A Review of Current Marine Demultiple Techniques with Examples from the East Coast of Canada

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ABSTRACT

Introduction

Multiple attenuation remains an integral part of a marine processing flow. Modern technologies and innovative geophysical concepts are constantly being incorporated into new techniques for multiple removal. The diversity of multiple attenuation methods available, and the continual rapid advance of multiple attenuation processes in general can make it difficult to decide which technique is best suited to your particular data set. This paper will review the techniques commonly available for use today, including surface related multiple elimination (SRME), de-aliased Radon transform, deconvolution techniques in the tau-p domain, frequency discrimination and pattern recognition. The distinct advantages and drawbacks of each method will be discussed and their performance demonstrated using an example from the East Coast of Canada, where a variety of multiple problems are present.

The sample 3D survey reviewed in this paper was shot over an area with a characteristically hard and rugose water bottom. Differing water bottom topography and subsurface structures resulted in several areas with distinctly different multiple problems. Figure 1(a) shows a test line from a region with a shallow, flat water bottom and the high amplitude multiple it generates. The test line in figure 1(b) shows a slightly deeper, more rugose waterbottom with a complex multiple overlying flat horizons. Peg-leg multiples from major reflectors also begin to appear deeper in the section. The final test line, figure 1(c), shows a deep water line with a flat water bottom that generates a multiple which coincides with a major reflector. The reflector, in turn, generates several high amplitude peg-leg multiples.

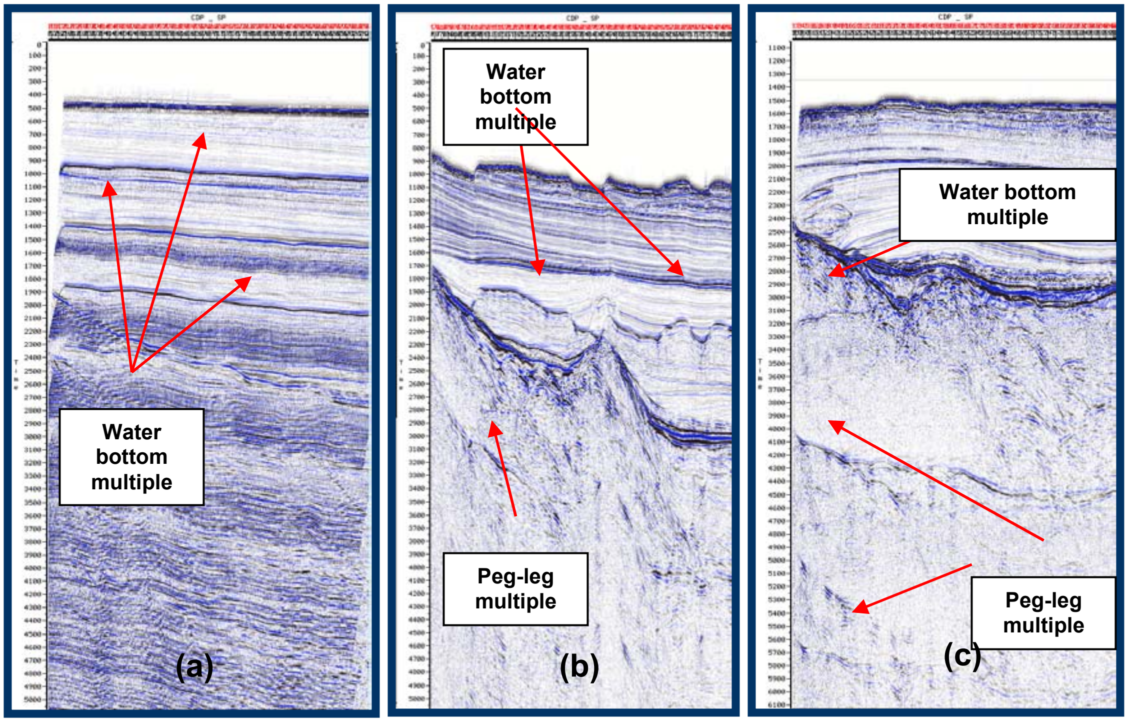

Fig. 1: Test line stacks from one survey demonstrating varied and severe multiple problems.

Surface Related Multiple Elimination (SRME)

Surface Related Multiple Elimination techniques are based on work done at Delft University (Verschuur, 1992). They focus on attenuating all multiple energy relating to the surface through an entirely data driven process. The principle rests on the concept that generating all surface related multiples affiliated with one reflector is simply a matter of propagating the recorded data down to that particular reflector. In practice, the recorded data itself is used as a first estimate of the primary wavefield. The process then becomes a series of cross-convolutions of common midpoint (CMP) gathers. The SRME algorithm generates a pre-stack multiple model that can then be subtracted from the data using an adaptive subtraction or pattern recognition algorithm. New innovations involve true 3D algorithms (although difficult and expensive) and non-iterative versions, so called “Partial SRME” (Hugonnet, 2002).

