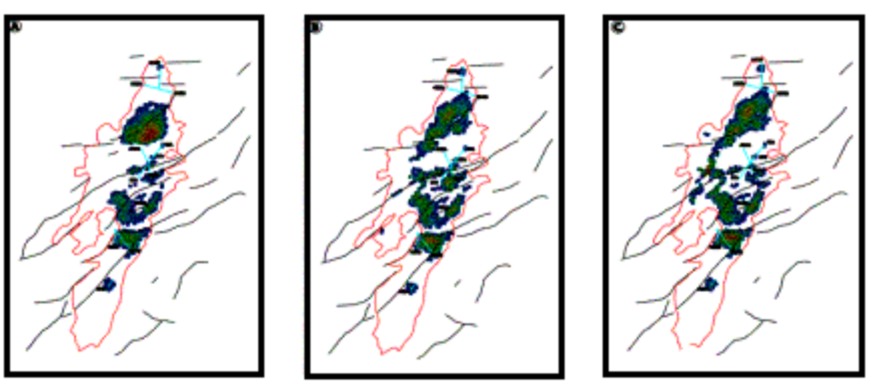
4D Case Study over Draugen Field

Geotrace. Geotrace, with processing centres in Houston, Dallas, Midland, London, Stavanger and Luanda, is one of the leading providers of 3D time lapse (4D) processing services. The Draugen Field in Norway was the location for one of the most successful 4D projects ever performed. On behalf of Shell and their partners, Geotrace processed a 1990 base survey and a 1998 monitor survey to obtain the information required.

The Draugen Field. In water depths of 250 metres, the Draugen Field lies approximately 1600 metres below the sea-bottom. The field is a north-south elongate, low-relief anticline, some 21 kilometres long and 6 kilometres wide with a maximum vertical closure of about 50 metres. The main reservoir is an excellent sand (porosity 27%, Net/Gross 97% and permeability 4 Darcy). Production started in 1993 and the current average production is 225,000 b/d. According to Shell, the operator for the field, the reservoir management strategy is to displace the oil with water from the north and south to the centrally located producers. Seawater is injected in sufficient volumes to maintain average reservoir pressure around the initial pressure of 2,400 psi. Draugen contains under-saturated oil, and free gas is not expected to form in the reservoir.

Models. Shell has stated, in their article published in the March 2000 issue of The Leading Edge entitled 'Time lapse seismic surveys in the North Sea and their business impact', that they had some uncertainties regarding the reservoir, prior to the 4D survey. The reservoir is separated from a large aquifer by impermeable shale over part of the field. The lateral extent of this shale was not accurately known. It was thought that the reservoir and aquifer may also have been in communication through sand-to-sand juxtaposition across small throw faults that intersected the sequence at several places. On top of this, the faults formed flow barriers in the reservoir. Prior to the time lapse project, several models were built by Shell using different communication paths between the aquifer and the reservoir (Figure 1).



Key:

Field Boundary

Fault

Well

Colour amplitudes: Change in water saturation*reservoir thickness*porosity

?????? Figure 1.?? Seismic effect on the reservoir simulations before 4D survey

These models could all be matched to the production data. However, these models had significantly different forecast production profiles for the field. Therefore, knowledge of the true communication path would allow optimisation of the production strategy. It was concluded by Shell, for a number of reasons, that seismic monitoring was the only viable option to reduce uncertainty in the future production profile.

Decisions. In 1999, a new high-capacity well was to be drilled, decisions on the development of the southern and western ends of the field were to be taken, and a decision on additional water-handling equipment on the platform was also planned. All these decisions obviously depended on the forecast production profile for the field. Hence, they could be impacted by the time lapse seismic. Therefore, the decision was made in 1998 to go ahead with the 4D project and to acquire a monitor survey.

Seismic Acquisition. In the summer of 1998, a streamer survey compatible with the pre-production 1990 base survey was acquired. Both were conventional marine streamer surveys. Although airgun size, number of streamers, streamer spacing, receiver group interval, and shot interval were all slightly different, the azimuth and offset ranges were compatible. The slight differences were caused mainly by unavailability of equipment and a desire to increase fold.

