Can fracking, for gas and oil, power the Scottish economy? *The Edinburgh Geologist*, 62, 18-25: Discussion by G. Dean and Reply by R. Thompson.

The opinions expressed in the original article and in this subsequent discussion are those of the authors and are not necessarily views held by the Edinburgh Geological Society. The Society's role is to facilitate debate, but nevertheless, this discussion is now closed.

Discussion on "Can fracking, for gas and oil, power the Scottish economy?"

By Graham Dean, Reach CSG, Cumbrian & Scottish Gas, Aberdeen

The article on Scottish shale gas by Professor Roy Thompson in issue 62 of *The Edinburgh Geologist* contains some unfortunate misunderstandings of shale geology. These largely arise from insufficient attention being paid to reports written by his academic colleagues (Reference 1) and the British Geological Survey (BGS) (Reference 2). Professor Thompson asks: ***Can fracking, for gas and oil, power the Scottish economy?*** His conclusion is that: *All in all Scottish shales may well have a success factor of zero.* When the errors are corrected his analysis does not support his conclusion.

An important parameter in analysing the prospectivity of a shale for shale gas is the Total Organic Content (TOC). ProfessorThompson wrongly assumes the TOC of Scottish shales are 2% and says:

Scottish shales with their modest organic carbon contents and shallow depths ,,,,,,,, barely correspond to even the poorest US-producing regions.

The BGS report (Reference 1) in contrast states that:

The total organic carbon (TOC) content of the Midland Valley shales is high (2-6% and often up to 20%).

Scottish shales correspond very favourably with US producing regions being both thick and with a high TOC.

Professor Thompson writes that:

Scotland's low thermal gradient (22–30°C/km) and weak Tertiary exhumation history suggest the great majority of its shales, with the possible exception of those contained within deep synclines (e.g. Clackmannan, Midlothian-Leven, Solway), will barely have reached gas-generating temperatures.

Again the BGS contradicts this view:

As a result of significant burial, uplift and erosion, the Carboniferous shales are mature for oil generation from shallow current-day depths over much of the study area, and gas-mature shales occur at current-day depths from about 2,300 ft (700 m) below the surface.

Figure 1 shows the burial history derived from samples from the Salsburgh 2 well in North Lanarkshire. Note that the shales have been buried much deeper than the present depths.

Figure 2 is a plot of the Vitrinite Reflectance (Ro %) from three wells in North Lanarkshire, West Lothian and Glasgow. The organic matter in the shale is geochemically mature for gas if the Ro measurement is over 1.0 or 1.1. Note this plot confirms the BGS statement that the gas-mature shales occur from about 2,300 ft below the surface.

Professor Thompson refers to the Scottish Government report written by KPMG:

How can that heavily populated area, of around 800 sq. mile, possibly be fracked from just 20 pads? The effective footprint that can be hydraulically stimulated from a single pad in Scotland is likely to be small on account of the complex geology, inconsistent stress field and geo-mechanical incompatibility of extended-reach drilling with shallow targets. I envisage an efficiently designed, Scottish, multi-well pad would drain an area of around one sq. mile

The KPMG report (Reference 3) does not state the area of shale that each pad produces from but recent fracked horizontal wells in North Sea gasfields have been up to 2 km long. Laterals this long in the Scottish shales should comfortably produce the volume of gas assumed in the report. So the 20 shale gas production pads will only access a small part of Scotland's potential gas production area. The KPMG report highlights the timeframe to get a pad on production and it is perhaps for this reason that they assume only some of the extremely large amount of shale gas in Scotland is produced in the near term.

The KPMG report models each pad producing 47 Bcf of gas if 15 laterals are drilled (Central case) and 94 Bcf if 30 laterals are drilled from the pad (High case). So each pad produces similar amounts to a North Sea gasfield. Shale gas production is equivalent to 20 North Sea gasfields in the Central case and 30 gasfields in the High case.

So, in contrast to Professor Thompson's conclusion, the wonderful geology of the Central Belt could contribute significantly to the Scottish Economy.

Fracking, not shale but still fracking, is already contributing significantly. This is not fracking onshore but fracking in North Sea gasfields and oilfields. In recent years several of the new gasfields in the North Sea have been enabled by fracking contributing to the recent rise in gas production from the North Sea.

