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Suppressing Sub-salt Converted Mode Interference - An Example from Deep-water Angola

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SUMMARY

Converted mode contamination of P-wave images is a well-known and pernicious problem in some geological settings. In this case study from Block 31, in Angola’s deep-water region, we demonstrate how forward modelling of the three main converted mode arrivals can be used in conjunction with reverse-time migration and adaptive subtraction to suppress shear-contamination of the imaged field data.
Introduction

It is well known that even in a marine environment the shear mode converted energy can contaminate a P-wave image. In shallow water overlying flat lying high velocity contrast layers, this occurs primarily due to high angle S-to-P mode conversion at the sea bed of upcoming shear energy. In this case, the upcoming shear is generated at the high velocity contrast layers (e.g. Jones 2013). In deep water salt provinces, similar contamination often occurs due to mode conversion at steeply dipping salt interfaces, which again converts S back to P on the upcoming wavefront (e.g. Ogilvie and Purnell, 1996; Lu et al., 2003; Lafond et al. 2003; Lewis 2006). These usually undesired contaminants of the image can sometimes be exploited so as to aid in the interpretation of the base of salt (primarily as they offer enhanced illumination due to different angular coverage: e.g. Lewis 2006; Jones and Davison 2014). However, usually there is a desire for them to be suppressed. This can be achieved by various means (e.g. Lafond et al. 2003; Huang et al. 2013).

In this work, we demonstrate a successful application of converted mode suppression of a base salt related mode conversion.

Methodology

We commence with a suitable interval velocity model for the P-wave data, and create a version of the model containing shear velocity within the salt body. Hence in this case, we are restricting ourselves to consideration of conversion only at the salt boundaries. 3D Finite difference shot modelling is then performed using a single scattering approximation, for four scenarios, so as to produce shot gathers corresponding to the PPPP, PSPP, PPSP, and PSSP modelled wave fields resulting from conversion at the top salt and reflection from the base of salt reflectors.

Figure 1 shows an inline from this 3D shot-modelling exercise after reverse-time migration (RTM) of the modelled shot data using the corresponding interval velocity models. Here we adopted a P-wave salt velocity of 4400 m/s and S-wave velocity of 2600 m/s (based on well analysis from the area).

Results

Following the modelling and associated RTM imaging of the converted mode wave field, various strategies were assessed for removing the energy from the RTM image of the field data. The simplest approach was to sum the three modelled converted mode RTM images (PSPP, PPSP, and PSSP) as shown in Figure 2, and then perform an adaptive subtraction of this compound image from the real RTM field data image. Other strategies were also assessed, including cascaded adaptive subtraction of the individual converted mode RTM images as well as 2D and 3D adaptation prior to subtraction.

The best results (shown in Figure 3) were obtained using 2D adaptive subtraction of the three summed RTM images. To avoid undesired damage to the real image, use of judicious muting of the modelled data was employed prior to adaptation and subtraction.
Figure 1 Interval velocity model and the RTM images of the three mode converted wavefields.

Figure 2 Sum of the modelled three converted mode RTM images, prior to adaptation.
Figure 3 Top - RTM image of the field data using the final velocity model. Bottom – image after 3D adaptive subtraction of the RTM image of modelled mode converted data.
Discussion

To a certain extent, use of these modelling techniques relies on the mode converted wave field being relatively simple. In other words, these forward modelling and subtraction techniques will probably work when both the top and base salt interfaces are relatively simple. If either surface was particularly rugose, the model that we use to create the synthetic forward modelled data will most likely be too much in error to yield synthetic data that could be meaningfully removed from the real data.

Further tests, assessing the viability of mode converted suppression in the pre-stack pre-migrated domain were also considered, but this would be much more expensive. Given that we have successfully improved the interpretability of the final image, this post-migration approach may be sufficient.

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