Surface multiple attenuation in shallow water, case study on data from the Bonaparte Basin, Australia

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Abstract

Multiples due to shallow water are observed in seismic data acquired in various places such as the Bonaparte Basin of Australia. In this paper we demonstrate through real-data examples, that Shallow Water Demultiple (SWD) workflow provides an optimal multiple attenuation solution in shallow water environment in comparison with conventional Surface related multiple elimination (SRME) alone.

SRME methods are not effective in attenuating shallow water multiples, primarily because the water-bottom reflection required by SRME for predicting the multiples is not recorded due to lack of near offset data. Predictive deconvolution domain is often used in processing workflow to suppress this type of multiples, but deconvolution would also attenuate primary events with a periodicity close to that of the water-layer. Hung et. al. (2010) presented a two-step processing workflow for removing free-surface multiples. The first step is SWD which uses a multi-channel prediction filter estimated from the multiples for attenuating water-layer related multiples, and the second step applies SRME for suppressing other long-period free surface multiples.

SWD is a wavefield-consistent method that first uses water-layer related multiples (WLRMs) in the data to reconstruct the missing water-bottom primary reflection and then applies the reconstructed reflection for predicting shallow WLRMs. It is a data driven process and takes into account the spatial varying nature of subsurface structures. Since the WLRM model predicted by SWD has similar amplitude and phase as the input data, very short matching filters can be utilized in the adaptive subtraction process.

Keywords: Surface multiple attenuation, SWD, SRME

Geological Setting

The data used in this paper was acquired in the Bonaparte Basin, Australia (Figure 1). The Bonaparte Basin is a large structurally complex basin that covers approximately 270,000 square km of Australia's northwest continental margin. The basin contains up to 15,000 m of Phanerozoic, marine and fluvial, silica-clastic and carbonate sediments (Cadman and Temple, 2003).

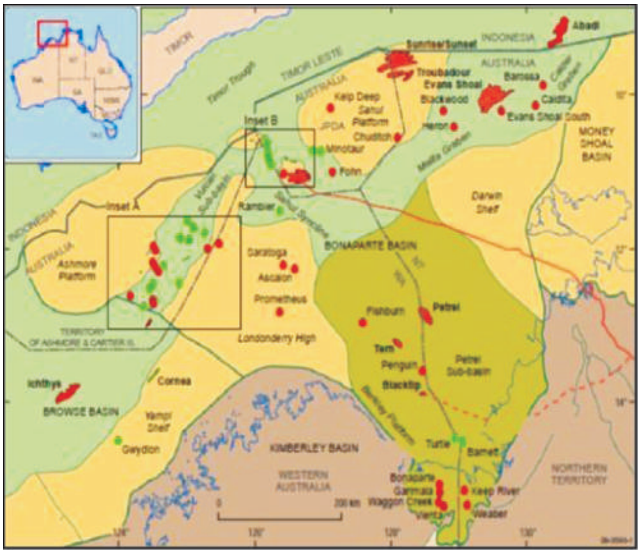


Fig. 1: Structural Elements of Bonaparte Basin (from DRET)

The basin has undergone two phases of Palaeozoic extension, followed by Late Triassic compression and further extension in the Mesozoic that culminated in the breakup of Gondwana in the Middle Jurassic (O'Brien et al, 1993). Convergence of the Australian and Eurasian plates in the Miocene to Pliocene resulted in flexural downwarp of the Timor Trough and widespread fault reactivation across the western Bonaparte (Cadman and Temple, 2003).

Processing Challenge

SRME is an effective data-driven method to attenuate surface multiple. However, as mentioned earlier, in the shallow water environment, the distance between the source and streamer is significantly larger than the water bottom depth, hence SRME is not able to model the water bottom correctly nor therefore attenuate shallow water multiples. Predictive deconvolution, either T-X or more usually Tau-P methods are generally used in these cases for attenuating shallow water multiples. A hard water bottom can result in multiples higher in amplitude than the primary, in which case deconvolution is not able to fully attenuate the multiples, and in most cases also attacks primary events that have a periodicity close to that of the water-layer. SWD, used in this case study is based on the concept of estimating shallow primary reflections from multiples. The concept is illustrated by a diagram depicted in Figure 2.

