

Introduction to the Gullfaks Area

by Arild Hesjedal and Petter Eltvik - Statoil

Reservoir Description

The Gullfaks area is located in the Norwegian sector of the North Sea, in block 34/10, approximately 175 km northwest of Bergen, see [Figure 1](#). The seven fields in the Gullfaks area are found in sandstones of early and middle Jurassic age, 1800 – 4000 m sub sea (Ref.1). Reservoir quality is generally very high, with permeability ranging from tens of mD to several Darcys depending on layer and location. [Figure 2](#) shows a composite type log indicating the quality and variability of the various reservoirs.

The Gullfaks Main field is over pressured, with an initial pressure of 310 bar at datum depth of 1850 m below mean sea level, and a temperature of 70 degrees C. The oil is undersaturated, with a saturation pressure of approximately 245 bar, depending on formation depth and location. The GOR ranges between 90 and 180 Sm³/Sm³, with stock tank oil gravity around 860 kg/m³. Structurally, the field is very complex and can be divided into three regions (Ref. 2): the so-called 'Domino Area' with rotated fault blocks in the west, and a Horst area in the east; in between is a complex 'Adaptation Zone', characterized by folding structures. The north-south faults that divide up the field have throw up to 300 meters. In the western part the faults slope typically around 28 degrees downward to the east, whereas in the eastern horst they slope 60-65 degrees downwards to the west. The field is further cut by smaller faults, with throws of zero to few tens of meters, both in the dominant north-south as well as east-west direction. Many of these lesser faults have slopes of 50-80 degrees. This results in complex reservoir communication and drainage patterns, and is a major challenge in optimally placing wells in the reservoir.

The Gullfaks Satellites fields are Gullfaks Sør, Rimfaks, Gullveig, Gimle, Gulltopp and Skinfaks, see [Figure 3](#). Production from the first three satellites started in 1998, while Gimle came onstream in 2005 and Gulltopp and Skinfaks is scheduled to start in 2007. The reservoir description is similar to the Gullfaks Main Field, but the fields contain more gas than oil – often with a significant gas cap. The initial pressure of Gullfaks Sør is 450 bar at datum depth of 3300 m below mean sea level (MSL) and at Rimfaks it is 410 bar at datum 2860 m MSL.

Reservoir Management

The Gullfaks main field is now on decline, and production is reduced by a third from the peak year 1994, when oil production exceeded 30 MSm³. Recoverable oil reserves are currently estimated at 360 MSm³, of which approximately 330 MSm³ have been produced by the end of 2006. The uppermost Brent sequence contains roughly 80% of the reserves, with the deeper Cook and Statfjord formations contributing the remainder.

The Gullfaks satellite production varies from field to field, but as a whole they are still at plateau producing 4 MSm³ of oil and 4 GSm³ of gas per year. Recoverable oil reserves are currently estimated at 50 MSm³, of which approximately 27 MSm³ have been produced by the end of 2006. In addition gas volumes of 17 GSm³ have been produced to date.

The Gullfaks main field has been produced with pressure maintenance, mostly through water injection, but natural water influx has also contributed. Gas injection has been employed in the past to drain attic oil, but also to avoid reducing oil production during periods of restricted gas export. Gas flaring as a production control mechanism was eliminated in 1998. WAG injection is also being employed in parts of the field to improve vertical sweep. Large differences in reservoir quality between adjacent layers have in some parts of the field resulted in water override and inefficient vertical sweep. The dense fault pattern has necessitated close well spacing in some areas, which again; often combined with good internal reservoir quality, has resulted in rapid water and gas breakthrough in producers. A few wells are currently shut in due to high H₂S levels.

The Gullfaks satellites field has been produced with pressure maintenance by gas for Rimfaks and to some extent Gullfaks Sør. Gullveig, Gulltopp and Skinfaks have water influx and are produced with natural depletion while Gimle will have water injection.

Infrastructure and facilities

Gullfaks was discovered in 1978 and the main field put on production in 1986, with sub sea wells producing to the GF-A platform, the first of the three gravity base concrete platforms. Water depth is between 130 and 180 m. The GF-B and GF-C platforms were installed and started production in 1988 and 1990 respectively. GF-A and GF-C have integrated production and drilling, as well as water and gas injection, facilities. GF-B has 1st stage separation only, with further fluid processing on GF-A and GF-C, and is without gas injection facilities. Following a three-stage separation process, the field gas production is exported by sub sea pipeline to shore, where NGLs are removed, while the produced oil is stored offshore and exported by tankers.

