4. Modelling results vs 4D seismic response

In July 2014 an ocean bottom cable (OBC) seismic survey (one of many over the years performed on Gullfaks) was shot. One of the objectives of the seismic interpretation was to assess possible changes in the Top Shetland reservoir from the start of production. The OBC seismic survey from 2008 was used as the baseline for the 4D interpretation, to be able to investigate possible changes due to Shetland production.

The expected response from depletion of Shetland, giving a rise in effective pressure increase the grain contact giving increased P-wave and S-wave velocity. Amplitude and time shift changes have been studied for both compressional waves (PP) and converted waves (PS). A hardening effect is seen on the 4D time shift between 2008 and 2014, and the outline is remarkable similar to the results from the A-8 PTA model. A comparison of the reservoir pressure at the time of acquisition of the 2014 survey and the 4D amplitude changes and the time shift between 2008 and 2014 is given in Figure 4.1.

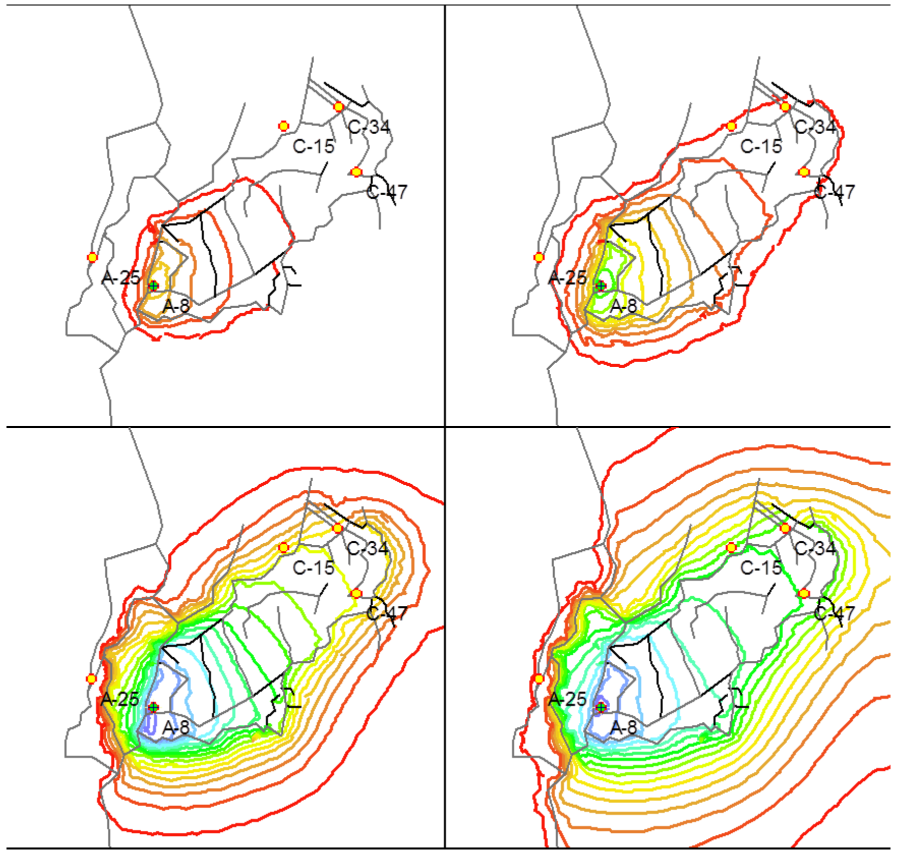

Figure 3.4.2. Reservoir pressure evolution: January 2013 (upper left), March 2013 (upper right), July 2014 (lower left), November 2015 (lower right).

