

**Introduction**

Festningsprofilet is a well known geological profile where we “literally” will walk through the geological history from the Permian up to Cretaceous. It will be like walking upwards in a hydrocarbon well from the reservoir and to surface and it provides us with a unique opportunity to see what is below the surface and what rocks we will typically drill though while constructing a well.

Drilling and Geology are two disciplines that depend heavily upon each other when a well is to be planned. This is reflected in the drilling program i.e. the planning document for all drilling operations where a substantial part is devoted to geological considerations. The drilling engineer needs to know what is the geological target of the well and he also needs information on which rock types he will meet on the way to mitigate potential drilling problems.

The figure below is a simple example of maybe one of the most important figures you will find in a drilling program. On the left in the figure, you will find the stratigraphic column showing the drilling engineers which rock types they will meet while drilling downwards. This is important information with respect to choosing the correct drilling equipment and avoid drilling problems. On the right in the figure, the pore pressure and the fracture pressure in sg (specific gravity) are given. The mud density in sg (kg/litre) must always be above the red curve to avoid kick and below the blue line to avoid fracturing and mud losses to the formation. These pressure gradients and information about the geology downhole will be decisive with respect to how one should design the well (where the different casings should be set).

![Stratigraphic column and pressure gradients](image)

**Figure 1 – Stratigraphic column and pressure gradients**

While walking along the Festningsprofilet, we will get familiar with a stratigraphic column (from bottom to top). **An important part of the exercise will be to construct/draw this column and the information obtained, will later be used in the Storvola Exercise.**
Objectives of Exercise

- Part1 - Draw the stratigraphic column for the Festningen profile
- Part2 – Identify problematic rocks with respect to drilling
- Part3 – Solve some questions related to construction of a well for a given case.

Important: Bring with you paper/pencils in the field so you can take notes. If possible, to bring a camera can also be good.

REMEMBER HARDHATS

Since this will be our first expedition day, we need to be focused on doing the right things.

There will be a wrap up of the exercise on the boat the same evening where two groups will have to present their results.

Part1

While you walk along the Festningen profilet, you shall make a “rough” estimate of the stratigraphic column. We can assume that the total length is 2000 meters from bottom to top. The information gained here will later be used in the Storvola project. On the resource CD you will find a PowerPoint named: “StratigraphicColumn_Festningen_HelpFigure” which you can use for this.

![StratigraphicColumn_Festningen_HelpFigure](image)

Figure 2 – StratigraphicColumn_Festningen_HelpFigure

Part2

While walking along Festningen, you shall also try to identify rock types that can cause drilling problems. Which rocks etc can cause problems related to:

- Slow penetration rates and need for appropriate bits?
- Stuck pipe problems (loose formation, swelling clay/shale)
- Lost circulation
- Drilling into caves/Karst
• Directional drilling problems (e.g. caused by hard rock)

This type of information will also be needed for solving the Storvola exercise.

Part 3
In the following we will work through a case, where we walk through the well construction sequence of a well. A casing program will be constructed using the information given in Figure 1. Then we will highlight important issues that one has to be aware of when drilling the different well sections and which drilling problems that may occur. The purpose of the case is to give an introductory understanding of the process of constructing a well.

The case
A subsea vertical exploration will be drilled in order to investigate if there is an oil reservoir in the limestone/dolomite formation seen at the bottom of the geological profile. The water depth is 225 meters (250 meters measured from RKB). A pore pressure prognosis is given in Figure 1. This is only an estimate of what is expected since this is an exploration well. The reservoir temperature is expected to be around 170°C.

One suspects that there is shallow gas present and some boulders are expected at shallow depths. In some of the shale layers (e.g. in the upper part of Trias) reactive shale can occur. A layer of fractured shale is suspected at around 2700 m.

The following hole and casing sizes is planned for the well:

<table>
<thead>
<tr>
<th>Hole section</th>
<th>Casing size</th>
<th>Setting depth from RKB</th>
<th>Mudweight (s.g.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36”</td>
<td>30”</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>26”</td>
<td>18 5/8”</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Run BOP (Blow out preventor on riser)</td>
<td>17 ½”</td>
<td>13 3/8”</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>12 ¼”</td>
<td>9 5/8”</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>8 ½”</td>
<td>7” liner</td>
<td>?</td>
</tr>
</tbody>
</table>

Questions to be answered

Type of well and choice of an appropriate rig.

1) Why can this well be classified as an HPHT well (high pressure and high temperature well) and what is special with this type of wells?

2) What type of rig would you choose to perform the drilling operation?

Preplanning/Casing design.

Casing design and choice of appropriate mudweight for the different hole sections is very important part of the well design process. This often involves computer models and advanced planning. However it is possible to make some simple estimates in advance.

3) Try to find out where you will position the different casing shoes and give some arguments for the choices you make.
4) Which mudweights would you choose for the different hole sections and what determines which mudweights we can use?

**Top hole sections (36” and 26”)**

5) What operational problems/challenges can occur during drilling of the upper sections and what can be done to prevent/reduce these (tools and procedures)?

6) What can you say about cementing of the two upper sections?

**Running Riser and BOP**

The blowout preventor (BOP) is run on the riser. The riser connects the BOP and the rig. From this point we have well control and mud returns are taken on the rig.

7) Which barriers do we have in a drilling operation and explain the main difference between the annular preventer and the other rams (pipe, shear).

**Drilling the 17 ½” section**

Stuck pipe is known to be a severe event that can be quite expensive and in worst case a fishing operation or a sidetrack can be the final results.

8) Give an overview of different effects that can lead to a stuck pipe incident and what can be done to prevent this? (also use information given in the case description)

9) Discuss which bits you will use in the different hole sections and give some advantages/disadvantages associated with each type (roller cone, PDC, hybrid bits, natural diamond bits).

**Drilling the 12 1/4” and the 8 ½” reservoir section**

10) The upper sections are usually drilled with water or a waterbased mud system (WBM). It is common to switch to an oil based mud (OBM) in the lower sections. Discuss some advantages/disadvantages with using OBM in this HPHT well.
11) An unintended inflow of gas during drilling is called a kick. If this kick is not brought under control a blowout can be the final disastrous results.


During drilling of the 8 ½” section at around 4300 meters a kick is taken. What can be the reasons for taking a kick and describe briefly the following operational steps.

12) Is there any potential for lost circulation in the reservoir section?

**Production wells**

The exploration well revealed that there was oil in the reservoir. After some appraisal wells have been drilled, it is time to start drilling production wells.

13) Discuss what well profile you would choose to optimise the production and which challenges you foresee with respect to directional well control taken into account the geological information given initially.

14) What downhole drilling equipment will you use to drill the directional wells?

**Presentation**

Two groups will be asked to give a powerpoint presentation of 5-10 minutes of their main results on the boat the following evening

Group1 – Presents their results from Part 1 & 2

Group2 – Presents their results from Part 3

**Responsible teacher**

Kjell Kåre Fjelde