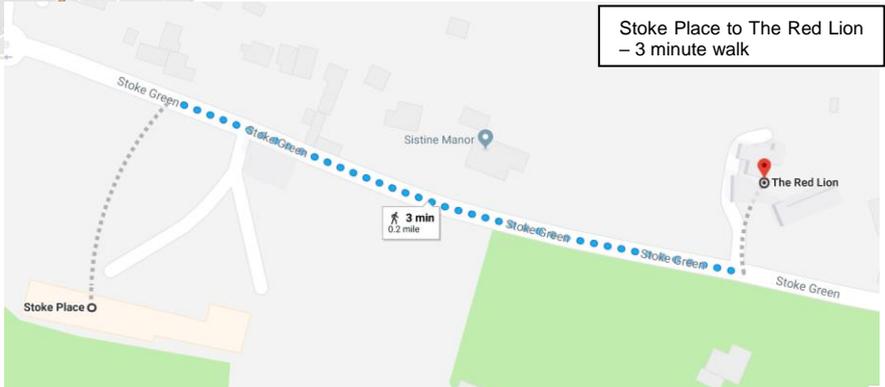


GMN technical meeting - meeting details

- Topic:** Seal capacity and hydrocarbon column height estimations - impact on PFG predictions (75% focus)
Mudrock mineralogy and log response (25% focus)
- Start:** 10:00 7 February 2018
Finish: 14:00 8 February 2018
- Venue:** Stoke Place, Stoke Green, Stoke Poges, Slough, Buckinghamshire, SL2 4HT
Tel: +44 (0) 1753 534 790, Email: enquiries@meldrumhouse.com
Website: www.stokeplace.co.uk
- Host:** Nexen
- Secretariat:** Francesca Tate, OTM Consulting; francesca.tate@otmconsulting.com
Tel: +44 (0)1372 631957
Dawn Dukes, OTM; dawn.dukes@otmconsulting.com
Tel: +44 (0)1372 631954
- Hotels:** The Stoke Place offers a range of rooms including breakfast, members should book early to secure their room of choice to avoid disappointment. To book you hotel room, you can use the link on the Stoke Place website or consider using booking.com
- Travel to Meeting:** 8 miles from Heathrow Airport, 3 miles from Slough Station, 45 miles from Gatwick Airport
- Dinner - Wednesday:** Dinner will be hosted by Nexen at The Red Lion Pub, Stoke Green, Slough SL2 4HN. Please advise OTM in advance of any dietary requirements



Wednesday 7th February			
<i>Arrival with tea/ coffee</i>			<i>10.00</i>
1	Safety notice & logistics	Francesca Tate, OTM	10.15
2	Welcome and objectives for the meeting	Francesca Tate, OTM	10.25
3	Introductions	All	10.30
4	Hydrocarbon column height estimation – how, who and does it matter for PPFG predictions?	Stephan Petmecky, Nexen	10:45
5	Seal capacity & hydrocarbon column height estimations – impact on PPFG predictions	Mira Persaud / Claudia Kaiser OMV	11.15
<i>Tea/ Coffee</i>			<i>11.45</i>
6	An overview of seal assessment and the associated subsurface uncertainties	Cindy Prin / Tom Sinclair, Shell	12.15
7	Seal Capacity and Hydrocarbon Column Height Estimations - Impact on PPFG Predictions & HC Prospectivity.	Akpofure Isiakpere, Total SA	12.45
<i>Lunch at venue</i>			<i>13.15</i>
8	Seal capacity & hydrocarbon column height estimations – impact on PPFG predictions	Pamela Tempone / Sascha Doering, Eni	14.30
9	Capillary sealing efficiency and estimation of hydrocarbon column heights	Bernhard Krooss, RWTH Aachen University	15.00
<i>Tea/ Coffee</i>			<i>15.40</i>
10	Breakout discussions on topics brought out during Dr Krooss's presentation	Group discussions / All	16.00
<i>End of day 1</i>			<i>17.15</i>
<i>Dinner</i>			<i>19.00</i>

Thursday 8th February			
<i>Arrival with tea/ coffee</i>			<i>08.45</i>
11	Safety notice	Francesca Tate, OTM	09.00
12	Pore Pressure Prediction Uncertainty associated with Mudrock Mineralogy	David Tassone, Woodside	09.10
13	Top Seal & Fault Seal Analysis in the Barents Sea: A Case Study	Georg Röser /Johanna Chevallier-Messbacher, Wintershall	09.40
14	Seal Capacity and Column Height Estimations for PPFG – Should we be doing more?	Benjamin Quaillet, Tullow Oil	10.10
<i>Tea/ Coffee</i>			<i>10.40</i>
15	Establishing reasonable ranges of hydrocarbon column heights for exploration wells	Toby Harrold / Pascal Rouille, Repsol	11.00
16	Roundtable discussion	Group Discussion	11.30
17	Meeting wrap up to include discussion on: <ul style="list-style-type: none"> • Additional members • Future topics • Host for next meeting • GMN administration Any follow-up action as a result of the meeting	Francesca Tate, OTM All	12.30
<i>Lunch at venue</i>			<i>13.00</i>
<i>End of Day 2</i>			<i>14.00</i>

