Ex. PGS 1079

Summary

In mid 1999, BP acquired a 3-D survey over the West of Shetland area specifically for time interpretation of the reservoir dynamic behavior over the component fields. This was described EAGE meeting last year[i]. This formed a turning point in BP's use of 4-D from experimentati commercial use. The results were very useful in field management and well planning. Before that, acquired a number of repeat 3-D seismic surveys which in addition to their prime objective, were fou be useful for time lapse interpretation. Since then, BP has in 2000 acquired a further five '4-D' dat covering nine producing fields. These have all been undertaken with the express purpose of obta data that will allow a tighter control of reservoir management, and thereby enhance commercial valu

In all cases a major objective has been to influence infill well locations. Specific problems differ field to field. In the West of Shetland area, the 4-D is a powerful tool in assessing hyd communication. Forties is using it to identify unswept oil and to improve reservoir characterisati proposed EOR. In Montrose, the data will help determine remaining options for field develop Accurate determination of the movement of the gas-oil contact is important in Harding, and in Ma the data will be used to improve the reservoir description.

Context

The increase in the use of 4-D seismic within BP has reflected that in the industry (Figure xx). Alt the 1999 West of Shetland survey was the first acquired by BP for 'commercial' rather than experin purposes, repeat survey data collected for other reasons had been used for time lapse interpretat Magnus, Gulfaks and Forties.

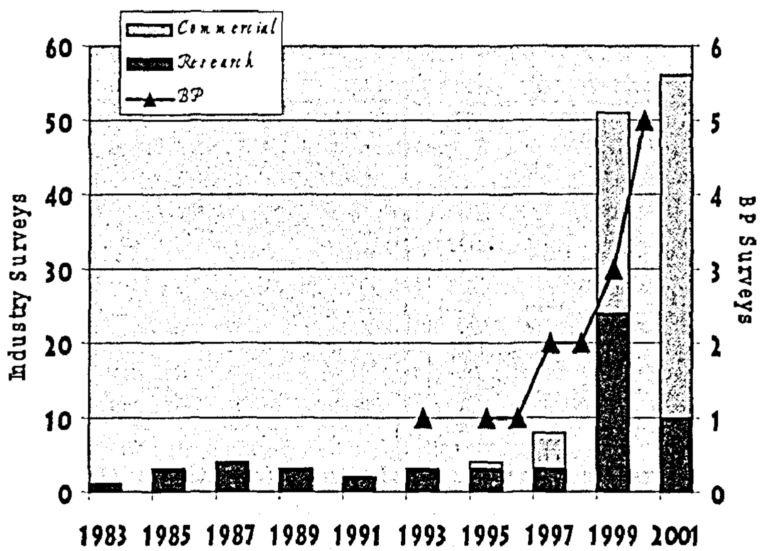

Figure 1: Growth in Use of 4-D in the North Sea.
(Industry data supplied by JNOC)

Prior to conducting a survey, a num important questions must be answe

- Are the rock and fluid properties suitable?
- Is the seismic data quality adequate?
- How will the reservoir characteristics affect interpretation?
- Has there been sufficient disturbance of the initial conditions as a result of production?
- Will the seismic answer th reservoir management questions in a useful times
- What will its value be, and risks involved?

Ex. PGS 10

Loyal Schiehallion		BP*, Shell BP*, Shell, Murphy, Statoil, Amerada Hess, OMV	strategy and drilling opportunities.

* Operator

Case Studies

Forties

Forties infill drilling commenced in 1992. By 1995 it was apparent that the process of identifying i targets from simulation models would fail to deliver economic targets beyond 1997 due to a lac resolution in these models. A second 3D survey was shot in 1996 to complement the first Forties volume acquired in 1988, thirteen years after the start of production. Since 1997 Forties infill targe has relied on images of lithology, fluid, and fluid saturation change derived from these seismic volu This has allowed those areas of the field with significant pools of remaining oil us to be identified.

