Solid Earth Discuss.,
https://doi.org/10.5194/se-2019-55-RC1, 2019

Solid Earth
Discussions

Interactive comment on "Uncertainty in fault seal parameters: implications for CO_2 column height retention and storage capacity in geological CO_2 storage projects" *by* Johannes M. Miocic et al.

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Received and published: 27 April 2019

This manuscript raises important concerns regarding the applicability of conventional oil industry methods of fault seal analysis to the issue of CO2 trapping in underground storage facilities. The early sections provide a succinct review of the oil industry methods, highlighting the appropriate fluid properties which are relevant to the calculation of fault seal capacity (column height) for oil and gas and also CO2. The issues related to the wide variation in the CO2 experimental data are also well put. The Monte Carlo modelling technique used in this manuscript gives an interesting overview of the uncertainty in predicted column height as a result of uncertainty in the various input pa-

rameters. Emphasis is placed on how the different fluid properties of CO2 (as opposed to oil or methane) can lead to increased uncertainty.

There are some points which I believe need correction or clarification, in order to tighten the authors' arguments:

In a number of places, starting at the top of p.4, the units of IFT are incorrectly stated as mN/cm instead of mN/m - the values quoted make it clear they should all be mN/m. This should be corrected throughout the ms.

Also at the top of page 4, I do not recognise the stated depth variability for hydrocarbon IFT. Firstly, IFT is not "fairly constant" but varies with depth. Oil IFT is stated to decrease with depth but in my experience it increases with depth - see Figure 9 of Yielding et al 2010, uploaded - from 25 mN/m at the surface to about 40 mN/m at around 3km. For methane, IFT decreases from around 75 mN/m at the surface, also to around 40 mN/m at 3km (see same figure).

On Figure 3, it is not clear to me how the CO2 lines have been derived for the two 'empirical' equations (Bretan & Yielding). I can see that the oil and methane lines differ appropriately because of their different density contrast with water. On density difference alone however, the CO2 line should be between oil and gas, so I assume the CO2 line is reduced because of either IFT or CA input or both (in a manner similar to eqn 10). However, both the Bretan & Yielding equations were based on agglomerated oil AND gas data (i.e. the data pool is blind to fluid type), so it is not clear to me what generic 'hydrocarbon' values for IFT & CA have been assumed, in order to compute the CO2 values via eqn 10. I request that these hydrocarbon IFT and CA values be added to the caption (already contains the CO2 values).

Related to the above point, the model results in D & G of Figs 5 & 6 report the effect of different ranges of wettability when using the Bretan & Yielding eqns. However, as you mention in the Discussion, these equations were derived as the maximum of observed data in oil & gas systems - so arguably they correspond to one extreme of

the wettability range for hydrocarbons (least wettable). Depending on how that 'least wettable' state relates to your average CO2 wettability, I'm not sure if you are right to look at an uncertainty range which is symmetric about your chosen mean for CO2. Maybe I'm over-thinking this, perhaps you can offer a simple clarification.

In the MC modelling, do you assume that all input parameters are independent? Is this valid? (E.g. do IFT and CA co-vary for CO2?).

In the MC modelling, I don't think it is mentioned in the text (or tables) what value of pore-throat size is used. A value of 100 nm is mentioned in the caption of Figure 7 but it isn't clear if this is used for all other models. This is an important point, because in general in oil industry fault seal analysis it is believed that the increasing seal capacity with increasing phyllosilicate content is overwhelmingly due to a corresponding decrease in pore-throat size. Pore-throat size is observed directly in microscope analysis and also back-calculated from Hg-air injection tests. Thus your results in Fig.7, showing smaller column height for phyllosilicate-rich fault rock than for qtz-rich fault rock because of changing CA, might be countered by the qtz-rich fault rock having larger pore throats. Maybe include this pore-throat variation in the input parameters to the Fig.7 models?

The following are minor typos and points of expression:

p1, line 15, should be "assess"

p1, line 16, "As with" might be better than "In similarity to"

p1, line 25, omit "," after storage

p2, line 23, replace ";" by ":"

p2, line 24, model not models

p2, line 27, omit "potentially"

p3, line 17, replace "lighter" by "less dense"

p3, line 23, replace "transport" by "trapping" (transport is controlled by permeability)

p4, line 9, replace "higher" by "greater"

p4, line 22, replace "catalases" by "cataclasites"

p4, line 24, insert "typically" before "> 1km"

p4, line 26, replace "with" by "in"

p5, line 24, insert "and" before "clay bed"

p5, line 24, replace "do" by "does"

p6, line 15, replace "sometimes" by "typically"

p7, line 30 onwards... I was confused by FRC (fault rock composition) and FRCC (fault rock clay content). I think you only need one of these, make it consistent in text and tables.

p9, line 3, insert "(see Figure 7)" after "57"

p9, line 26, insert "(and hence smaller pore-throat radius)" after "content" (see earlier comment)

Fig.4 - label the contours explicitly, to save the reader having to work out their values.

Table 1, last column. I assume the heading should be a lower case sigma, for standard deviation? The upper case symbol confused me for a while.

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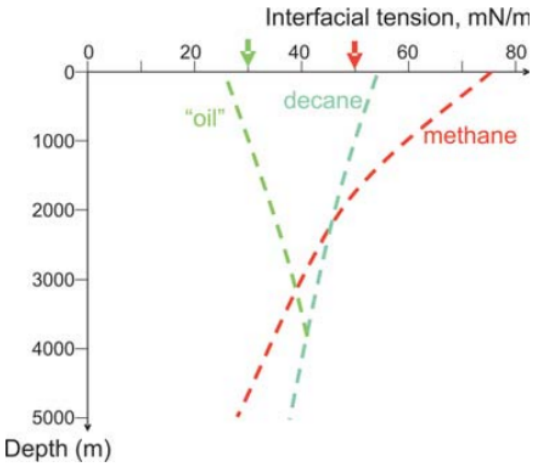

Fig. 9. Some published estimates of the variation of hydrocarbon–water interfacial tension with respect to depth (pressure & temperature conditions). The methane & decane curves indicate experimentally-measured trends from Firoozabadi & Ramey (1988). The 'oil' values are from Nordgård Bolås *et al.* (2005), constructed from empirical equations of Firoozabadi & Ramey (1988). Arrows show typical industry default values for oil–water (green) and gas–water (red) (d'Onfro, pers. comm., 2007).

Fig. 1.