4D Illumination and Elastic Modelling

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Abstract
It is well known that ray trace modelling studies can be used to assist in designing optimal acquisition parameters.

Here we demonstrate the application of ray-based modelling tools to a North Sea 4D data volume to assess where in the previously acquired existing 4D data we may have problems as a result of the given acquisition.

In addition, we employ elastic modelling to assess the expected magnitude of the 4D effect.

By processing the synthetic data generated by elastic modelling of the reservoir response both before and after production, we are able to compute synthetic difference sections representative of the expected changes in the reservoir due to production.

These synthetic difference data are compared to the observed real difference data.

Introduction
3D ray trace modeling studies are often used to assess the ability of a given acquisition design to illuminate a subsurface target. In addition, using the same technique, we can assess the impact of perturbations in the overburden velocity model on the lateral position of features (such as a fault).

In the context of 4D processing, it is important to be aware of the differences in illumination that arise from differences in acquisition layout, so as to avoid misinterpreting acquisition differences as fluid change response differences.

In this work, we contrast illumination studies performed on two vintages of data shot orthogonally (1984 and 1999) that constitute the members of a 4D study.

After commenting on the impact of acquisition differences on illumination, we move-on to consider elastic modeling of the reservoir using parameters representative of the baseline and monitor states. Synthetic finite offset CMP seismic data are created for the baseline and monitor models, and these two data sets are processed through to pre-stack migration so as to provide difference attributes which are then compared to the results obtained from the real data.

Some interesting discrepancies are evident, which are perhaps related to azimuthal anisotropy in the overburden.

Norwegian North Sea Example
The example shown is from the Ula North Sea oil field, in the Vestland Arch in the Norwegian-Danish basin. The data processing included DMO and pre-stack time migration (preSTM), and both AVO and simple amplitude attributes were computed. The main reservoir interval lies just below the Top Ula event, so we would expect to see 4D fluid movement changes here. Conversely, the BCU sits above the reservoir, so should be free of true production effects. We use these two markers in our assessments, so all the maps shown are keyed to these horizons.

Initial studies of the illumination for the two surveys (which were shot orthogonally) indicated that no large differences in illumination exist other than near the major crestal fault on the anticlinal structure. The two illumination maps shown below in figures 1 & 2 (for the Top Ula horizon) are very similar. However, these maps indicate surface impact points after re-binning onto the migration output grid, and this re-binning of the ray-trace hit points may have smeared subtle differences. This detail is under further investigation. Shown in figure 3 is a perspective view of the difference map on the Top Ula horizon.

In figures 4 & 5 we see the baseline and repeat models for a crestal crossline through the well. These initial models are not particularly representative of the actual reservoir state, but were meant to demonstrate the effect of creating a gas cap through gas injection. In figures 6 & 7 we see the migration results from synthetic data computed from these models. Figure 8 shows the amplitude differences between the 1984 and 1999 stacks for these synthetic migrated data.

The reservoir properties for the supposition of a gas injection induced gas cap can be summarized as follows:

Model 1: injection induced gas cap	
Baseline Reservoir Properties	**Repeat Reservoir Properties**
OWC Western Flank 3508m OWC Eastern Flank 3788m	5 meter thickness 100% gas cap 80% oil 20% gas to 3500m 40% oil, 60% brine to 3788m on eastern flank

Model 2: current model	
Baseline Reservoir Properties	**Repeat Reservoir Properties**
OWC Western Flank 3508m	40% oil 60% gas to 3500m, both flanks

OWC Eastern Flank 3788m	20% gas, 80% (oil+water mix) to 3647m on eastern flank

Conclusions

Modeling both the illumination patterns arising from differing acquisition layouts, and the differences in elastic response to reservoir change can yield insight into the significance and reliability of 4D attributes.

In this North Sea case study, we contrast the real 4D data with synthetically modeled data, and comment on the restrictions inherent in these data.

Significant differences visible on the BCU maps for the real data (above the reservoir) indicate that we have non-production related changes. As the data were acquired orthogonally, these changes could perhaps be related to azimuthal velocity variations in the overburden.

Acknowledgements

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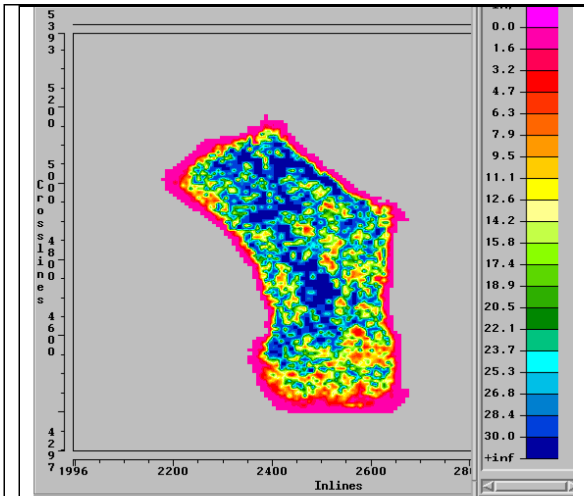