In order to further utilize the processing capacity of the Gullfaks installations, third party processing on GF-C of fluids from the nearby Tordis Field commenced in 1994. Later the Vigdis and Visund fields have been hooked up the GF-A for oil storage and export. Production from Gullfaks satellites sub sea development started in 1998. Nevertheless, capacity is still available for the processing increased volumes from the main field. The third party processing contributes to the IOR potential by extending the economic life of the installations, as well as offering a welcome source of injection gas.

Wells

Primary drilling is now practically completed on Gullfaks, and identification is under way of infill drilling targets to secure continued, efficient, oil extraction. On GF-C only a few primary drilling targets remain and three wells are being utilized to develop the Gimle field.

The platforms have in total 136 drilling slots in addition to 35 sub sea wells tied back to GF-A and GF-C. At the main field, 9 producers and 30 injectors, are currently in operation. Many of the wells are "designer wells", with multiple reservoir targets and long high angle and/or horizontal sections (Ref. 3). Several of the reservoir sections require sand control, and to date, 47 wells have been gravel packed. Propped, hydraulic fracturing is also an important tool for effecting reservoir management strategy, with 18 wells fractured to date (Ref. 4). Seven wells have been completed with DIACS (Downhole Instrumentation and Control System) to improve oil recovery.

Gullfaks Improved Oil Recovery (IOR)

An important goal for the Gullfaks license is to increase the recoverable oil reserves to 450 MSm³, through launched technology programme and improved reservoir management. Locating the remaining oil is an important part of this programme. A project was named "Gullfaks Oil Drive" (Ref 5) was launched as early as 1998. In 2006, a Gullfaks IOR project was started as part of the corporate initiative for improved oil recovery. The projects draws upon expertise from across the organization, where different organizational units contribute team members on a continuous basis over periods of months. Petroleum Engineering, G&G, Drilling, Well Technology, Production, Health and Safety and Economics are working together as experts in team.

Time lapse (4D) seismic is considered to be a key element in the process of locating the remaining oil. So far several wells have successfully been drilled based on this technology, and more similar wells will be drilled in the future.

The Norwegian Petroleum Directorate (NPD) has an award for improved oil recovery (IOR) in order to recognizing licenses, companies, projects or individuals that have created additional value on the Norwegian continental shelf through brave actions and plans. In 2005, the Gullfaks licence won this prestigious award and in the justification NPD stated the following:

"Statoil, the operator, and the partners Petoro and Hydro, have through many years been working on ambitious plans to visualize all subsurface volumes inside, and even some outside, the license boundary lines that could lead to economic projects. They have taken bold steps, involving large expenditures, to ensure that they can implement plans within the limited time frame of a main field in decline. That includes drilling advanced wells to exploration targets outside existing fields, and on their way discovering additional reserves in new horizons. They have changed the way sand production is handled to allow further production increases."

The Gullfaks licence expires in 2016, but currently efforts have been started with a goal to extend the life of Gullfaks towards 2030.

References

1. H.M. Ånes, O. Haga, R. Instefjord and K.G. Jakobsen: "The Gullfaks Lower Brent Waterflood Performance" paper presented at The 6th European Symposium on Improved Oil Recovery, 21-23 May 1991 in Stavanger, Norway
2. Fossen H. & Hesthammer J: "Structural Geology of the Gullfaks Field, northern North Sea", In Coward M.P., Daltaban T.S. & Johnson H. (editors) Structural Geology in Reservoir Characterization. Geological Society, London, Special Publications, 127, 231-261.
3. Samsonsen B., Jacobsen B.G., Skagestad T. & Kerr S., Statoil a.s.: "Drilling and Completing a High Angle Well with Coiled Tubing Technology" paper SPE 48941 presented at the 1998 SPE Annual Technical Conference and Exhibition held in New Orleans, Louisiana 27-30 September
4. Bale A., Owren K., and Smith M.B.: "Propped Fracture as a Tool for Sand Control and Reservoir Management" SPE 24992, presented at EUROPEC, Cannes, France 16-18 November 1992.
5. Agustsson H., Stroenen L.K., and Solheim, O.A.: "The Gullfaks Field: "Creating Value by means of a Multidisciplinary Reservoir Management Approach", paper OTC 10739 presented at the 1999 Offshore Technology Conference, Houston, Texas, 3-6 May 1999.