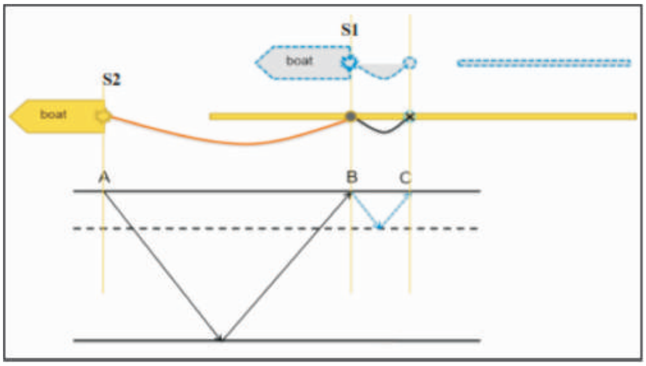


Fig. 2: Schematic diagram illustrating the reconstruction of water bottom reflection using multiples. (After Hung & Yang, 2010 c)

For a particular shot (S1) fired by the gun, the water bottom reflection in the near offset, BC, is not recorded because of the gap between the source and the nearest receiver. The reflection will not be properly recorded in the farther offsets because it is in the post-critical range due to the shallow seafloor. Nevertheless, it is possible to recover the reflection BC because it is embedded in a multiple reflection (indicated by the path ABC) of another shot S2. Therefore, by reconstructing the water bottom reflection from the multiples in the recorded data, the problem faced by SRME can be resolved. (After Hung & Yang, 2010 c).

Multiple Attenuation Process in Shallow Water

There are two ways to describe the process of SRME, as described by Hung et. al. 2010b. One is the iterative approach that is described by Berkhout and Verschuur (1997):

$$\Delta P = P(I + AP)-1 \qquad (1)$$

Where P is the acquired data, ΔP represents the primary response and A is the surface operator that involves source properties and free-surface reflectivity. The other is the inversion method that is proposed by Biersteker (2001):

$$\Delta P = P - P\ F \qquad (2)$$

Where F is a multichannel prediction filter and is equivalent to a scaled version of primaries (Hargreaves, 2006). These two ways of implementation can be utilised in turn to attenuate free-surface multiples in shallow water environment by first tackling short-period water-layer multiples and then handling remaining long-period surface multiples generated from other sub-surfaces.

For the first step, since water-bottom reflections are not available and hence the iterative method is not possible for predicting water-layer multiples, an approach that is similar to the inversion method is used for estimating F_w - the multichannel prediction filter associated with the water-bottom. In this case, the design window for F_w should include either simple or peg-leg (or both) water-layer multiples. Deterministic information of bathymetry that is normally available from the navigation data can be used for designing gaps in the inversion process for obtaining F_w. In deriving F_w, the spatial non-causality property of the operator is taken into account in our implementation (Hung and Notfors, 2003). By convolving the resultant operator with the input data, the water-layer multiple model can then be generated. Since the estimation process of F_w has already included the effect of the surface operator, the multiple model has the correct amplitudes and phase for the water-layer multiples. Hence, in the subtraction process, direct subtraction or adaptive subtraction using very short matching filters is adequate. This minimises the risks of changing other events significantly, especially those primary events that are close to the multiples. This first step constitutes the process that we call shallow water demultiple (SWD).

In the second step, the iterative approach (conventional SRME) is used for handling free-surface multiples that have longer period. Since the water-layer multiples have already been handled, the data corresponding to the multiple generator, i.e. the water-bottom in this case, needs to be first muted off to form the input for SRME. In practice, the length of the mute time is associated with the operator length of F_w. With this data preconditioning, relatively simple extrapolation methods can be utilised for SRME. Moreover, targeting long-period multiples allows more flexible control of adaptive subtraction parameters.

