3D Surface related multiple elimination in the presence of a complex water bottom geometry – A case study from offshore Nigeria

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Summary

In this case study, we look at some practical aspects of predicting and attenuating surface related multiples from a 3D dataset, acquired offshore Nigeria. The water bottom dips in a cross line direction giving multiples whose raypaths lie outside the acquisition line direction requiring a 3D surface-related multiple elimination (SRME) scheme. In common with 2D SRME schemes 3D SRME is performed in two phases: the first phase involves creating a multiple model for each target trace, the second phase involves adaptively subtracting the multiple model from the input data, usually using filters derived using a least-squares approach. The first phase (multiple prediction) was performed using a new approach to 3D SRME described by Bisley, Moore and Dragoset (2005). The method, '3D General Surface Multiple Prediction' (3D GSMP), enables a high quality 3D multiple prediction for surveys acquired in areas of complex geology and with irregular acquisition geometry. An important feature of this method is its ability to predict multiples at true azimuth, taking the true raypath of the multiple through the water layer into account, the sensitivity of multiple prediction to azimuth and other issues relating to 3DSRME are discussed by Moore and Bisley (2005). A more detailed description of the method is discussed by Moore and Dragoset (2008). Unlike other implementations of 3D SRME, minimal preprocessing was required, and the input data was not regularised, extrapolated to zero offset, or interpolated to harmonise the shot and receiver sampling intervals. The key parameters required for 3D GSMP include selection of aperture, and spatial sampling, which have an impact on effectiveness of the multiple prediction and the cost.

Introduction

The seismic survey, offshore Nigeria, was acquired to aid field development and well planning through identification and mapping of turbiditic sandstone reservoirs of Miocene age. The objectives of the survey were to provide improved resolution over previous surveys and to provide a possible 4D baseline for future field monitoring and management. The field lies in a deepwater environment (water depths, which vary between 1300 m – 1900 m). Figure 1 shows a water bottom time map of the survey area. The water-bottom times that give rise to the surface-related multiples range from 1.7 s in the north and 2.5 s in the south; the survey was acquired in a south easterly direction giving rise to water depths that dip in the inline and crossline directions.

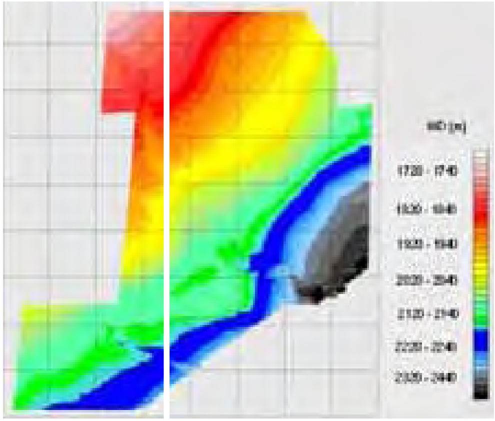

Figure 1: Water-bottom time map of the survey area.

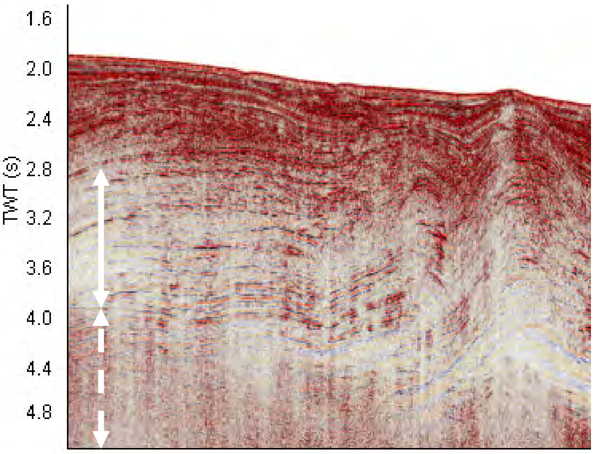

Figure 2: Crossline from the 3D stack volume before SRME. The location of this line is shown on Figure 1. The primary target zone is indicated by the solid line, the first water-bottom multiple bounce and scattered multiple energy can be seen below 3.8 s indicated by the white dashed line. The irregular topography gives rise to diffracted multiples which are 3D in nature.

Figure 2 shows a typical crossline stack from the survey along the track annotated in Figure 1: the target reflectors and first-order water-bottom multiple are shown by solid and dashed white lines. The zone of interest containing the reservoirs sands is between 2.8 s to 3.7 s two-way time (TWT) and the first-order water-bottom multiple is at a TWT of 3.4 s in the north to 5.6 s in the south. The steeply dipping and irregular topography of the waterbottom gives rise to complex multiple reflections and diffractions whose ray paths lie outside the plane of the acquisition sail-line direction. Although the multiples lie beneath the primary target zone, previous experience showed that the multiple energy will migrate into the target zone if left poorly attenuated. Previous attempts using 2D multiple schemes failed to attenuate the multiple sufficiently to prevent contamination of the target zone.