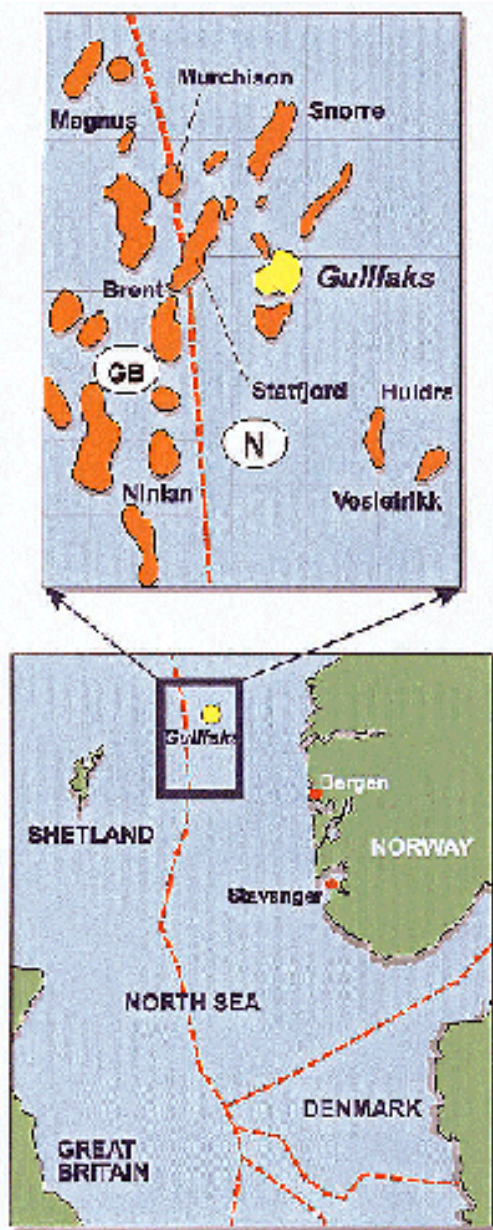


Figure 1 : Geographical location of the Gullfaks Field

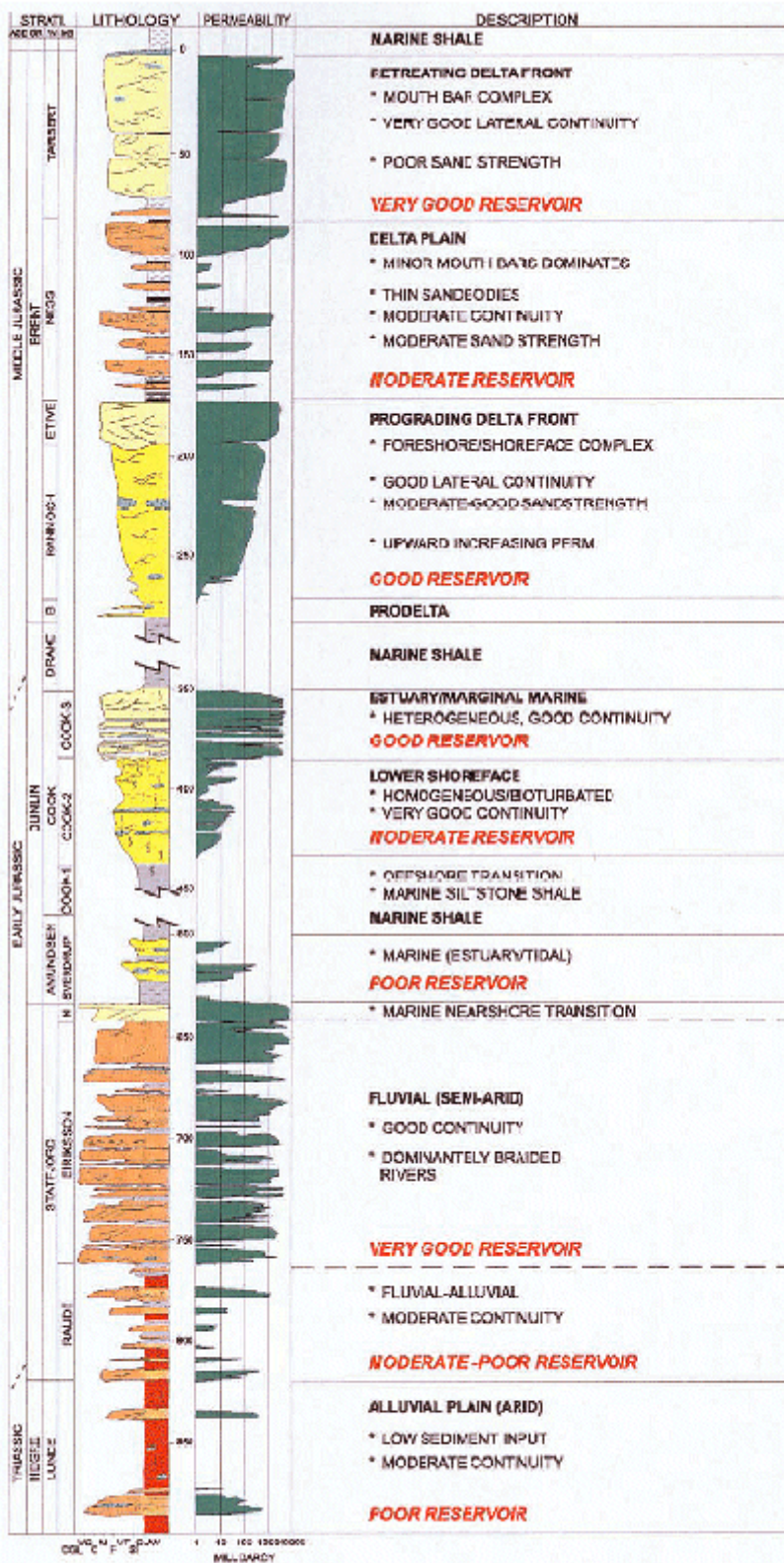


Figure 2 : Composite log display of the