References:

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3. KPMG, 2016. Economic Impact Assessment and scenario development of unconventional oil and gas in Scotland. A report for the Scottish Government. ISBN: 978-1-78652-396-9
4. Reach, 2013. Geochemical Evaluation Salsburgh-2 Well Midland Valley of Scotland. For Reach CSG by M.N.D. Kaye, OceanGrove Geoscience Ltd, Project No. GC100119. Confidential Report

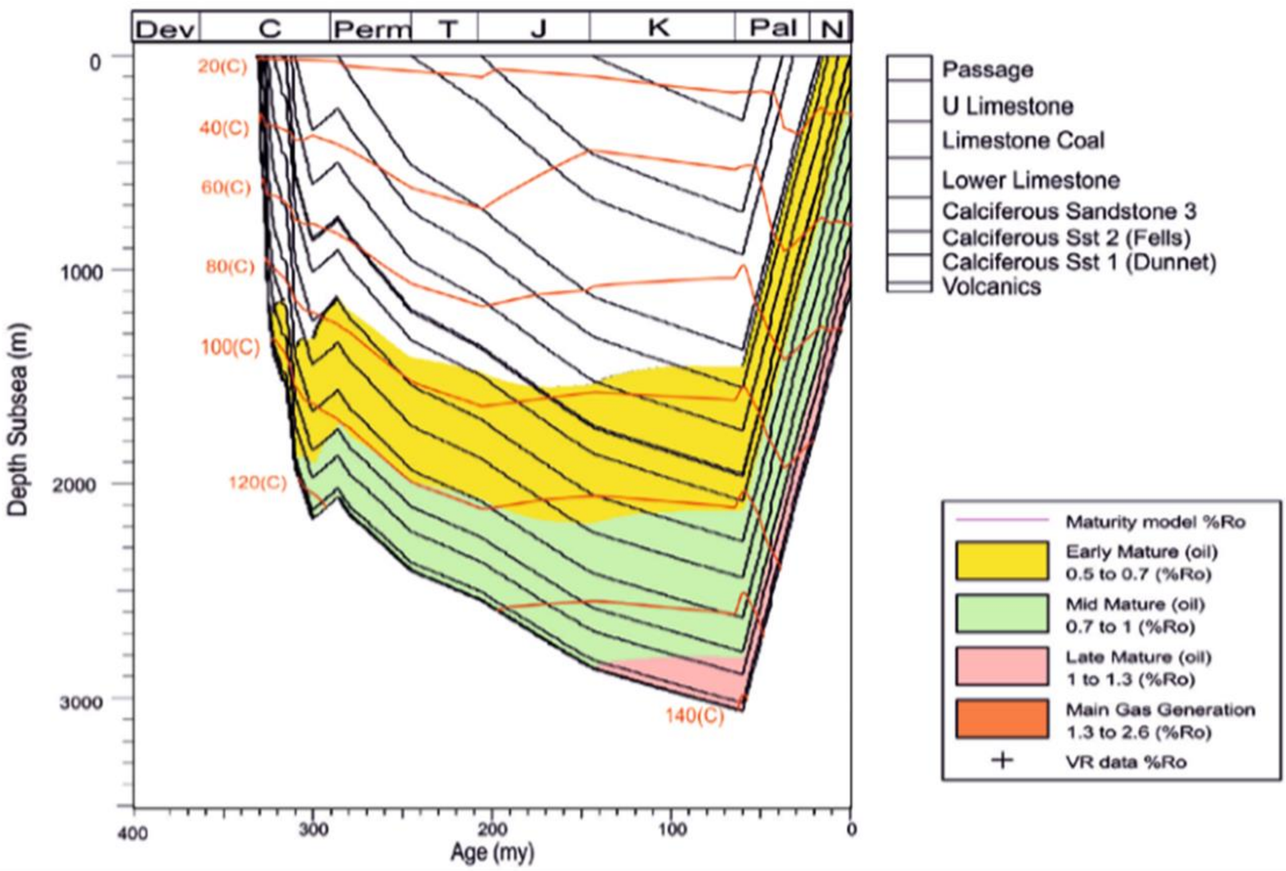

Figure 1: BasinMod model results from **A thermal model of Salsburgh 2 borehole** Vincent, C. J. REPORT CR/13/044

Figure 1. Reproduced by kind permission of ReachCSG from BGS Confidential Report CR/13/044