Acquisition and data preparation

The impact of field survey characteristics and data preparation for surface related multiple attenuation are discussed by Moore and Bisley (2005) and Dragoset et al (2006).

Data acquisition

The survey was acquired in April and May of 2007 using point-receiver acquisition technology. A total of 475 km^2 of data were acquired. The sources and streamers were towed at shallow depths of 5 m and 6 m respectively, with the objective of achieving a useable bandwidth of 10-90 Hz. Ten cables of 5600-m length were deployed at a separation of 50 m: the inline spacing between point receivers was 3.125 m. Dual sources were deployed having a shot interval of 18.75 m, giving a nominal fold of 75.

Throughout acquisition constant streamer separation was maintained by the application of streamer steering. Strong currents were encountered in some areas resulting in high feather and relatively poor fold of coverage.

Data preparation for 3DGSMP

Shot domain processing was performed at a 2 ms sample rate at single-sensor trace interval to compensate for perturbations and attenuate noise introduced during acquisition. The processing at single-sensor trace interval included receiver motion correction; attenuation of swell induced cable noise and waterborne noise. Shot-by-shot designature using calibrated marine source designature minimised wavelet distortion arising from variations in source characteristics. Digital group forming incorporating a digital antialias filter to 12.5 m trace interval and temporal resample to 3 ms was performed prior to input to 3D GSMP.

Multiple analysis and parameterisation for prediction of Multiples

For 3D SRME the multiple model for each target trace is predicted by computing a Multiple Contribution Gather (MCG). The principles behind generation and application of the Multiple Contribution Gather are explained in detail by Moore and Dragoset (2008). For 3D GSMP, the MCG is created on a regular 3D grid, each node of which represents a possible downward reflection point (DRP) within some aperture of the target trace. A trace at each grid node is then formed through the convolution of the two traces that best connect the grid point with the source and receiver endpoints of the target trace.

Stacking the MCG gives a single trace that is the predicted multiple for the target trace. Analysis of an MCG will give information about the need for 3D demultiple, and the parameters required. The parameters affecting the multiple prediction are crossline aperture, which will be dictated by the complexity of the geology, and spatial and temporal sampling within the MCG, which should be selected to minimise aliasing (Dragoset et al 2006). Figure 3 shows a crossline MCG for one representative target trace. The MCG was generated using aperture width of 1000 m and a grid spacing of 25 m. The central red line drawn on the MCG represents the inline position of the target trace.

Observations-

- If the apex of the multiple energy is centred on the red line the multiple can be estimated and removed using a 2D method, if the apex of the multiple falls to one side of the centre a 3D method is required. In this case, the apex of the multiple falls approximately 150 m off centre, implying that 3D demultiple is required and an aperture width of 300 m is sufficient to model the multiple.

- The MCGs are stacked together to form the multiple model. Selecting an aperture that is too large will introduce noise and increase cost, selecting an aperture that is too small will result in inadequate modelling of the multiple.

- For offsets greater than 500 m spatial aliasing occurs, implying that a finer grid spacing within the MCG would be required if the geology dictated that apertures greater than 500 m are required to model the multiples.

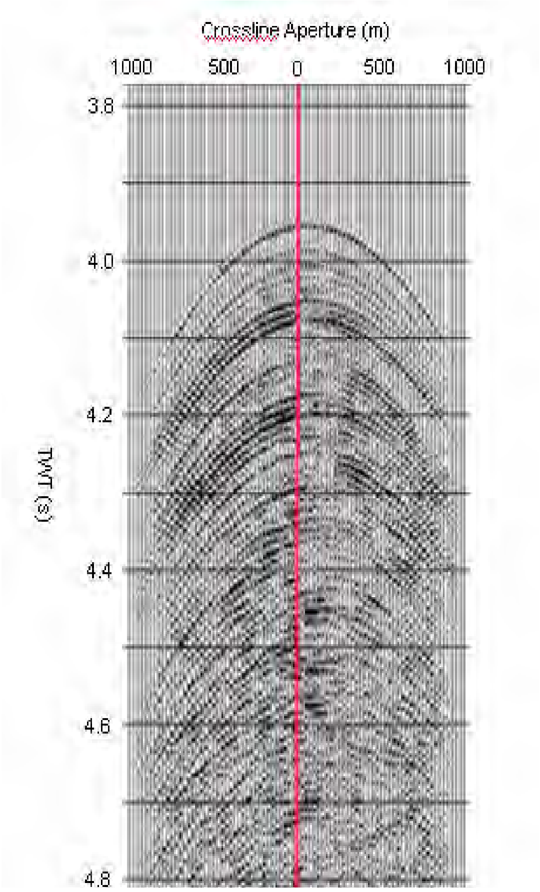

Figure 3 Multiple Contribution Gather (MCG) Constructed using an aperture width of 1000 m.