The application of this technology has allowed well targets to be ranked, and as a consequence, there been a progressive improvement in the average size of target accessed and initial well rate achieved. anticipated that the 2000 data will provide an up to date fluid image and improved reser characterisation. Together with continuous improvements in processing technology this will enable i drilling to be sustained until at least 2002, and will support planning of the potential EOR project.

Foinaven

Preliminary examination of the results of the 2000 4D seismic data over Foinaven has shown no m surprises. It has strengthened confidence in reservoir management strategy, and emphasized importance of water injection.

In common with Schiehallion and Loyal, amplitude brightening is indicative of increasing gas satura or oil pressure (with no change in phase); dimming is indicative of increasing water saturation or redu gas saturation. In the example shown, the overwhelming observation is a brightening between 1993 1999 and a dimming between 1999 and 2000. Although subtle details remain to be worked, this supp the interpretation that the water injection campaign has been effective in raising reservoir pressure. is demonstrated by the drop in production GOR of most of the Lower T34 wells. Other sands in the demonstrate the same phenomenon, but the uppermost sand, which was first produced after the survey had been acquired, shows a significant brightening, attributable to pressure reduction b bubble point and gas evolution. This is similar to the brightening seen in the underlying sands evide 1999. The reduction of gas production is significant in reservoir management, as reservoir energ conserved, and production is at less risk of restriction by facility constraints.

Ex. PGS 10

The 2000 4-D largely confirmed the understanding of the field that had developed during 2000. understanding and the increasing trust in the simulation model is rooted in the history matching of production data, and well results together with the 199 interpretation. Strong quali correlations between the amplitude data and sim pressure plots indicate th increased level of confiden the two independent 'measur reservoir pressure is justified

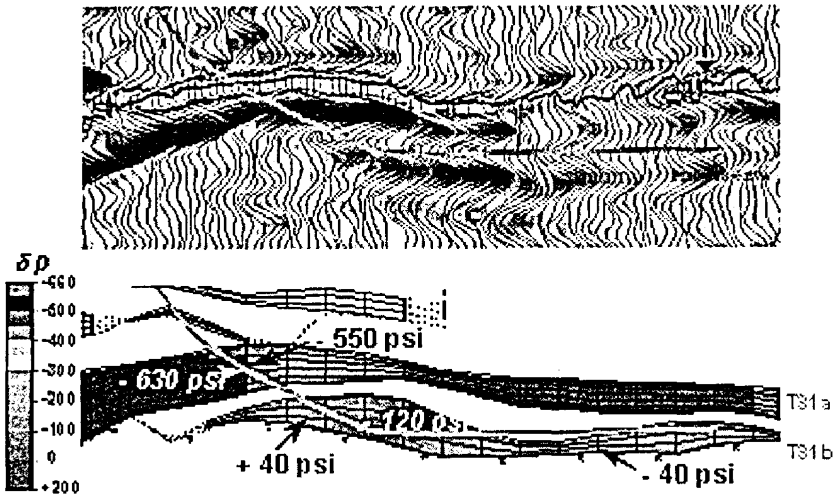

Figure 3: Schiehallion Example.

Initial processing of the 2000 was carried out on board in a under three weeks, so that da would be available for planni the 3Q/4Q drilling program Comprising two wells, this w designed to drain a significan unswept pool in the centre of field in a deeper sand, which from the 1999 appeared to be largely unaffected by existing wells. Thi the lower sand shown in ().

The simulator predicted that the sand would show slight depletion in the east, with weak support fro west. When drilled the sand section was depleted by about 120 psi. The overlying sand, already acc by a nearby producer has strong indications of seismic brightening, interpreted to be due to evolved a result of production. The simulator predicted depletion of around 550 psi, MDT measurement sh this to be around 630 psi. The pressure predictions were good, partly as a result of using the 4-D d matching the simulator. A downdip injector has since been drilled to support both sands in prefere an additional producer, which was the original plan. This decision was made as a direct result of th information.

