

Geomechanics Initiative Meeting – Agenda

Topic: Primary topic: Drilling in Depleted Reservoirs
Secondary Topic: Fracture Analysis

Date: Monday 12th April and Tuesday 13th April 2021

Time: 10.00 – 15:30 (European time) Monday 12th April
10.00 – 12:30 (European time) Tuesday 13th April

Location: Virtual, MS Teams

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Attendees:

	Company	First Name	Last Name
1	Aker BP	Andreas	Bauer
2	Aker BP	Tron Golder	Kristiansen
3	CNOOC Petroleum Europe Limited	Ben	Fletcher
4	CNOOC Petroleum Europe Limited	Phil	Highton
5	CNOOC Petroleum Europe Limited	Rob	Webber
6	Eni S.p.A	Federica	Ferrari
7	Eni S.p.A	Giulia	Gallino
8	Eni S.p.A	Riccardo	Mandrioli
9	Eni S.p.A	Ada	Crottini
10	Eni S.p.A	Nicola	Daniele
11	Eni S.p.A	Stefania	Di Martino
12	Eni S.p.A	Antonio	Monaco
13	Eni S.p.A	Cesare	Follone
14	Eni S.p.A	Alessandro	Pozzi
15	Eni S.p.A	Filippo	Campana
16	Eni S.p.A	Silvia	Haiz
17	Eni S.p.A	Gianfranco	Bagnoli
18	OMV	Mira	Persaud
19	OMV	Manuel	Blumenthal
20	OMV	Bansri	Raithatha
21	OMV	Nikolas	Bartl
22	OMV	Bogdan	Popina
23	OMV	Volker	Schuller
24	OTM Consulting	Richard	Shelton
25	OTM Consulting	Dawn	Dukes
26	Shell	Sergio	de Gennaro
27	Shell	Isaac	Foo
28	Total E&P	Frederic	Bourgeois
29	Total E&P	Sandrine	Vidal-Gilbert
30	University of Vienna	Michael	Ketterman

Monday, 12 th April			UK time	EUR time
1	Welcome and objectives for the meeting	Richard Shelton, OTM	09:00	10:00
2	Introductions	All	09:15	10:15
3	Infill wells in North Sea and Offshore Angola	Frederic Bourgeois, Total	09:30	10:30
4	Stress path prediction in depleted reservoir	Federica Ferrari and Silvia Haiz, Eni	10:15	11:15
Lunch			11:00	12:00
5	Stress paths during depletion and re-pressurization in the Valhall field	Andreas Bauer, Aker BP	12:00	13:00
6	Reducing the uncertainty of fault reactivation risk using fault seal analysis and Mohr-Coulomb friction	Volker Schuller, OMV / Michael Ketterman, University of Vienna	12:45	13:45
Break			13:30	14:30
7	Fault characterisation	Phil Highton, CNOOC	13:45	14:45
End of day 1			14:30	15:30

Tuesday, 13 th April			UK time	EUR time
8	Welcome	OTM, Richard Shelton	09:00	10:00
9	Shell experience of depleted HPHT fields	Sergio De-Gennaro, Shell	09:05	10:05
10	Roundtable: Uncertainties in Geomechanics	All	09:50	10:50
Break			10:50	11:50
11	Meeting wrap up to include discussion on: - Member update - Future topics - Next meeting format/ timing - AOB	OTM, Richard Shelton	11:00	12:00
End of day 2			11:30	12:30

Topic

Two topics are planned for the next GIN meeting. Members may choose to talk on either or both topics depending on their experience. The topics are as follows;

1 Introduction

1.1 Drilling in Depleted Reservoirs

Geomechanics play an important role in maximizing economics from depleted reservoirs. The main geomechanics process in depleting reservoirs is the resulting reduction in total stresses as the rock bulk volume shrinks and hence a resulting drop in the fracture gradient. If depletion is very high, this may result in increased cost to access reserves, this could be to access deeper reservoirs or in the main reservoir where depletion is so low that a sub hydrostatic fluid column may frac the reservoir. One may have to add well cost in the form of more casing strings. There may be low permeable reservoir layers, interbedded shale layers, baffles or faults that create steep pressure gradients or pressure gradient steps, and corresponding changes in the fracture gradient. Depletion can be large enough and low pressure may be in place for a long time so that cap-rock pore pressure is depleted with an associated fracture gradient drop in cap-rock. If the reservoir below the cap-rock is soft or the depletion is very high (HPHT) the compaction in the reservoir can also change stress, pore pressure and hence drilling conditions in the overburden. If these changes are large enough casings may be sheared off.

The risks associated with the reservoir depletion is typically lost circulation, kicks, blow-outs, wellbore instability, stuck pipe, differential sticking and sheared off wells with lost production.

It is important to predict the above scenarios up front in order to handle the risk and ensure the optimum economics for the project. It is therefore important to be able to predict how the drilling conditions may change with time. In this session we will look at the geomechanics role in depleted reservoir exploitation. Some areas to focus on may be:

- Stress path prediction, how good are we at predicting the stress path the reservoir will follow during depletion (and injection)? Will a small intact core plug give you the answer?
- Wellbore strengthening, how good are we at predicting the strengthening effect of mud additives to increase the fracture breakdown pressure, can we treat shales?
- How good are we at predicting changes in the cap-rock above a depleted reservoir accurately?
- Techniques to handle small or zero mud windows, like Lost circulation material, liner and casing drilling, Managed pressure drilling and Underbalanced drilling, what works best?