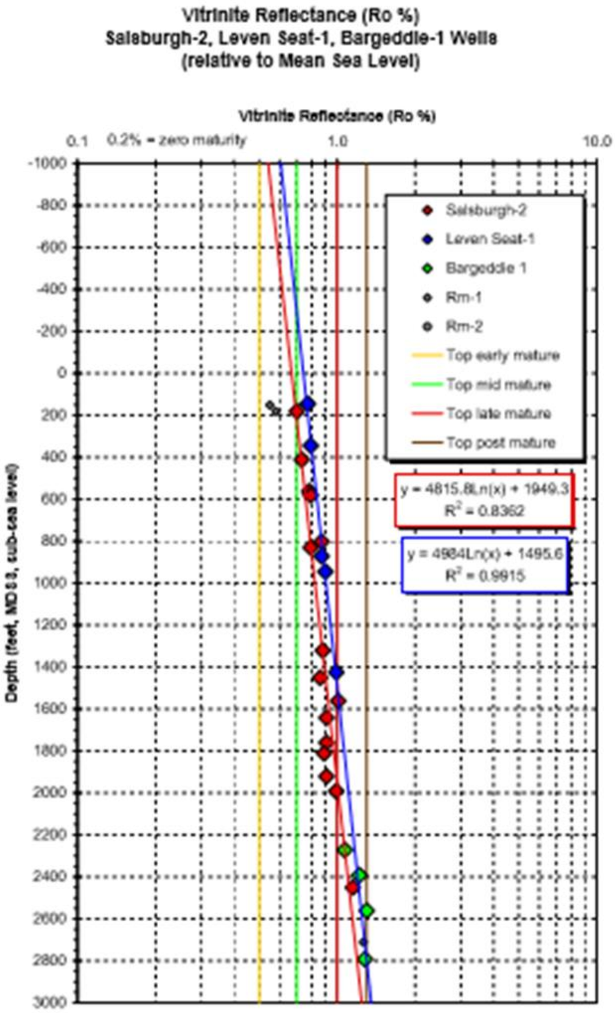

Figure 2: Vitrinite Reflectance (Ro%) measurements from several wells: Leven Seat in West Lothian; Salsburgh in North Lanarkshire; and Bargeddie-1 in Glasgow.

Figure 2. Taken from and discussed further in Reach (2013) (Reference 4)

Reply to Discussion on "Can fracking, for gas and oil, power the Scottish economy?"

By Roy Thompson, GeoSciences, Edinburgh University

Dear Editor,

Nothing of any consequence is raised in Graham Dean's comments. Nevertheless, you ask for a reply: here it is.

First – "*Insufficient attention.*" Readers of *The Edinburgh Geologist* with an interest in fracking should peruse Professor John Underhill's recent article in *The Conversation*. This totally independent work was published while my 'opinion piece' in *The Edinburgh Geologist* was 'in press'. John is Chief Scientist at Heriot-Watt University where he also holds the position of Chair of Exploration Geoscience. The article's title '*There may be a huge flaw in UK fracking hopes – the geology*' gives a succinct indication of where at least one other 'academic', besides me, feels errors and misunderstandings about fracking in Scotland lie. The article is beautifully crafted in simple, down-to-earth, non-technical language. It is available on-line. I thoroughly recommend it.

Secondly – "*Carbon content*". Graham Dean says that I "*wrongly assume the TOC of Scottish shales are 2%*". Well, I did not assume: I assembled my own database of 768 shales, from all across the UK, each with at least eight measurements of organic geochemistry, before carefully analysing all the data and arriving at the conclusion that the average TOC of Scottish shales is 2%. My database is built up from Appendices in BGS reports, from tables in published scientific papers, as well as data gleaned from MSc and PhD theses. Interestingly TOC in shales is lognormally distributed, not normally distributed, and so requires particularly careful statistical attention, especially when used in resource estimation. It is important to be clear that TOC is only one out of multiple issues (Underhill, 2017; Meija et al., 2015), including several petrophysical parameters and elastic properties, that all need to be satisfied for a shale-gas/oil play to work.