Gullfaks reservoirs, showing variation in reservoir quality

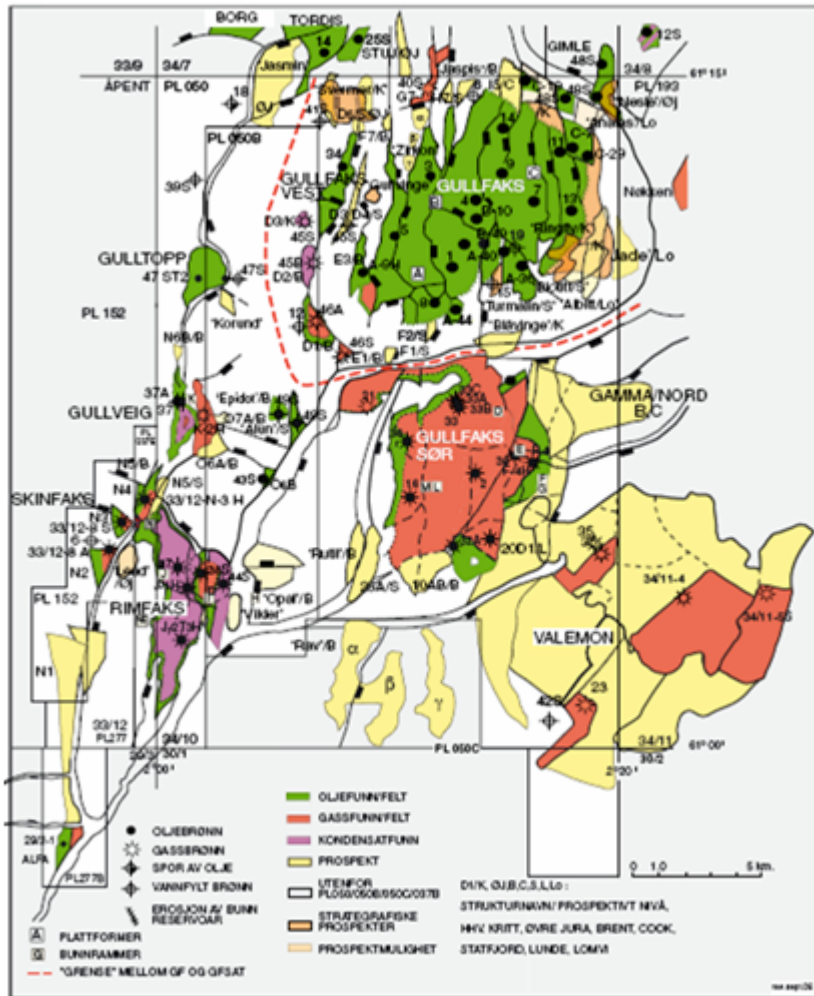


Figure 3 Overview of the fields, discoveries and prospects in the Gullfaks area