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Surface Multiple Attenuation Developments in the Clair Field

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SUMMARY

Multiples are a key problem over the Clair area, mainly caused by the complexity in the overburden. The paper describes a much improved combination of demultiples techniques, which have been applied to the latest Clair South West HDOBC survey. The sequence consists a top-down approach removing successive multiples with PZ summation, Wavefield Extrapolation Multiples Modeling, GSMP and TauPQ deconvolution.

Water bottom WEMM plays a key role, effectively predicting water layer multiples in a 3D sense. GSMP complements the results of the other techniques against short period multiples, but more importantly it also predicts other long period surface multiples which are cutting through at reservoir level.

The results are a much improved level of multiples suppression, although some surface multiples contamination is still present, and internal multiples have not been attenuated.
Introduction

The Clair field is located in the UKCS, 75km West of Shetland, and represents one of the largest hydrocarbon accumulations in the North Sea. Multiples are a key problem that affects all the seismic acquisitions in this area, mainly caused by the complexity in the overburden (Figure 1). The high reflectivity seabed creates strong water layer reverberations. A fast velocity layer is present at surface, followed by a velocity inversion. These and other significant velocity contrasts below the seabed generate surface and interbed multiples, so multiple attenuation is an important requirement for all projects in the Clair field.

Due to the better attenuation of the water layer multiple and the wide azimuths recorded compared to towed streamer several 3D multicomponent surveys have been acquired in the area. Two sparse orthogonal geometry 3D OBC acquisitions were carried out in 2002 and 2006, and two high-density 3D OBC surveys with in-line shooting geometry were acquired in 2010 and 2012.

The strategy for multiple attenuation on the Clair projects has evolved throughout the years as new technology developed. For the early sparse orthogonal surveys, gapped deconvolution in the Tau-PQ domain was introduced and applied immediately after P-Z summation to attenuate water layer multiples and other short period multiples. This was followed by a pass of shot-domain gapped deconvolution in the Tau-P domain to tackle further residual multiple energy.

A step change took place with the 2010 HDOBC Clair Ridge survey, when wavefield extrapolation multiple modelling (WEMM) was introduced before TauPQ deconvolution to predict and subtract source-side reverberations of any order in the water layer. The results of this approach were extremely positive, and represented the starting point for the subsequent 2012 HDOBC survey (Clair South West), where it was successfully adopted for fast-track products.

However, further work was required to respond to the high level of multiple still present in the data. Surface related multiples from generators below the seabed were addressed with the adoption of 3D GSMP, and more source side multiples energy was removed through enhancements to the adaptive subtraction workflow. Other tests were performed to tackle multiples generated by internal reflectors. The outcome is a much improved pre-migration multiple removal sequence. The methods adopted and the results of their application to the 2012 Clair South West dataset are discussed in this paper.

Figure 1 Kirchhoff depth migrated shallow section (merge of upgoing and downgoing wavefield data).

Multiple removal strategy

To attenuate the considerable multiple energy in the Clair data a top down approach was tested and adopted. This method involves attenuating each generator in turn starting from the primary generator the high reflectivity seabed followed by other surface multiples from deeper events. Finally shallow interbed generators were considered.
Figure 2 Orders of multiple attenuated at each stage of the multiple attenuation sequence. BLUE is the downgoing at the receiver removed by PZ summation, ORANGE is the source side water layer multiple removed by WEMM, RED is the surface multiple removed with GSMP and Green is the required primary upgoing event.

The advantage to OBS acquisition in this area is the ability to separate the upgoing data from the downgoing and therefore remove the receiver side ghost and water layer multiples. The method used to generate the upgoing for this Clair project is PZ summation, scaling the Z component as a function of the calculated seabed reflection coefficient (Ball and Corrigan, 1996). Prior to summation the geophone data is matched to the hydrophone data using the upgoing refractor of the hydrophone (P) and Geophone (Z) data (Shalkwijk et al. 1999; Melbo et al. 2002). The generated upgoing data was the input to the subsequent multiple attenuation.

The next multiple attenuation focussed on the source side multiple. The multiple model was generated using a wavefield extrapolation multiple modelling (WEMM) technique (Dawson et al. 2010). This uses 3D receiver gathers as input and models an additional water layer multiple, modelling all orders of source side water layer multiple. As this uses the 3D receiver data and a 3D representation of the seabed the multiple modelled generate is a 3D model. This model is then adaptively subtracted from the input data.

The next set of multiples to be attenuated are the surface multiples with an upwards reflection on interfaces below the seabed. For this two methods were considered. The first was wavefield extrapolation multiple modelling using a full earth model, the second 3D GSMP (Generalised Surface Multiple Prediction). Following testing the method used in was 3D GSMP which has the advantage of being entirely data driven.

GSMP is a Schlumberger Geosolutions technique using the SRME approach (Moore et al. 2008). Due to the dual surface in OBS data the method has to be adapted from the streamer (surface) method. Two methods have been implemented the first makes use of streamer data along with the OBS data to generate the multiple model. The second method shifts the receivers to the surface before generating a multiple model. Due to the lack of coverage over the whole acquisition of towed streamer data and the relatively shallow seabed the second method was used for this project.
The final pre-migration multiple attenuation applied was Tau-PQ deconvolution. This method has been applied to all the legacy projects and in this case was used to attenuate any remaining water layer and other relatively short period multiples generated in the near surface.

![Figure 3 Kirchhoff depth migrated raw sections after PZ summation (A), WEMM (B), GSMP (C) and TauPQ deconvolution (D).](image)

**Results**

The results of the multiple attenuation sequence applied are illustrated in figure 3. The raw migrated section after PZ summation (panel A) shows the high level of multiple reflections energy present in the data before any de-multiple process is applied. A large amount of source side water layer reverberations are modelled and removed by WEMM first (panel B). GSMP subsequently (panel C) successfully tackles other surface related multiples. GSMP was particularly effective in modelling the surface to Base Tertiary multiple which is situated over the main area of interest (this event was also predicted during testing using a full image WEMM). The final pass of gapped deconvolution in the TauPQ domain attenuates the remnant multiple energy (panel D).

The comparison between panel D and panel A clearly shows how the combination of model driven and data driven techniques determined a relevant improvement of the imaging throughout the whole section, and particularly in the upper and lower cretaceous. As the multiple energy is progressively removed, the underlying deeper structure is unveiled, and is now much easier to interpret.

**Conclusions**

The pre-migration multiple removal strategy described here stems from the lessons learnt from previous Clair OBC projects, and is further strengthened by the addition of GSMP. Water bottom WEMM plays a key role, effectively predicting water layer multiples in a 3D sense demonstrated by the attenuation of the multiples below the high amplitude sills. GSMP complements the results of the other techniques against short period multiples, but more importantly it also predicts other long period surface multiples which, as it happens in the South West area, are cutting through at reservoir level.

While very good results were achieved with the Clair South West high density OBC dataset, the multiples problem in the Clair area is complex, and it has not been fully resolved. Some surface multiples are still left in the data, and little was done against internal multiples. Internal multiple
techniques were tested and gave some promising results, but the actual generators of the multiples are not clear therefore more work is required.

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References


