Feasibility of Maui C sands 4D seismic

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Abstract

In January 2001, Shell Todd Oil Services acquired a limited time-lapse seismic test data set over the Maui gas field, repeating four tracks of the earlier 1991 3D survey. The results of these test data showed a clear movement of the GWC and identified water over-ride, thereby proving the feasibility of full-field 4D to monitor gas displacement in the Maui C sands.

Introduction

4D seismic, or time-lapse seismic, are different names for the same technique. In essence it is simple. Take the difference between two seismic data volumes, the second acquired some time later after production has caused appreciable fluid movement or pressure change. The difference data will only show a significant signal where, due to production, fluids have moved or pressures have changed.

The value of 4D lies in its ability to map the produced reservoir volumes, and 'see' where wells cannot. This quality has an immediate advantage: remedial wells can be better placed for draining the remaining hydrocarbons, while the risk of dry or un-productive wells is reduced. Even better is to use 4D early in field development to develop an early understanding of reservoir behaviour. Then less remedial action will be required, costs will be less, and production can be optimised for each stage of field life.

In recent years, 4D has become one of the main new technologies of the major international oil companies. For Shell, 4D is one of its four strategic projects, with centrally supported global implementation. Already many successes have been recorded. The benefit-cost ratio of 4D within Shell has been substantial proving an enormous business value. In New Zealand, the Maui Joint Venture partners have over the last year initiated feasibility studies and preparations for a full field 4D for the Maui field are underway.

Maui gas field

The Maui Field is the largest producing field in New Zealand providing over 80% of the county's natural gas, i.e. an equivalent 50% of total New Zealand energy requirements. The field was discovered in 1969, production began in 1979, and the field has been producing since at high rates. In 2000, questions were building up with respect to optimising remaining production in this maturing large gas field. For example, the upper, completed, part of well MB-09 unexpectedly started producing water, despite remaining gas reserves at a lower level. Also, history matching results suggested potential complications in the static/dynamic model. The view therefore emerged that time lapse seismic could be a consideration for the Maui C sands.

Feasibility of 4D for Maui gas field

Until recently, the prevailing belief in STOS was that the declining Maui field did not warrant further 3D acquisition. This was partly justified by the limited quality of the 1991 3D data. However, the high quality of the 1999 reprocessing of the 1991 data started to change this perception. The reprocessed data clearly showed the gas-water contact and thereby the extent of the initial gas column in the field (Figure 1). This does however not automatically mean that 4D is feasible. The difference in seismic response to original and residual gas saturated rock is typically very small. Our quick feasibility studies concluded that any 4D seismic differences would indeed likely to be quite subtle, but that changes should be detectable:

- a small, but not insignificant acoustic impedance change was to be expected as a 4D response, see Figure 2. However, this impedance increase ?ln(AI) was uncertain and could vary between 0.02 and 0.05, dependent on the remaining gas concentration.
- analysis of the seismic data quality showed that the larger 4D effects would be detectable in the presence of non-repeatable "noise", see Figure 2.
- synthetic difference seismic data, generated from dynamic models, showed field-wide images of water encroachment.

However, given the critical uncertainties with regard to acoustic modelling and seismic repeatability, the justification for a full 3D monitor survey would be difficult.

3D test data for time-lapse purposes

In January 2001, Shell Todd Oil Services acquired a limited timelapse seismic test data set over the Maui gas field, repeating four tracks of the earlier 1991 3D survey.

The test data and the corresponding 1991 data were 4D-processed in parallel by the Shell processing Centre in Rijswijk, The Netherlands. Processing was carefully controlled to minimise differences between the two data sets while preserving the 4D signal. Post-stack matching and time alignment were performed by the 4D implementation team in Shell Research.

Results of the test data

Figure 3 shows the 4D difference results together with synthetics generated from two MoReS (Shell proprietary dynamic reservoir modelling software) models of the Maui-B C sands. The latter model was conceived after the water over-ride was noticed in well MB-09, the first model was made prior to this occasion. The water over-ride zone is clear in the synthetic of the recent model, as well as on the actual 4D difference seismic. This is the clearest possible demonstration of the potential added value of 4D for Maui.