Attendees for GMN Meeting

	Company	First Name	Last Name
1	RWTH Aachen University	Bernhard	Krooss
2	Eni S.p.A	Pamela	Tempone
3	Eni S.p.A	Sascha	Doering
4	Nexen Petroleum UK Ltd	Stephan	Petmecky
5	OMV Exploration & Production	Claudia	Kaiser
6	OMV Exploration & Production	Mira	Persaud
7	OTM Consulting	Dawn	Dukes
8	OTM Consulting	Francesca	Tate
9	Repsol	Toby	Harrold
10	Repsol	Pascal	Rouille
11	Shell	Cindy	Prin
12	Shell	Tom	Sinclair
13	TOTAL E&P	Akpofure	Isiakpere
14	Tullow Oil	Benjamin	Quaillet
15	Tullow Oil	Peter	Evans
16	Wintershall Holding GmbH	Georg	Röser
17	Wintershall Holding GmbH	Johanna	Chevallier-Messbacher
18	Woodside Energy Limited	David	Tassone

Apologies

	Company	First Name	Last Name
1	ConocoPhillips	Chris	Grieve
2	Maersk Oil	Gareth	Yardley

Topic

Two topics are planned for the next Geopressure Management Meeting. Members may choose to talk on either or both topics depending on their experience. The breadth of these topics is to give all companies the opportunity to contribute.

The main discussion topic for the meeting (which is expected to take up around 75% of the time) is:

Seal capacity and hydrocarbon column height estimations - impact on PPFG predictions

1. Introduction

In exploration the nature of seals is of great importance in understanding what potential column heights can exist in the subsurface and how to design a well to access them.

Hydrocarbon sealing capacity can be influenced by multiple factors. In normally or slightly overpressured systems, solely looking at the fracture pressure limit of the system to assess seal capacity could lead to significant overestimations of column heights with potentially detrimental consequences for well design/cost.

The aim of this session is to discuss which methodologies are being applied when, who determines which approach is the most applicable and how the predicted column heights are calibrated?

Some specific questions regarding column height prediction workflows for well planning/design are:

- Which approach is preferred - capillary entry pressure, fracture pressure, permeability limitations (or something else, e.g. statistics)?
- How do we decide which approach is most appropriate? Or: Under which geological conditions is it safe to move away from the fracture pressure approach as the worst case/high scenario?
- How good are we in predicting HC column heights? Who is keeping a record of this?
- Whose job is it to predict column heights – the PPFG prediction or the petroleum systems expert or both?
- Do you have in-house tools (for capillary entry pressure derived column heights) and who owns it?
- What makes a good seal and how can we identify them pre-drill?
- How do we predict the overpressure increase across a seal – is it gradual or a sudden step change and how severe can the pressure change be?
- How many fields have you worked on which are
 - filled to spill
 - filled to hydraulic leak capacity (i.e. fracture pressure)
 - filled to capillary entry pressure leak capacity
 - filled beyond capillary entry pressure capacity but not to spill (migration barrier)
 - empty due to catastrophic seal failure
- How do you define the high/worst case – tallest, lightest column on top of highest aquifer pressure?
- Does HC column height prediction actually matter, i.e. is the overall uncertainty larger than the buoyancy effect of the estimated HC column?

The discussion subtopic for the meeting (which is expected to take up around 25% of the time) is:

Mudrock mineralogy and log response

2. Introduction

Mudrocks have extremely low permeabilities and it is usually not possible to measure their internal pressure directly. Consequently, standard pressure prediction practice is to infer mudrock pressure from other information such as petrophysical logs. The relationship between log response and pore pressure is usually quantified in terms of velocity-stress models, normal compaction trends and Eaton exponents.

Mudrock mineralogy varies between basins and also vertically within a basin due to changes in sediment provenance and post-depositional mineral transformations (e.g. Smectite to Illite). The goal of this topic is to understand the impact mudrock mineralogy has on the way that we infer pressures in mudrock sequences.

Some relevant questions are:

- How do changes in mineralogy affect log response? Are some petrophysical logs affected more than others?
- Can changes in mudrock mineralogy have a large impact on our log property-pressure calibrations and the resulting pore pressure estimate?
- What workflows are needed to highlight changes in mineralogy?
- What workflows are needed to calibrate our log based pressure models for the appropriate mudrock types present?
- Are there measurements (in the well or laboratory) that are needed to improve our log-based pressure estimates?
- Are different analyses needed whether the cause of overpressure is disequilibrium compaction or secondary mechanisms?