Seismic Processing. The time lapse processing objectives were to ensure that the data differences between the two surveys were due to fluid movements. To achieve that, Geotrace had to ensure the locations of the two surveys agreed by registration analysis, that traces with same source and receiver locations had the same signal and that irregularly acquired data was standardised. Regular and random variations in the two acquisition geometries resulted in different and irregular subsurface illumination and this was addressed by use of a new proprietary technique, Contribution Scaling. Various other techniques were used to match timing, amplitudes, frequencies and phase. Figures 2-4 illustrate the seismic data quality of the base, monitor, and difference volumes for a line through one of the southern water injectors. They clearly show how well the two seismic cubes were matched. The reflection of the top of the brine-filled reservoir sand is a hard reflection (red) that dims significantly when the reservoir is filled with oil. Note the hardening of the top reservoir event and the disappearing of the flat spot on the monitor section. Before time lapse, all reservoir models had assumed that water movement would occur along both flanks of the field. It was clear from the time lapse results that the risk of water encroachment is significantly higher along the western flank of the field than along the eastern flank.

New Models. According to Shell, uncertainty in the forecast production profile was significantly reduced. This reduction in uncertainty was a result of the improved quality of the reservoir characterisation that came about through the use of time lapse seismic data to refine simulator runs and could be used to better predict future performance as well as to optimise further development of the field. The updated reservoir model (Figure 5) was used to predict the performance of a new horizontal well at several alternative locations.

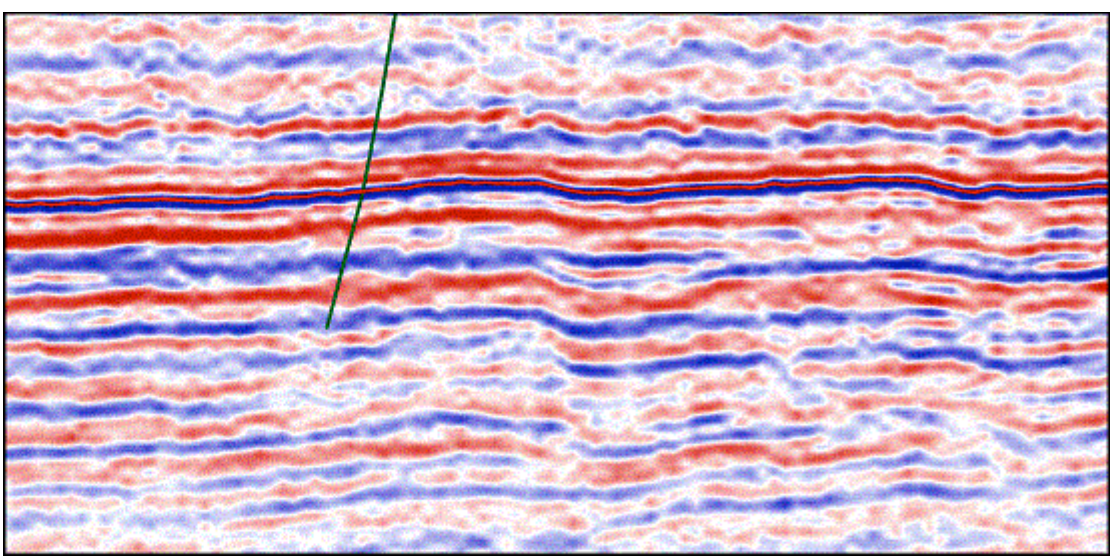


Figure 2.? Base survey inline across southern water injection.? (Courtesy of Shell Exploration and Production)