Field Data

The seismic data discussed in this paper was acquired using a dual source and four streamers. Source and streamer depths are 5m and 7m respectively. The length of each streamer is 6km with channel spacing of 12.5m and the streamer separation is 100m. The shots were fired flip/flop at an interval of 18.75m. This results in nominal fold of 80. The nearest offset is approximately 93m. The seafloor depth in this area ranges from 20m to 150m, therefore the seafloor reflection is close to the critical angle. This poses problems to SRME.

By using the peg-leg multiples generated by Wangarlu Formation of the Late Cretaceous and Top Echuca Shoals Formation (Base Aptian) of the Early Cretaceous horizons and the seafloor as shown in Figure 3, we reconstructed the water bottom reflections for this dataset. They were then utilized for predicting the water-layer multiples. Since multiples predicted by SWD generally match well with those in the data in terms of amplitude and phase, we used very

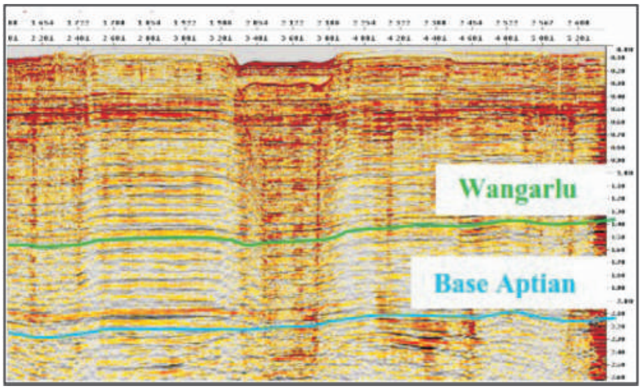


Fig. 3 : Wangarlu and Base Aptian Horizons

short matching filters in the subtraction process to minimize the risks of affecting those primary events that are close to the multiples.

Processing results

Figure 4 shows the seafloor bathymetry of the survey area which varies from 20m to 150m.

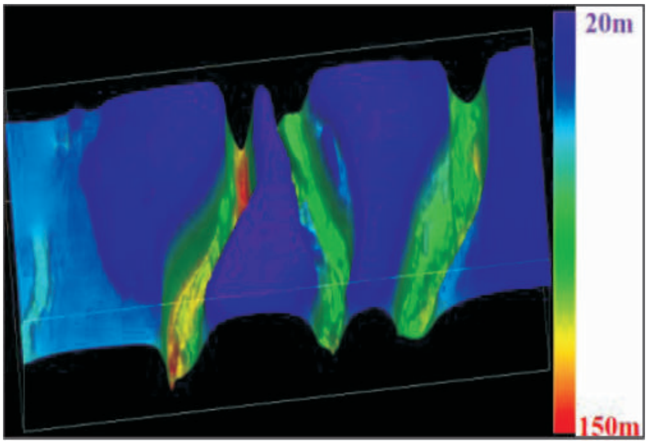


Fig. 4 : Seafloor Bathymetry

Figure 5a shows an input stack line. The water depth in this area is less than 200ms (two-way travel time). Since the nearest recorded offset was approximately 93m, the recorded water-bottom reflection is in the post-critical angle.

At this depth, as indicated by the arrow in Figure 5a, the water-bottom reflection is not well defined and it poses problems to conventional SRME. By deriving multi-channel prediction filter from the data, the estimated water-bottom reflection at near offsets was reconstructed as explained above.

With the estimated prediction operators, SWD was then applied to the data and the result is depicted in Figure 5b. It can be observed that most of the water-layer multiples have been effectively attenuated as highlighted by the circles in Figure 5a and 5b. Figure 5c displays SRME applied to the SWD data, the difference is marginal.