3. Presentations

Each company is asked to prepare slides for approximately 30 minutes of presentation and 10 minutes for Q&A.

As witnessed at previous meetings, the demographic of the group continues to evolve and with this we politely request that presentations are sourced from each company's global resource pool and not only from the North Sea (unless of course your company only holds North Sea acreage). The meeting is a technical forum and these presentations are intended to provide a background to stimulate the discussion period. Please ensure you include case studies; and come armed with company and other industry experiences, to bring the lessons learnt and best practices to life more effectively.

4. Organisation

Please advise OTM who will be attending if you have not done so already, as there is a limit on numbers in the reserved meeting room.

We also need to know if you require remote access (teleconference/ videoconference) to the meeting including all names of those who wish to attend remotely.

5. Abstracts

Please find overleaf:

5.1. Hydrocarbon column height estimation – how, who and does it matter for PPFG predictions?

Stephan Petmecky, Nexen

The presentation will describe some of the factors limiting hydrocarbon column heights in reservoir rock. Each scenario's applicability will be critically assessed and discussed. Depending on which limiting mechanism is chosen for an undrilled exploration lead/prospect, e.g. capillary entry pressure versus fracture pressure, the resulting column heights might vary significantly.

The difficulty of accurately predicting column heights for an exploration well will be demonstrated, along with the question of who actually is accountable for providing these estimates. Hydrocarbon phase in combination with column heights do have a significant impact on commerciality assessments of prospects, but do they actually matter when it comes to pressure prediction itself? It will be shown that, at some point, the added uncertainty in pore pressure due to the buoyancy effect of a HC column will become insignificant compared to the overall uncertainty in aquifer pressure. However, if the column height is deemed important enough to be included in the PPFG prediction, how are they being incorporated? Adding the largest possible gas column to the high case pore pressure curve could be considered too conservative and might increase well cost unnecessarily.

5.2. Seal capacity & hydrocarbon column height estimations – impact on PPFG predictions

Mira Persaud / Claudia Kaiser, OMV

In many OMV locations, the limitation of the seal capacity (in terms of capillary pressure, fracture pressure or fault reactivation) is not the key driver on hydrocarbon column height estimations. However, there are a few areas where this is a critical factor, for example for some developments, and water injection projects, and potential gas storage projects. We will present a few examples from these areas, to show our workflow. We will discuss the fact that in many of our exploration areas, the overall uncertainty of the PPFG prediction is larger than the buoyancy effect of the estimated HC column.

5.3. An overview of seal assessment and the associated subsurface uncertainties

Cindy Prin / Tom Sinclair, Shell

The assessment of the caprock or top seal of a prospect can be an overlooked workflow where the focus on a prospect is the reservoir quality and the petroleum system (charge, phase and migration). This talk aims to give an overview of a seal assessment workflow and then focus on how basin scale pore pressure analysis early on in the prospect maturation cycle can help to identify, understand and reduce the uncertainties for risking the top seal when a prospect is being evaluated. A basin scale pore pressure study can help to assess:

- The overburden or lithostatic gradient. How well constrained is the calculated overburden gradient? Does it vary spatially across a basin?
- The pore pressure regime of the caprock. How is it predicted, quantitatively or qualitatively? What are the uncertainties associated with the prediction and how are these carried across to a prospect?
- The interpretation of the fracture gradient. Is it a Leak Off Pressure calibration or a calculated minimum stress?
- Pore pressure plumbing. The use of basin modelling and offset wells to understand the retention and communication of pore pressure in a basin.

5.4. Seal Capacity and Hydrocarbon Column Height Estimations - Impact on PPFG Predictions & HC Prospectivity.

Akposure Isiakpere, Total

The first step towards estimating HC column height is to understand if the true controlling factor of HC column height in your prospect is the seal capacity or its integrity i.e. discounting other factors such as insufficient charging etc which could lead to over-estimation of HC column heights. Once this has been established, the nature of seal needs to be determined prior to estimating the Pe and S3 of the seal.

Understanding the type of seals in a prospect is key as this has a direct impact on the capillary entry pressure and/or the minimum stress and consequently the height of possible hydrocarbon column. It is important to determine both the Pe and S3 as some prospects could be breached by the Pe before the S3 is reached (especially in shallow buried shaly seals).

In TOTAL, capillary entry pressure (Pe) is estimated from laboratory measurements on cap rock cores and/or databases of relevant analogues, depending on the context and availability of such data. Extrapolation of these laboratory results to in-situ real life is indeed debatable. Minimum stresses on the other hand are estimated from stress models calibrated to representative Leak-Off Test and reservoir pressure data.

