamental flaw of the paper is its failure to acknowledge that well integrity is a product of local regulation, technology and prevailing operational culture. To complicate matters further, these three elements are highly variable across countries and also evolve progressively with the passage of time. Therefore, the search of Davies *et al.* for analogues, and their attempt to extrapolate failure rates from a diverse international dataset to the UK situation are, in our view, unjustifiable and indefensible. Even the two UK cases cited are misleading:

(i) The 1981 blowout of the first well to be drilled in what later became the small Hatfield Moors Gas Field (Ward *et al.* 2003) did not occur due to a lack of casing integrity *per se,* as Davies *et al.* imply; rather it was the entirely unexpected encounter with over-pressured gas at only 483m depth (exceptionally shallow by the standards of most European onshore gas fields), at a time when the wellhead was not fitted with a blow-out preventer (BOP). This geological exploration well was actually seeking a gas-free sandstone which could then be used for storage of injected gas. It accidentally discovered a gas field. It was thus *not* an example of failure of well integrity in a properly purpose-designed , failing despite the use of best practice.

(ii) The failures at Singleton took place long before the UK HSE introduced well examination and before it was matured and applied onshore. It is extremely unlikely that such a sub-standard well would ever get constructed in 2014, let alone put into production.

By equivocating well integrity data and anecdotes across continents and jurisdictions, the paper appears to be using innuendo to talk-up a potential future problem in onshore unconventional hydrocarbon development in the UK, to a degree that is simply not warranted by the evidence presented in the paper. Asking the question as to which of the datasets will provide the most appropriate analogues is to miss the point entirely. The trite answer is: "None of the datasets are applicable because of the differences in geology, regulatory environment and operational practice. The lack of evidence of problems reinforces this argument". The more robust answer is that:

a) unconventional hydrocarbon development in the UK is a new, emerging industry that has yet to function at scale; there isn't a problem yet and so actions can be taken now to ensure there won't be a problem

b) the approach should be to adopt the recommendations of the UK's Joint Royal Academies' Report (Royal Society and Royal Academy of Engineering, 2012) to ensure that the future well stock is constructed to the highest standards, while themselves enhance existing practice.

c) these actions will guarantee that wells are designed for control and containment, the risk of an incident thereby being reduced to a level that is as low as reasonably practicable

The paper has an unfortunate tendency towards speculation: Davies *et al.* propose a set of hypothetical possibilities to imply there is a problem that must be addressed. An example of this is the section (our emphasis):

> *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. Surveying the soils above abandoned well sites would help establish if this is the case.*

In essence, the paper seems to be making a case for creating a cottage industry based on speculation rather than evidence. From the perspective of hydrogeological regulatory practice, establishment of such a cottage industry is not warranted, for the following reasons:

(i) The Environment Agency and its predecessor organisations (for one of which Younger worked for many years, specifically on policing groundwater pollution incidents) have, since the foundational legislation came into force in 1963, regularly inspected active onshore oil / gas well sites, and would generally have also been at least informed when sites were abandoned. Point discharges of polluted water or gas from any source tend not to go unnoticed in a densely populated country such as ours, and it is therefore highly likely that any major issues with abandoned onshore oil and gas wells would have been picked up long since. It is absolutely certain that, on checking their old records, it would then have been realised that the source was an old hydrocarbon well. Indeed the Singleton case presented by Davies *et al.* in their paper ironically provides a good worked example of the efficacy of this reactive approach on the part of UK regulators:

the problem was picked up and dealt with. Given this regulatory environment, the lack of a general inventory of inspection data for every single abandoned hydrocarbon well is, in this case, *not* absence of evidence, as Davies *et al.* imply: rather, it is evidence of absence. By analogy, in the case of abandoned mines, many of which give rise to point discharges of polluted water and / or gas in hazardous quantities, such issues were always picked up by pollution prevention officers, and samples etc taken - decades before there was any framework for actually dealing with them (e.g. Henton 1979). There is no reason why the Agency officers would have neglected to do the same for oil and gas wells, had there been any detectable problems.

(ii) The notion that abandoned wells are likely to leak pre-supposes the existence of a driving head (for water or gas). The chances of this are slim enough in the case of conventional reservoirs, though at least some of them had pre-exploitation heads in excess of hydrostatic. (Post-exploitation, of course, such pressures have usually been depleted). In the case of *unconventional* reservoirs, it is emphatically *not* the case that they ever have driving heads – the gas / oil is so tightly bound that they never exceed bubble pressure until the water level in the well is lowered drastically during production. (That is – *inter alia* – precisely what makes such reservoirs 'unconventional'). Add to this the fact that unconventional reservoirs are in strata that hydrogeologists regard as aquitards – and are therefore not hydraulically connected up-dip to meteoric recharge areas – and the likelihood of a significant driving head post-abandonment is negligible. Again, the contrast with coal mines is telling – they generally ARE inter-connected all the way back to outcrop, and that is why we get significant water discharges from them (e.g. Kortas and Younger 2007; Gandy and Younger 2007); it is also noteworthy that once mine workings are drowned by rising groundwaters, any release of methane from them abruptly ceases (e.g. Hall *et al.* 2005; Younger 2014) – there is no reason why depleted unconventional gas reservoirs should behave any differently when groundwater heads within them recover. So even if Davies *et al.* were right about conventional reservoirs (which we do not believe they are, for reasons already given) the suggestion that this will apply equally to unconventional reservoirs is entirely specious. If we apply the source-pathway-receptor model which regulators worldwide now use to assess pollution risks (e.g. Health Protection Agency 2009), there is no credible source in this case (due to the lack of driving heads), modern well abandonment procedures eliminate the pathway, and thus sensitive receptors at or near surface will not be at risk.