Fig.1:1984 Full Offset bin count on Ula

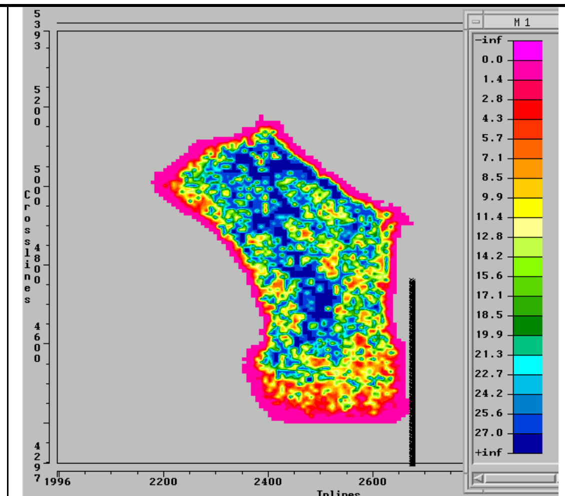

Fig.2:1999 Full Offset bin count on Ula

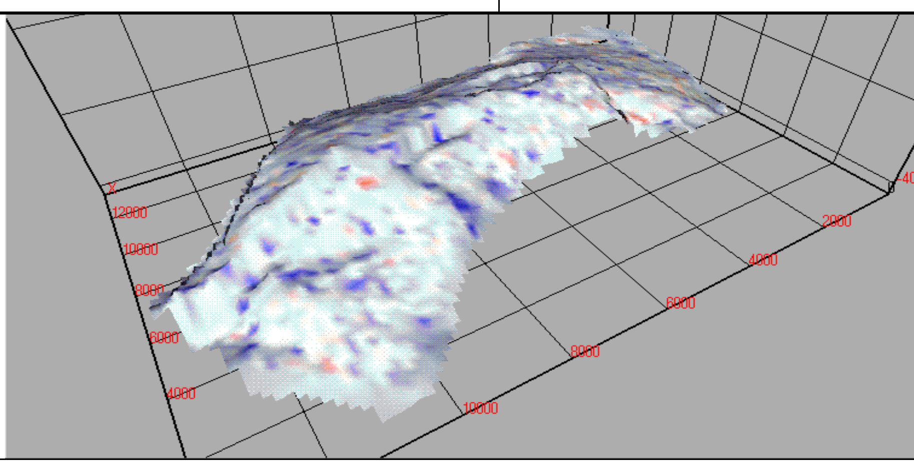

Fig.3: Illumination difference on the Ula

Results for Model 1: the hypothetical gas injection scenario

Fig.4: GXII Baseline Velocity Model.

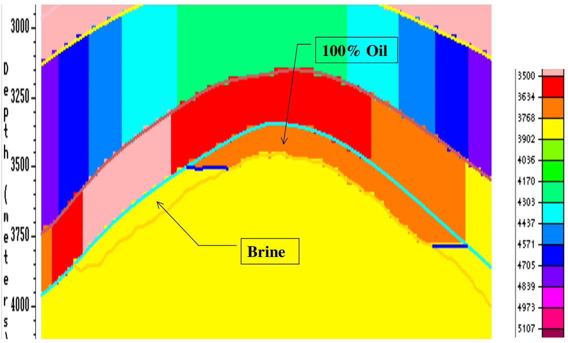

Fig.5: GXII Repeat Velocity Model.

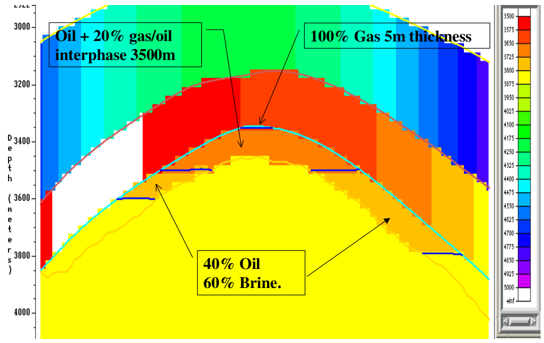

Fig.6: Baseline migration Result.

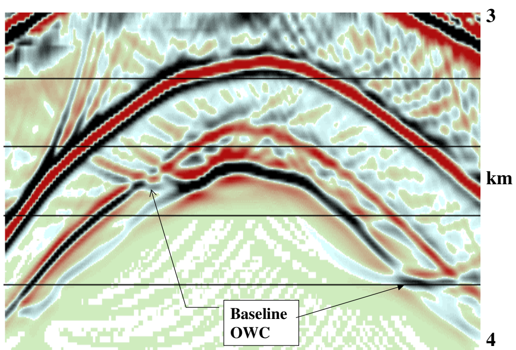

Fig.7: Repeat migration Result.

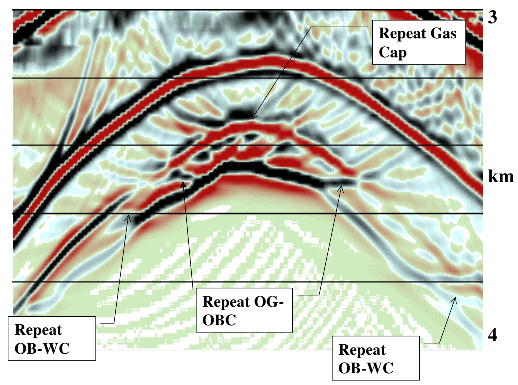

Fig.8: (Baseline - Repeat) amplitude difference elastic modelling difference results