The highest Scottish TOC value in the BGS database is 17.56%. This is almost three times higher than the next highest value and very different from my median of 1.8%. The sample has all the appearances of a geostatistical outlier. Intrigued, I delved a little further. I found that it is from 142 m depth in the Spilmersford borehole to the east of Pencaitland. This hole was drilled for stratigraphic purposes back in 1967 and positioned close to the eastern edge of the Midland Valley. For once the borehole log is available on BGS's Geology of Britain viewer. It records a dull, splint, 10 cm-thick coal at 142 m. My curiosity aroused, I immediately telephoned BGS and followed the call up with two emails. No response. Presumably the sample listed in the BGS database is not a coal, but from the seatclay (with coal laminae) immediately below or from the 33 cm-thick, planty mudstone (with coal laminae common) above. I had hoped BGS might enlighten me. Instead I was resigned to never knowing where the sample came from. However, further ferreting now suggests to me that it is from the overlying planty mudstone. This mudstone has a phyllosilicate/clay content of 95% - way over the 30% limit normally desired for successful fracking. Such a thin, ductile horizon, despite its high TOC, would be quite hopeless as a fracking target.

Thirdly - Dean writes *"BGS contradicts [my] view*" on thermal gradients. But the numbers I cite in my *Edinburgh Geologist* article are taken directly from the definitive BGS compilation of onshore borehole temperatures. Dean chooses to support his assertion using two diagrams, which relate to thermal history, both taken from confidential reports. It is impossible to know what assumptions lie behind the unpublished thermal modelling calculations, or to determine what lithologies were sampled for the vitrinite reflectance measurements. Nevertheless, the merest glance reveals a major difficulty. The thermal model has incorrectly generated inconceivably high temperature gradients both at the present day and end-Cretaceous (when surface temperatures were around 20^{o}C). Last winter, when first preparing my *Edinburgh Geologist* article, I had noted exactly the same problem in other BGS reports (e.g. the Milton of Balgonie borehole). I emailed BGS over my concerns about their burial/exhumation calculations. This time, success: I received a response saying they would get back to me. Sadly I never heard anything more.

So what's the problem? Figure 1 looks impressive, but it is just a model as is clearly stated in the caption. The crux of the matter lies with the thermal gradients of 40 K/km. These should fall much closer to 25-30 K/km, as found onshore in Scotland today, or even only 25 K/km as reconstructed by Ceri Vincent's other modelling study for the Midlothian-Leven syncline. In short the burial and exhumation model needs to lift the basal Salsburgh strata from a peak temperature of around 140^{o}C, which is required to generate VRs of 1.1 (cf. fig 2), while at the same time producing sensible present-day temperatures. One rather obvious way to solve the VR/temperature/uplift trilemma would be to bury the sandstones, at end-Cretaceous, at 140^{o}C and at 4 km depth [(140 - 20)/30 = 4 km] so Salsburgh would have experienced 3 km of uplift, rather than 2 km. As the data and modelling are confidential there is no way of understanding why this simple adjustment has not been made. Accepting such a resolution - of much deeper burial and subsequent exhumation - would of course make Prof Underhill's argument that "*fracking for gas, in the UK, is 55 Ma too late*" even more cogent - something that he and BGS co-workers first demonstrated over a decade ago (Underhill et al., 2008).

Fourthly – "*The KPMG report*". In addition to my comments about KPMG's lack of geological understanding, Professor David Smythe has separately pointed out, in his submission to the Scottish Government, that KPMG has produced development scenarios for Scotland based on some unspecified planning application examples from England. Furthermore, he points out that KPMG's most serious error is to have 'cherry picked' their scenarios from unusually optimistic US production forecasts. My conclusion about the KPMG report is exactly the same as Professor Smythe's. His summary is blunt and to the point, and I fully endorse it: "*KPMG's assumption[s] render all their economic predictions and the accompanying timescales essentially worthless*".

Fifthly - "*wonderful geology*". "Wonderful" is a strangely subjective adjective to use. This is a discussion about the utilitarian properties of the shales in Scotland's central belt: whether they stimulate wonder in the eye of the beholder is totally irrelevant.

Lastly - "*Fracking*" and "*the recent rise in gas production from the North Sea*". Pointing to enhanced production from one, unnamed, short lateral is totally inconsequential and inappropriate. The industry regulator (OGA) has just published definitive, up-to-date figures. These show gas production across the whole UK continental shelf to be continuing its dramatic fall.

References

Meija, C. et al. 2015. An integrated workflow for hydraulic fracture stage design. *First Break* 33: 51-57.

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