It would therefore be more effective, in the context of an activity that has yet to happen, to require that all wells are designed and constructed in a way that provides for long term operational integrity through adherence to the Well Integrity Guidelines, (Oil and Gas UK 2012b) and enables abandonment in accordance with the Well Abandonment Guidelines, (Oil and Gas UK 2012a). These documents, along with their Norwegian equivalents, represent the best available international guidance for well design and long term safe abandonment. This is, indeed, consistent with the principal finding of the UK's Joint Royal Academies' report on shale gas fracking (Mair *et al.* 2012). Under today's system of well examination, well examiners ensure that the design achieves these goals and requires evidence that the objectives have been achieved. This provides the best guarantee against any post-abandonment problems in the long term.

To conclude, present practices for well design and construction in the UK, and the "clean sheet" opportunity for regulating a future shale gas well inventory as recommended by the Royal Society and the Royal Academy of Engineering (Mair *et al.* 2012), provides a sound basis for future developments. In contrast, we believe the work of Davies *et al.* is fundamentally flawed as a basis for either quantifying the possible risks posed by a future shale gas activity, providing a coherent answer as to how that future stock of wells should be managed, or even putting the risks into a wider context to allow stakeholders to judge whether, from a societal point of view, the risks are acceptable. Were the innuendos of Davies *et al.* to be accepted uncritically - which they likely will be by activists who are inveterately hostile to the oil and gas sector for other reasons – there is a very real risk that they will wrongly influence politicians and policy makers. It would be unfortunate if a key element of future UK energy policy were to be based on an analysis that is manifestly detached from present industrial best practice, in which the UK oil and gas sector actually leads the world.

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References

Gandy, C.J. and Younger, P.L. 2007, Predicting rebound in the South Yorkshire coalfield, U.K. Mine Water and the Environment, **26** (2): 70 – 78.

Hall, J., Glendinning, S. and Younger, P.L., 2005 Is mine water a source of hazardous gas? Proceedings of the 9th International Mine Water Association Congress 2005, Oviedo.pp 141-145.

Health Protection Agency, 2009. An Introduction to Land Contamination for Public Health Professionals. Chemical Hazards and Poisons Division Health Protection Agency, Cardiff. 52pp. (Available on-line: http://www.hpa.org.uk/webc/hpawebfile/hpaweb_c/1242198452810; last accessed 12-4-2014).

Henton, M.P., 1979, Abandoned Coalfields: Problem of Pollution. The Surveyor, 153: 9 - 11.

Kortas, L. and Younger, P.L. 2007, Using the GRAM model to reconstruct the important factors in historic groundwater rebound in part of the Durham coalfield, U.K., Mine Water and the Environment, **26** (2): 60 – 69.

Mair, R., Bickle, M., Goodman, D., Koppelman, B., Roberts, J., Selley, R., Shipton, Z., Thomas, H., Walker, A., Woods, E., & Younger, P.L., 2012, Shale gas extraction in the UK: a review of hydraulic fracturing. Royal Society and Royal Academy of Engineering, London. 76pp. (Available on-line: http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/projects/shale-gas/2012-06-28-Shale-gas.pdf; last accessed 12-4-2014).

Oil and Gas UK. 2012a, OP071 - Guidelines for the suspension and abandonment of wells, Issue 4, July 2012 and Guidelines on qualification of materials for the suspension and abandonment of wells, Issue 1, July 2012. (Available for purchase, on-line: http://www.oilandgasuk.co.uk/publications/viewpub.cfm?frmPubID=447, last accessed 30-4-2014).

Oil and Gas UK, 2012b, OP069 - Well Integrity Guidelines, Issue 1, July 2012. Available for purchase, on-line: http://www.oilandgasuk.co.uk/publications/viewpub.cfm?frmPubID=445, last accessed 30-4-2014).

Ward, J., Chan, A., Ramsay, B., 2003. The Hatfield Moors and Hatfield West Gas (Storage) Fields, south Yorkshire. Geological Society of London Memoirs **20**: 903 - 910.

Younger, P.L., 2014, Hydrogeological challenges in a low-carbon economy. (The 22nd Ineson Lecture). Quarterly Journal of Engineering Geology and Hydrogeology, 47 (1): 7 – 27. (doi 10.1144/qjegh2013-063).