Let's put some field data on the table and to discuss our observations and experiences!

1.2 Fracture analysis

This topic is broad and not very specific. Let's have a wide view of fractures in geomechanics. Let's discuss fractures, both natural and man-made. How good are we to handle cracks, flaws and defects in the rock mass in geomechanics? Aspects we could discuss and try to establish the current state of the art for are:

- Induced fracturing for stimulation, where are we now?

- Lost circulation prediction, where are we now?
- Fractured reservoir modeling with stress sensitive fracture aperture, where are we now?
- Fractures and flaws and their impact on the stiffness in the 3D and 4D geomechanics models, where are we now?

Let's put some field data on the table and to discuss our observations and experiences!

2 Presentations

Each company is asked to prepare slides for approximately 30 minutes of presentation and 15 minutes for Q&A.

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 discussion.

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.

3 Organisation

Please advise OTM who will be attending if you have not done so already.

4 Abstracts

1 Frederic Bourgeois, Total - Infill wells in North Sea and Offshore Angola

The presentation will focus on the studies performed for the drilling

- of infill wells in Elgin and Franklin fields: HPHT context in highly depleted sandstone reservoir with a disturbed overburden
- of infill wells in Block 17 Angola: deep water environment and unconsolidated reservoir

The study includes: calculation of fracture gradient for the overburden and the reservoir, minimum mud weight and fracture size calculation, stress path characterization

2 Federica Ferrari and Silvia Haiz, Eni - Stress path prediction in depleted reservoir

Recent challenges in oil and gas industry include the drilling throughout depleted reservoirs. Although the expected Pore Pressure Gradients (PPG) can be estimated from reservoir models matching the production history, more uncertainty concerns the prediction of the Fracture Gradient (FG) in such depleted reservoirs. A common approach consists of using the so called “stress path” for estimating the FG variation from the PPG changes. This talk will show a couple of examples in calculating the stress path, using different methods, and the implications on Wellbore Stability.

3 Andreas Bauer, Tron Golder Kristiansen, Roar Egil Flatebø, Assia Guida, Olav-Magnar Nes, Øyvind Skomedal, Nirina Haller, Helene Hafslund Veire, Aker BP - Stress paths during depletion and re-pressurization in the Valhall field

Reservoir depletion results in stress changes in the subsurface, mostly within the reservoir itself but also in the surrounding rock formations. Knowledge of those stress changes is crucial for assessing reservoir and well integrity, solids production, and wellbore stability during infill drilling. For the Valhall field, a chalk reservoir that underwent large depletion, water injection, and large compaction, a unique dataset of minimum horizontal stresses is available, acquired over a period of 38 years. The dataset exhibits horizontal stress changes within the reservoir that are almost as large as the pore-pressure changes, which is attributed to a combined effect of pore collapse, fault reactivation, and arching during depletion and re-pressurization. There is also evidence for significant stress changes in the overburden, and we hope that time-lapse (4D) seismic data, in combination with advanced rock-physics models, can be used to constrain those overburden stress changes and calibrate geomechanical models in order to estimate safe drilling windows for new wells.

4 Volker Schuller, OMV and Michael Ketterman, University of Vienna - Reducing the uncertainty of fault reactivation risk using fault seal analysis and Mohr-Coulomb friction

Following the Mohr-Coulomb mechanical behavior, fault strength can be described by the cohesion and the friction coefficient of the fault rock. The friction coefficient in particular depends strongly on the clay content of the fault rock, which in turn can be predicted using the shale gouge ratio (SGR) that is commonly used in fault seal analysis workflows. We present a simple approach to predict the friction coefficient of a fault at any given point using SGR and discuss the impact of structural heterogeneity.

5 Phil Highton, CNOOC – Fault Characterisation

The aim of this talk is to provide an introduction to some basic fault analysis techniques, illustrated with some examples including the definition of fault seal capacity and fault population analysis including a discussion of the use of these techniques in static and dynamic modelling and the prediction and anticipation of fault density and throws during well planning and operations well.

6 Sergio De-Gennaro, Shell - Shell experience of depleted HPHT fields

The ability to drill infill wells in depleted HPHT fields is considered a critical issue given the potential for the closure of the drilling mud weight window between the caprock and the reservoir. The difficulty is further increased by uncertainties in the minimum total principal stress change in the immediate overburden or caprock above the depleted reservoir (via the so-called stress arching effect). These changes can be substantial making the formation more susceptible to tensile failure due to too-high mud weight (in the well) or too-high pore pressure (in the caprock seal) fracturing the rock. The caprock seal may be depleted as well as the reservoir (via pore pressure diffusion), and therefore the minimum total principal stress may reduce further. Models and predictive tools are required to help explain the loss of fracture gradient within a changing stress field. We will present depleted drilling experiences with focus on what we have learned and achieved within the reservoir interval but also in the overburden or caprock. We will also discuss some key technologies implemented to overcome drilling issues including Managed Pressure Drilling, Drill-In Liner and Wellbore Strengthening.