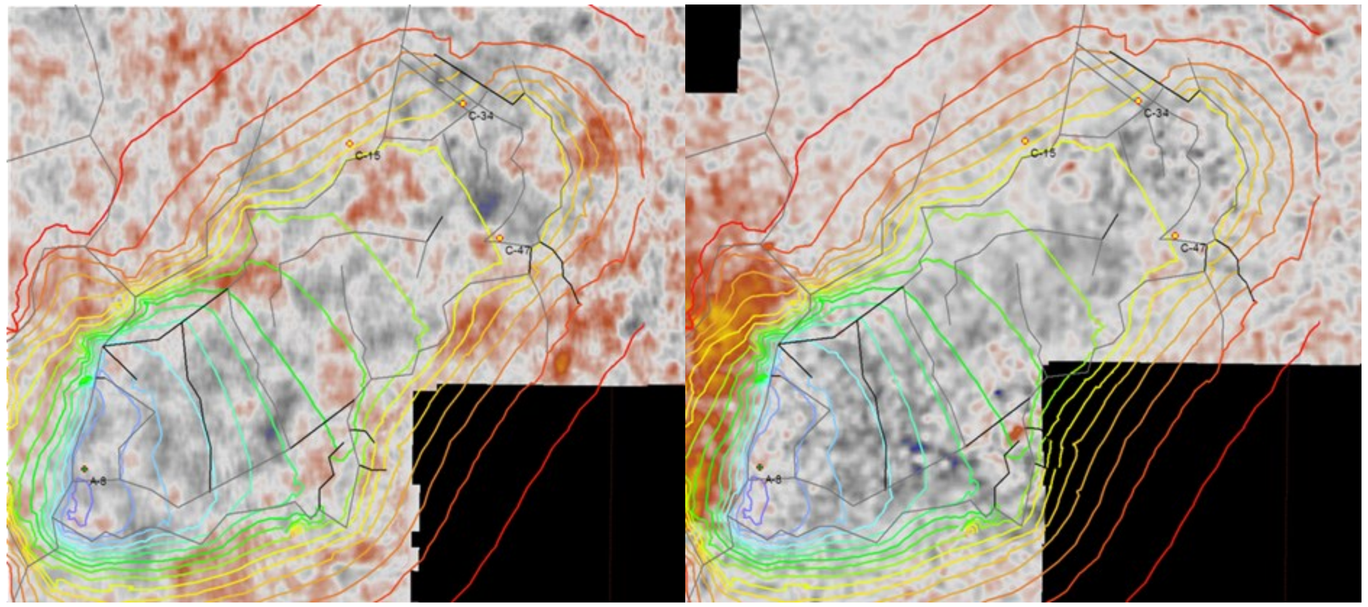

Figure 4.1 4D seismic amplitude difference (left) and time shift (right) at Top Shetland with the pressure map from the reservoir model during the seismic survey in 2014 superimposed. The 4D effect in gray and blue colors is remarkably captured by the A-8 PTA model.

5. Conclusions

The article considers a reservoir model built for a newly discovered carbonate reservoir in the Norwegian sector of the North Sea. The depletion which occurred after 2 years of production is modelled, and the model is history matched. The lateral pressure distribution from the model at the time when the seismic survey was shot is then compared with the 4D seismic interpretation, and the pressure effects interpreted from the seismic response match the pressures predicted by the reservoir model.

Extra-Deep Azimuthal Resistivity for Enhanced Reservoir Navigation in a Complex Reservoir in the Barents Sea

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Goliat is an ENI Norge-operated oil field located in the Arctic Barents Sea, 85 km NW of the city Hammerfest. The Goliat reservoirs have a complex structural setting characterized by a large number of faults and a high structural dip towards the flank of the structure. This challenging combination calls for horizontal production wells for effective drainage.

The Goliat field consists of several proven hydrocarbon reservoir units, but to date only Kobbe producers have been drilled. The Kobbe Formation is of Middle Triassic age and is divided into two main Upper Kobbe represents essentially a prograding deltaic system with mouth bars and lobes. In the Lower Kobbe, the system shifts into a more proximal, heterogeneous fluvial setting where sand bodies have limited lateral continuity.

One particular challenge is that the well design requires the 8½-in. reservoir section to be initiated in the overlaying Snadd shale. To minimize shale exposure in the landing section aggressive build-up rates are employed, decreasing the length needed in shale. However, a steep approach may lead to deeper penetration in upper Kobbe, in unwanted intra-shale drilling. Therefore, the key to successful well placement is the early detection of the reservoir top and the accurate mapping of the reservoir sand architecture remote to the wellbore.

One way to successfully navigate a complex reservoir like Goliat is to use extra-deep azimuthal resistivity (EDAR) can detect stratigraphic boundaries up 30 m from the wellbore in optimal resistivity environments (Hartmann et al., 2014). The development of advanced multi-component inversion modelling techniques (Sviridov et al., 2014) enhances the interpretations of resistivity data and can accurately provide real-time information regarding reservoir geometry.

EDAR service provided the capability to detect the top of the reservoir at about 20 m true vertical depth (TVD) and nearly 100 m MD before entering the reservoir, enhancing accurate wellbore landing. Extra-deep measurements also helped the uncertainty in fault detection, where related throw can be estimated based on the displacement of boundaries.

The use of a measurement with increased depth of detection (DOD), combined with advanced multi-component techniques and real-time 3D visualization of data and reservoir model were vital to ensure the successful placement of the well. Real-time mapping of the reservoir geometry was key to optimize reservoir exposure.

The outcrop of the Norwegian Continental Shelf. The star indicates the location of Goliat field. Source: NPD