MCGs were constructed and analysed at key locations across the survey, and the conclusion drawn from this analysis was that a crossline aperture of 375 m was sufficient to accurately model the multiples. This conclusion was further supported by comparison of the multiple models and adaptive subtraction results produced using different apertures. The spatial sampling (distance between gridpoints) within an MCG was chosen to be 25 m.

Results

MCGs are created and stacked for every prestack trace in the seismic survey, giving a multiple model that was then subtracted from the input data using a least-squares adaptive subtraction technique. Figures 4 and 5 shows crossline stacks and gathers (time windowed over the zone of interest) before and after application of 3D GSMP: Figure 6 shows difference plots. 3D GSMP has successfully removed both the water-bottom multiple and the scattered multiple energy generated by the complex overburden in this area. The primary reflection energy underneath the multiple has been revealed, un-attenuated, as indicated by the black arrow on figure 5(a).

Conclusion

The complex nature of the water-bottom in this area required 3D multiple prediction which was confirmed through MCG analysis. The ‘true azimuth’ 3D general surface multiple prediction method (3D GSMP) was used to successfully attenuate the multiple without the need to regularize or interpolate the geometry or extrapolate to zero offset. The key parameters to be considered are aperture and spatial sampling within an MCG. The former is required to ensure that the DRPs of the surface multiples fall within the MGC, the latter is important to prevent aliasing within an MCG.

Acknowledgements

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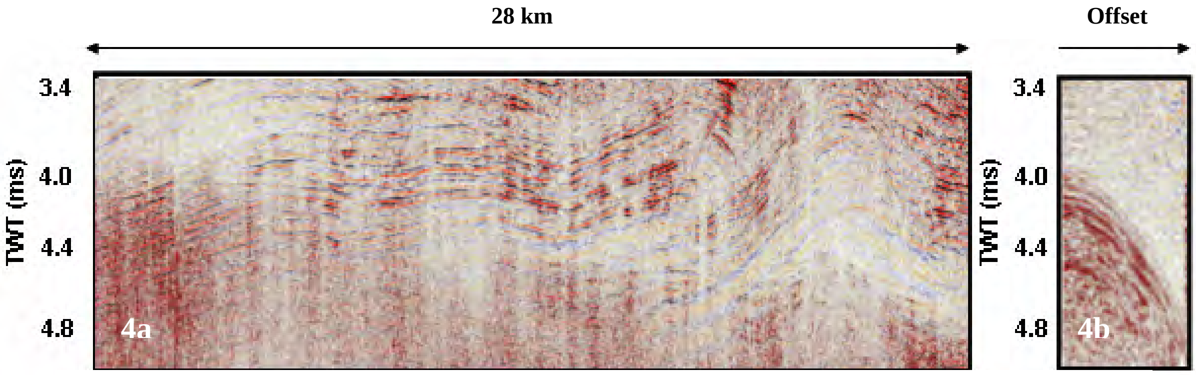

Figure 4 Data before 3DGSMP (a) Crossline stack and (b) CMP gather

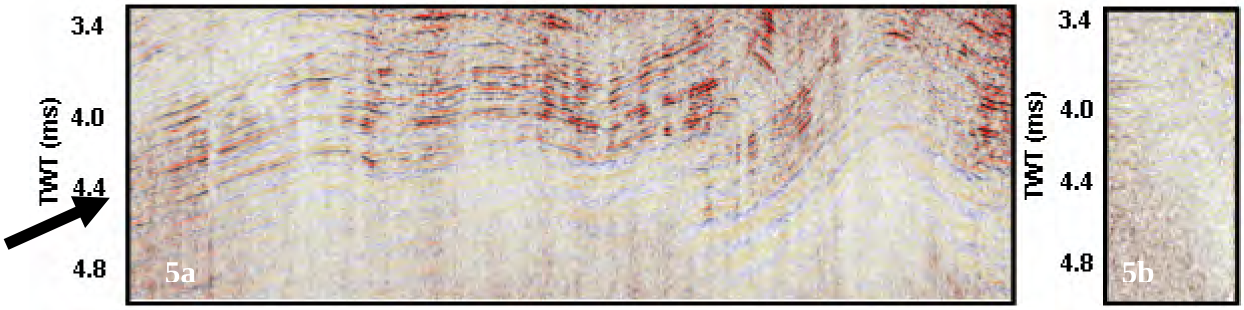

Figure 5 Data after 3DGSMP (a) Crossline stack and (b) CMP gather, the black arrow indicates primary reflections revealed un-attenuated after multiple attenuation

Figure 6 Difference plots showing multiples attenuated through use of 3DGSMP for (a) Crossline stack and (b) CMP gather

EDITED REFERENCES

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