In TOTAL, the Petroleum Systems Specialist is in charge of hydrocarbon height estimations and works in collaboration with the structural specialist for fault seal analysis if dealing with a fault seal prospect or with prospects which shows indications of hydraulic leakage. The PPFG Specialists checks for consistency of hydrocarbon column estimates to seal capacity and integrity during the pore pressure and fracture gradient (PPFG) prediction process. An in-house seal evaluation tool (SET) is used by the Petroleum System Specialists for prediction of HC column height and sealing capacity as well as a consistency check for direct hydrocarbon indicators with seal behaviour.

Hydrocarbon column height estimation could play a key role in the ranking of significantly overpressured prospects. In the absence of any indications of pressure release, the relationship between seal capacity and reservoir aquifer pressure could be one of the major factors in prospect ranking. This approach has been attempted in deeply buried and potentially overpressured prospects in the Niger Delta basin. In such a context, estimating both the reservoir aquifer pressure and seal capacity/integrity accurately is paramount to ensuring effective ranking. This presentation will show some examples in the Niger Delta basin, Nigeria.

In terms of the impact on the PPFG required for drilling operations, accurate hydrocarbon column height estimation is more important for shallow buried reservoirs, deeply buried reservoirs with significant aquifer overpressure and reservoirs with significant HC column height.

In other context such as deeply buried reservoirs with both hydrostatic aquifer and shale pressures and/or with relatively limited hydrocarbon column height, the impact on the PPFG prediction and drilling operations could be less significant

5.5. Seal capacity and hydrocarbon column height estimations - impact on PPFG predictions

Pamela Tempone / Sascha Doering, Eni

One of the most important roles of the Geopressure Team is to provide Pore Pressure and Fracture Pressure profiles that helps the safe drilling of our wells. However HC column estimation, that generally is the driver for the identification of the highest pressure that will be encountered while drilling, may be subject to large uncertainties. We will look at the most common workflow to estimate HC column in exploration wells for well planning purposes and 2 examples of wells where close integration of GEOP Team and PSM team has helped in constraining uncertainties and identifying exploration and drilling risks.

5.6. Capillary sealing efficiency and estimation of hydrocarbon column heights

Bernhard Krooss, RWTH Aachen University

Abstract to follow.

5.7. Pore Pressure Prediction Uncertainty associated with Mudrock Mineralogy

David Tassone, Woodside

Clay mineralogy impacts how mudrocks compact with increasing effective stress and depth of burial. For this reason, mudrock mineralogy is important to understand from a pore pressure prediction perspective as it can similarly also cause anomalous compaction. In overburden sections, however, it can often be challenging to show the value in better understanding mudrock mineralogy and compaction for the sole purpose of pore pressure prediction.

In this presentation, we show two case studies conceptualised to highlight the pore pressure prediction uncertainty associated with mudrock mineralogy and log response. In both case-studies, mudrock mineralogy has the potential to over- and under-estimate mudrock pore pressures pre-drill and during operations, impacting both safe well design and real-time decision-making.

5.8. Top Seal & Fault Seal Analysis in the Barents Sea: A Case Study

Johanna Chevallier-Messbacher, Wintershall

HCC height is of importance for the evaluation of a prospect. However, controlling factors are numerous. In preparation for a bidding round, large 4-way & 3-way dip closures were assessed in terms of their sealing capacity. The top seal and fault seal capacity were computed based on capillary strength and hydraulic strength of the sealing facies. This talk presents the methods and workflow applied. Assessing sensitivities for the various input parameters is also part of the work. The talk tackles questions on the potential and limits of hydrocarbon column computation in exploration.

5.9. Seal Capacity and Column Height Estimations for PPFG – Should we be doing more?

Benjamin Quaillet, Tullow Oil

In Tullow the department focusing on PPFG prediction is independent from the asset teams. This segregation makes it easier and more effective to obey the following rule: safety comes first; the prize only comes second. So when it comes to estimating seal capacity and hydrocarbon column heights the emphasis is more on “how bad can it be” rather than “how much can we bank on”. Our approach is pragmatic, we tend to use fairly simple models and software with basic assumptions as we are limited in resources and research but this has the advantage of making the studies quicker and within the reach of our non-PPFG colleagues. Do we need to invest more time and effort in refining our seal capacity and column height estimates? Up to now, unpleasant surprises in terms of PPFG have been rare and when it comes to exploration success, pleasant surprises have also been scarce lately. How much blame can we put on seal capacity though?

5.10. Establishing reasonable ranges of hydrocarbon column heights for exploration wells

Toby Harrold / Pascal Rouille, Repsol

Abstract to follow.