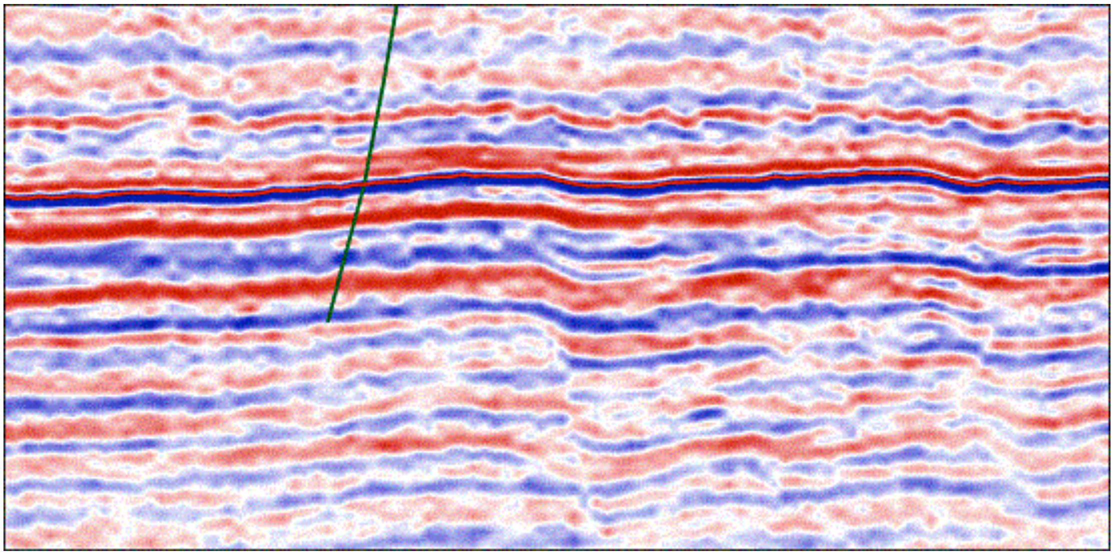


Figure 3.? Monitor survey inline across southern water injection (Courtesy Shell Exploration and Production)

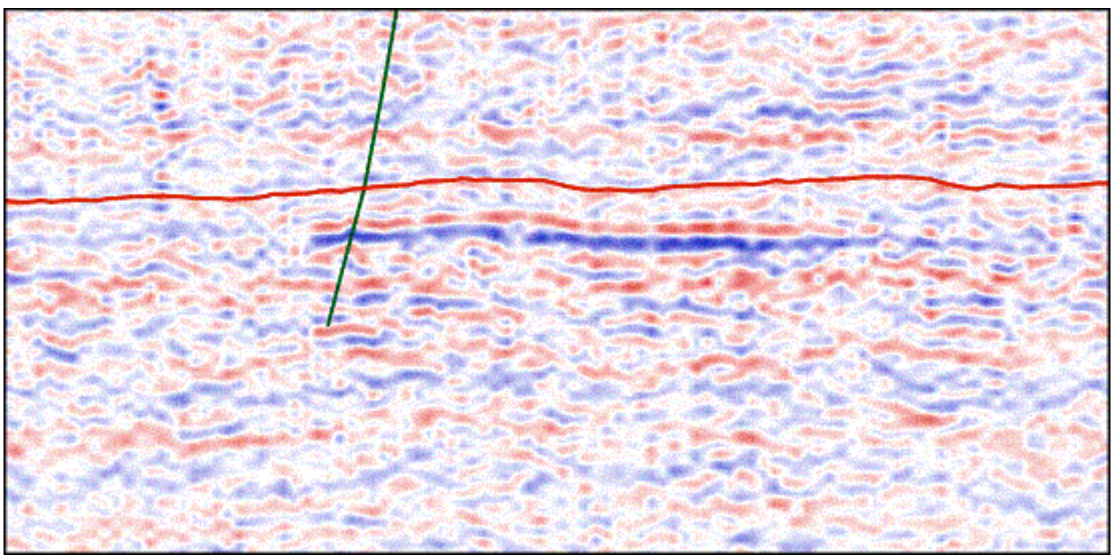


Figure 4. ?Difference volume inline across southern water injection (Courtesy of Shell Exploration and Production)

The optimal location was north of the platform, far away from the originally planned location west of the platform. Locating this well properly was especially important because it was intended to replace production from wells which will cut water in the future. The well was drilled in 1999 and tested at a record 76,775 b/d.