In addition to identifying by-passed gas, a full 4D should be able to validate one or more of the dynamic model scenarios or suggest updates to a realisation, thereby allowing improved reservoir management, optimised ultimate recovery and a reduction in reserves uncertainty. The results also indicate possible remaining gas in the northern part of the swaths. Interestingly, the present GWC cannot be seen on the monitor data alone, whereas the 4D difference data clearly show the vertical movement of the GWC.

Conclusions and way forward

- The time-lapse seismic test data have increased confidence in the reservoir model as well as demonstrated the feasibility of time lapse seismic for the Maui gas reservoir.

- The case for a full repeat of the 1991 3D data to monitor gas movement has greatly been strengthened.

- After a brief VOI exercise showing the business case, Joint Venture partners recently approved the full field 4D. Planning of this full field 4D is underway and acquisition is expected to start in March 2002.

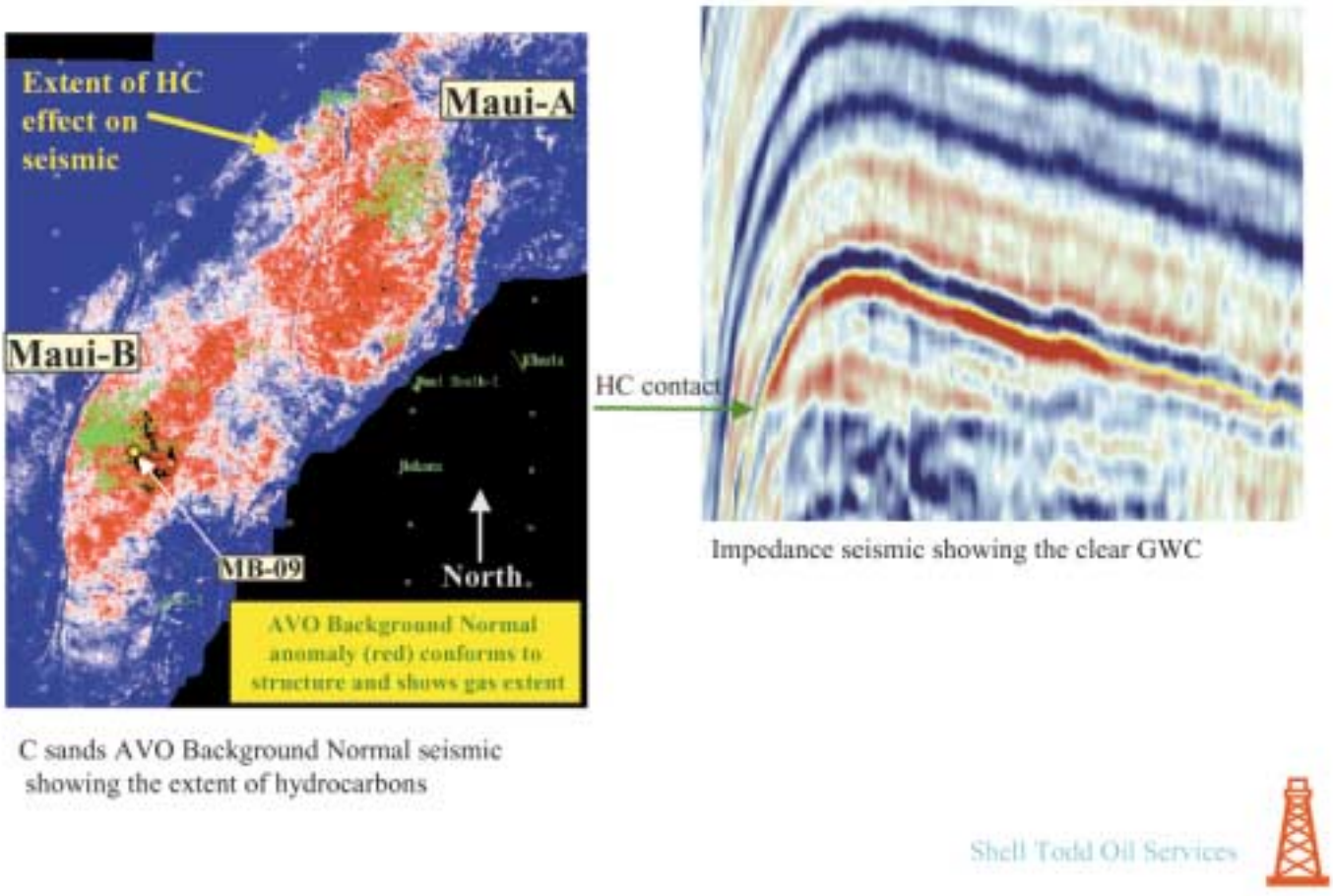

Figure 1: Maui C sands HC effect.