Loyal

The Loyal field is located in the West of Shetland area adjacent to Foinaven and Schiehallion. currently being developed as part of the Schiehallion project. Oil production started in 1998 and to four out of the six planned development wells have been drilled. Since start-up, two 3-D seismic su have been acquired over the field with the aims of optimizing the remaining wells and impr production forecasts. The time-lapse seismic data shows a strong response to pressure reduction a producing wells. This is because the bubble point pressure of the oil is close to intial reservoir pre As a result, gas evolves and its presence increases seismic reflectivity. In the longer term, seismic i of water movement are likely to have a bigger impact on reservoir management. This places demands on seismic quality, attribute analysis and interpretation. However, having multiple

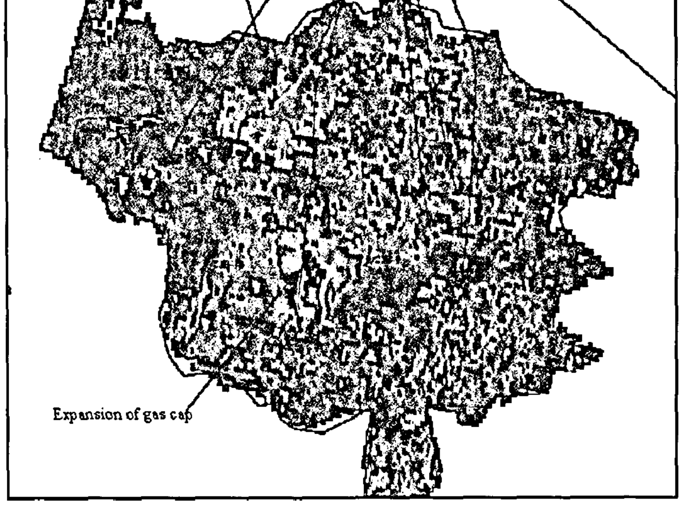

Figure 4: South Harding Top Reservoir amplitude Difference 1990 - 2000

In response to production and water inject models predict that the GOC has tilted. could be as much as 80ft down in the East 50ft up in the West. Multilateral infill wells planned to target the attic oil between existing wells and the GOC. As these wil drilled closer to the GOC than the earlier w the changes in the location of the GOC nee be mapped over the whole field. To this e repeat of the pre-production 3D seismic su was carried out in September 2000 an currently being processed in parallel with pre-production survey acquired in 1990. A track dataset has been produced, and re from this have qualitatively confirmed both gas movements predicted by the reser model and also the movement of injected wa

'MonArb'

The Montrose and Arbroath fields together with subsea tieback Arkwright are located south of Forties in an equivalent age Paleocene reservoir. The significant rock properties and predicted 4D respons expected to be comparable across these three fields and similar to the pre-existing Forties sei reservoir survey. This survey successfully reduced the risk on new well targets.

Field production commenced on Montrose in 1976 and on Arbroath in 1990, whilst the Arkwright was tied in during 1996. Development drilling is currently taking place on Arbroath.

The baseline 'Monarb' 3D survey was acquired in1993 and the 475 km^2 4D survey was acquired duri the summer of 2000 Time lapse processing of both surveys is currently underway and data delivery is expected in March 2001. Interpretation will focus on understanding sweep and identifying the remain infill and short range sidetrack options.

Marnock

The Marnock field is part of a development which consists of seven oil and gas fields. It is a condensate field with approximately 1TCF gas and 110MMstb condensate in place in a comb stratigraphic/ structural trap. Triassic fluvial sandstones form the reservoir and have porosities of 21% and permeabilities of 0.1 – 2000mD. Initial reservoir pressure was close to 9000 psi.

Rock property modelling on Marnock shows that observed pressure changes in wells, from 9000 – psi, results in large acoustic impedance (AI) changes, which could be detectable using 4D methods. saturation changes give rise to small AI changes and may not be observable.

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