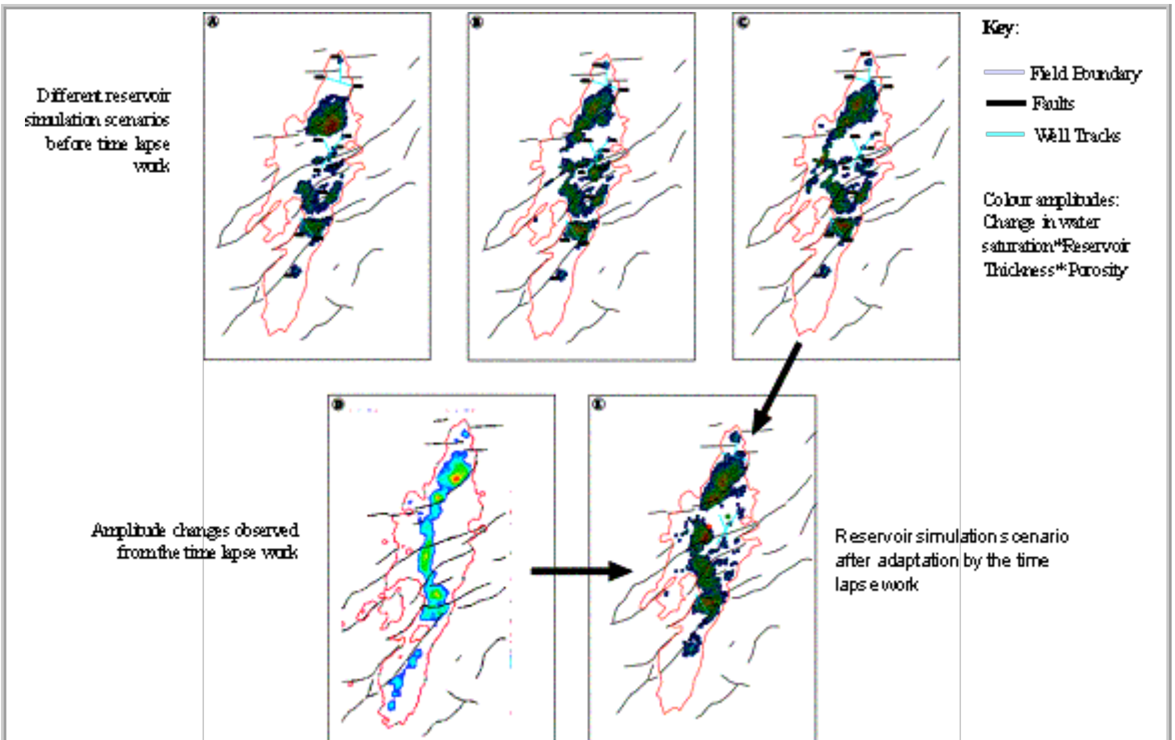


Figure 5.? Seismic effect on reservoir simulations after 4D

Value. According to Shell, the new reservoir models forecast an extension in plateau production of almost one year using this new well location. At the time, estimated net value of the project from accelerated production alone (using $15/b and a 10% discount rate) was some $84 million (pre-tax). Costs of the time lapse project were approximately $4 million. Further gains to be made by optimising the field development plan include:

1) Development of the western field extension will now be phased.

2) Uncertainty in the volumes of the southern field extension is reduced.

3) Reduced uncertainty in the production profile has also impacted the decision on the installation of water-handling equipment.

Future. A second time lapse monitor survey is planned for 2001, just in time to impact infill well locations. If the northern fault remains a barrier to fluid flow, then this will have a significant impact on this future infill drilling campaign.

Shell's Conclusions. In general, Shell concluded that careful planning and processing can result in excellent repeatability of streamer data. In the specific case of the work done by Geotrace on the Draugen Field, Shell concluded that a very clear time lapse signal could be observed on the difference data set; that time lapse yielded information on the location of the waterfronts; that seismic history matching of the dynamic reservoir model reduced uncertainties in the forecast for the production profile; that time lapse results impacted the location of a new production well within 6 months of the completion of the acquisition.

Geotrace's Conclusions. With 4D technology, the industry can find and extract more hydrocarbons with fewer, better placed wells.? Of course, having the technology is not quite enough - Geotrace's expertise in applying the techniques can and does make the real difference.