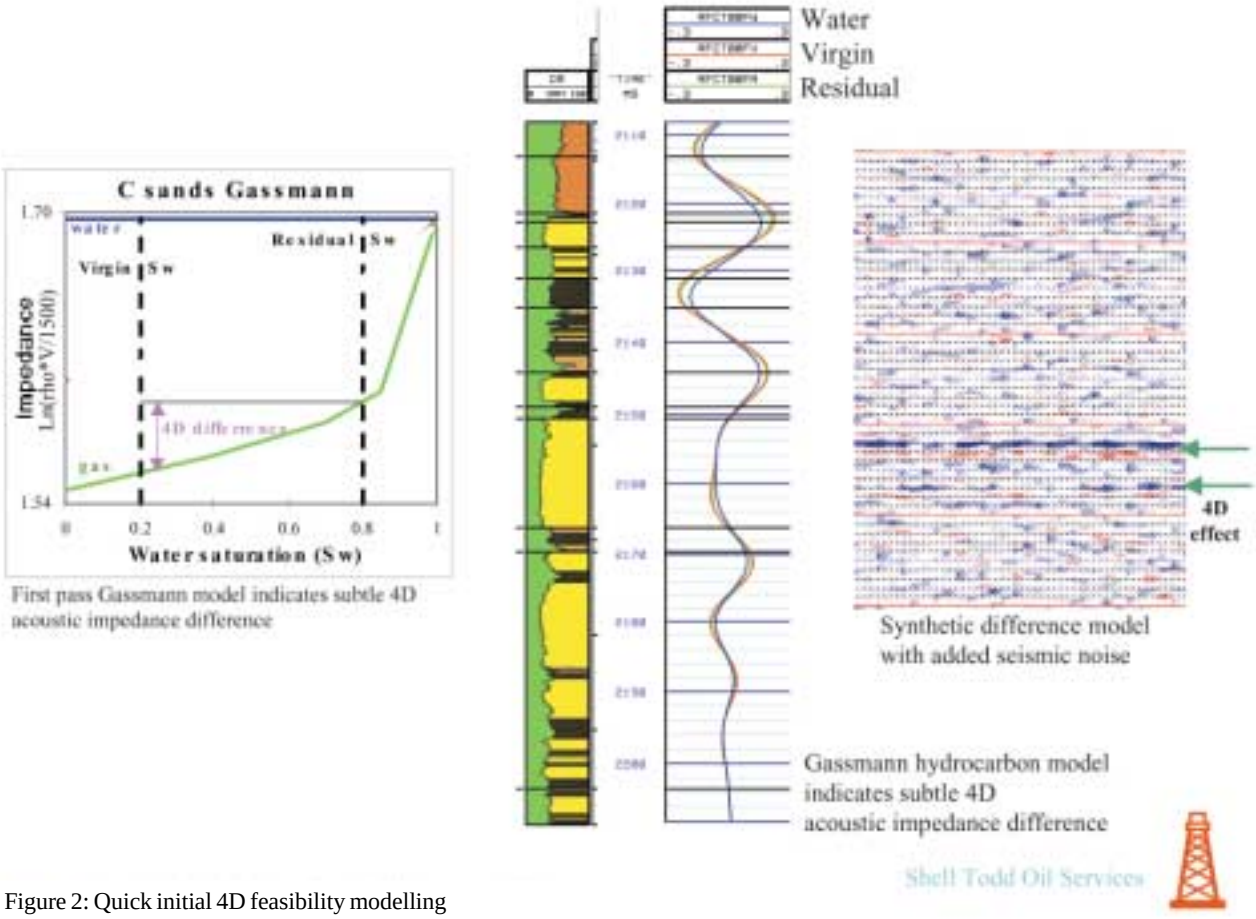

Figure 2: Quick initial 4D feasibility modelling

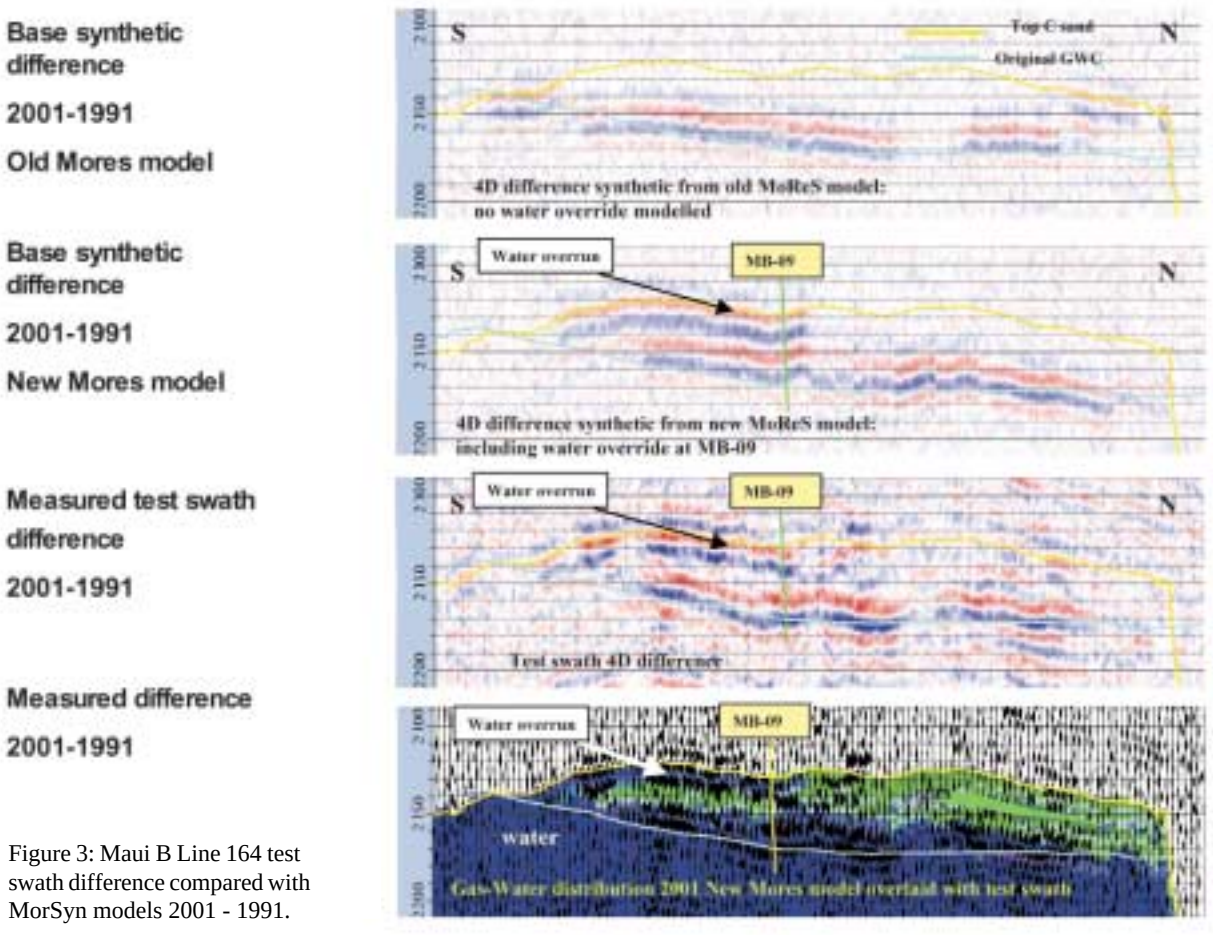

Figure 3: Maui B Line 164 test swath difference compared with MorSyn models 2001 - 1991.

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