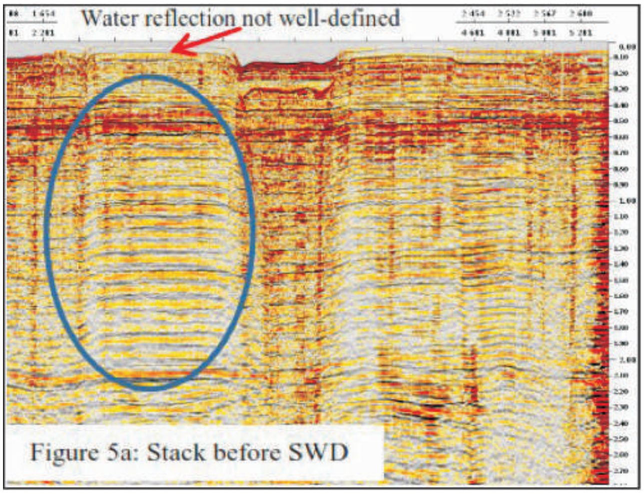


Fig. 5a : Stack before SWD

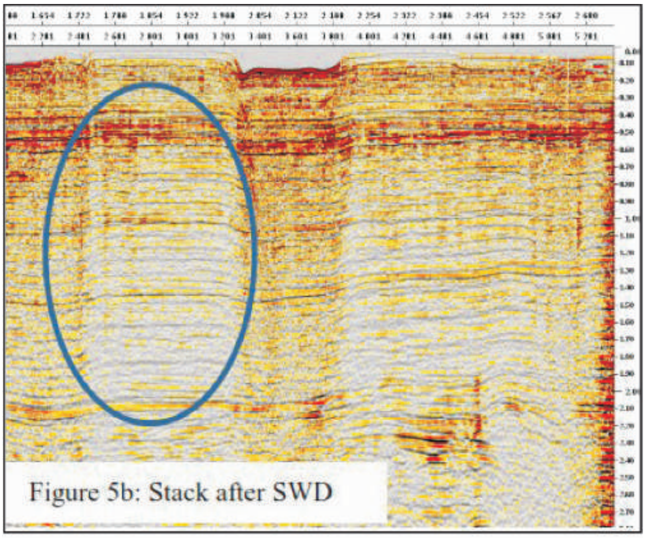


Fig. 5b : Stack after SWD

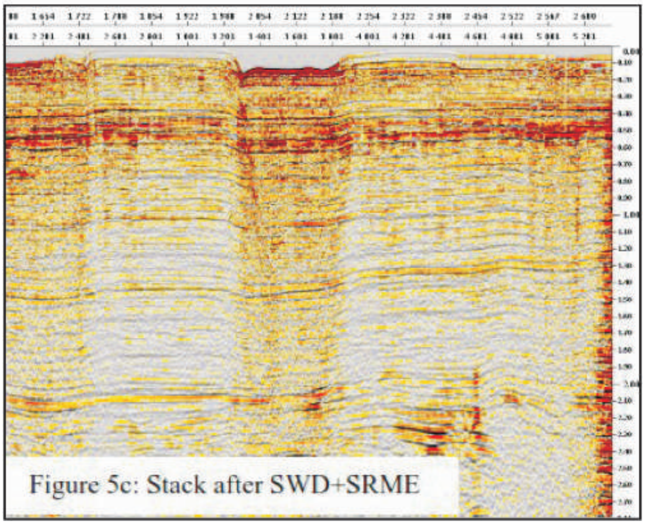
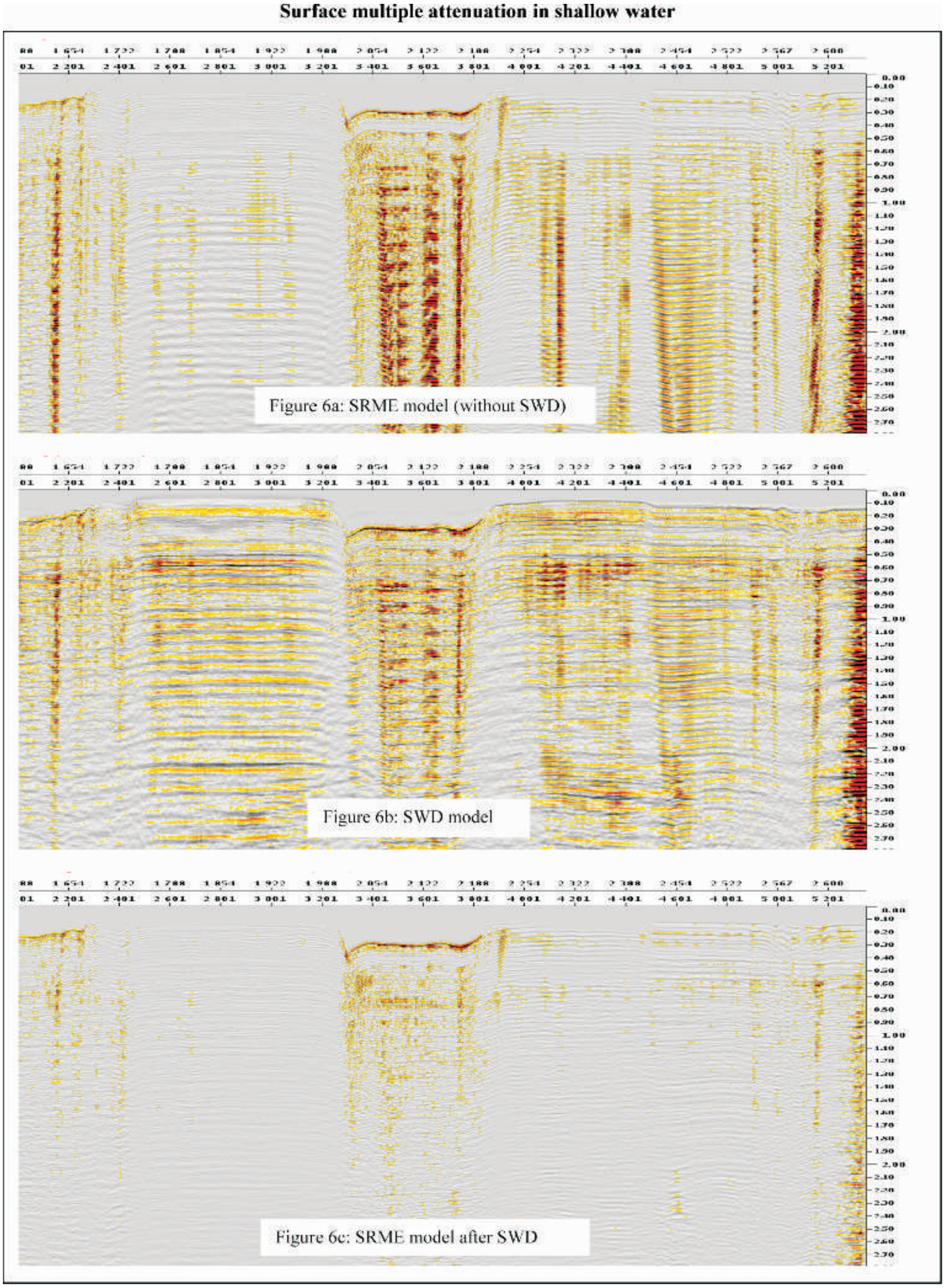


Fig. 5c : Stack after SWD + SRME

To highlight that the SRME method alone is not a viable option in the shallow water environments, Figure 6a & 6b show the comparison between SRME and the SWD models, which clearly shows that the SRME model is not adequate in attenuating the shallow water multiples. However, post SWD, the SRME model gives a much better result (Figure 6c).

Summary

To facilitate detailed seismic interpretation of the hydrocarbon reservoirs in the shallow water area of the Bonaparte Basin, one of the necessary seismic data processing steps is to effectively attenuate the shallow water multiples. As discussed in this paper the traditional methods are not adequate in suppressing these multiples. Through the successful application of SWD in the case study illustrated, we recommend that this technique should be considered as one of the effective multiple attenuation methods in the processing workflow for shallow marine data.



Surface multiple attenuation in shallow water

Figure 6a: SRME model (without SWD)

Figure 6b: SWD model

Figure 6c: SRME model after SWD

Acknowledgments

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