SRME techniques derive some definite advantages from their unique characteristics. The process is entirely data driven, which means no auxiliary information needs to be supplied. This means that SRME can target multiples with very little differential moveout, such as peg-leg multiples, or multiple energy residing on the near offset traces (Figure 2). However, the method requires a regularised geometry and consideration of aliasing issues. The geometry regularisation required by SRME combined with its iterative nature, can make it an expensive process. The practical application of most methods is 2D in nature and unable to account for 3D effects. The degree of attenuation is also highly dependent on the method of subtraction used. For these reasons, a common approach is to apply SRME techniques in combination with conventional Radon demultiples.

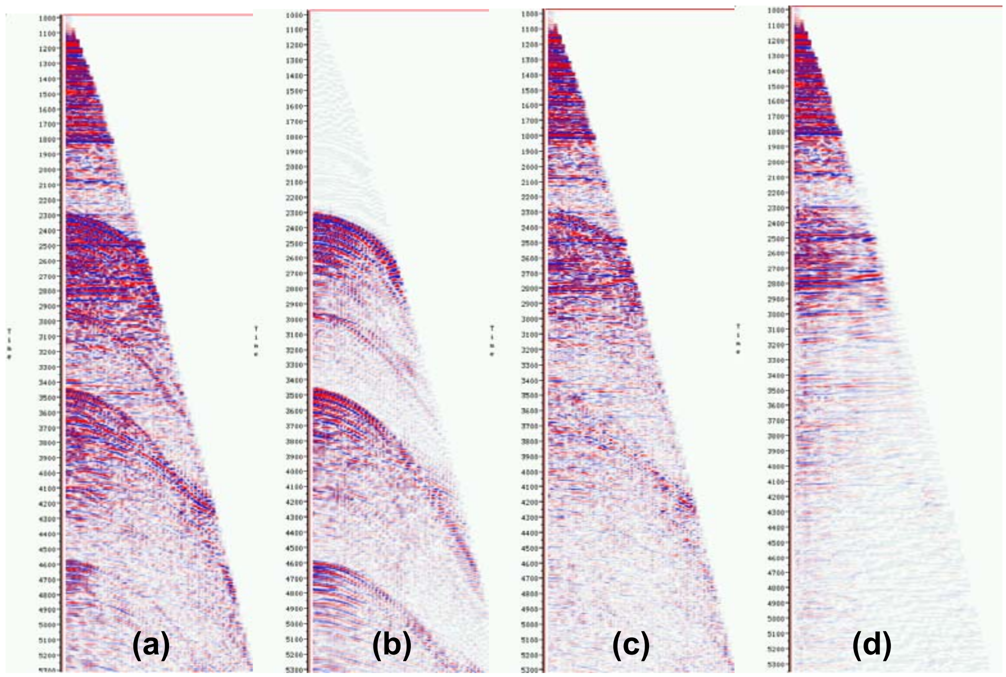

Fig. 2: (a) Input CMP gather containing 2D and moderate 3D multiple energy, (b) multiple model generated by one iteration of SRME, (c) result of least squares adaptive subtraction of (b) from (a). The high degree of attenuation of the multiple energy found on the near traces represents one of the benefits of SRME techniques. Application of conventional Radon demultiple removes residual multiple energy from the far offsets (d).

De-aliasing Radon Transform

High resolution, de-aliased multiple attenuation in the Radon domain is classed with those demultiple algorithms that rely on residual moveout to discriminate multiples from primaries. Velocities must be picked with sufficient accuracy to distinguish primary energy from slightly slower multiple energy. Standard Radon methods involve transformation of common midpoint gathers into the parabolic Radon domain, where the multiple removal is more efficient and effective. However, limited apertures and sampling of the data can cause smearing and aliasing in the Radon domain. In addition, the relatively large residual moveout associated with marine multiples fit parabolas rather poorly. Newer generation algorithms have been written to tackle the de-aliasing and resolution problems (Herrmann, 2000). These high resolution, de-aliased algorithms are necessary for accurate transformations to and from the Radon domain, and assist in maintaining primary amplitudes while removing the effects of spatial aliasing.

The Radon demultiple is currently the mainstay of marine demultiple processing flows (Figure 3). It provides a high degree of attenuation, especially on long period multiples found in deep water. It works similarly well in all areas, but experiences difficulties when the moveout differential decreases, such as with peg-leg multiples or multiple energy found on the near traces. Diffracted and 3D multiples also pose problems due to their distorted moveout behaviour.

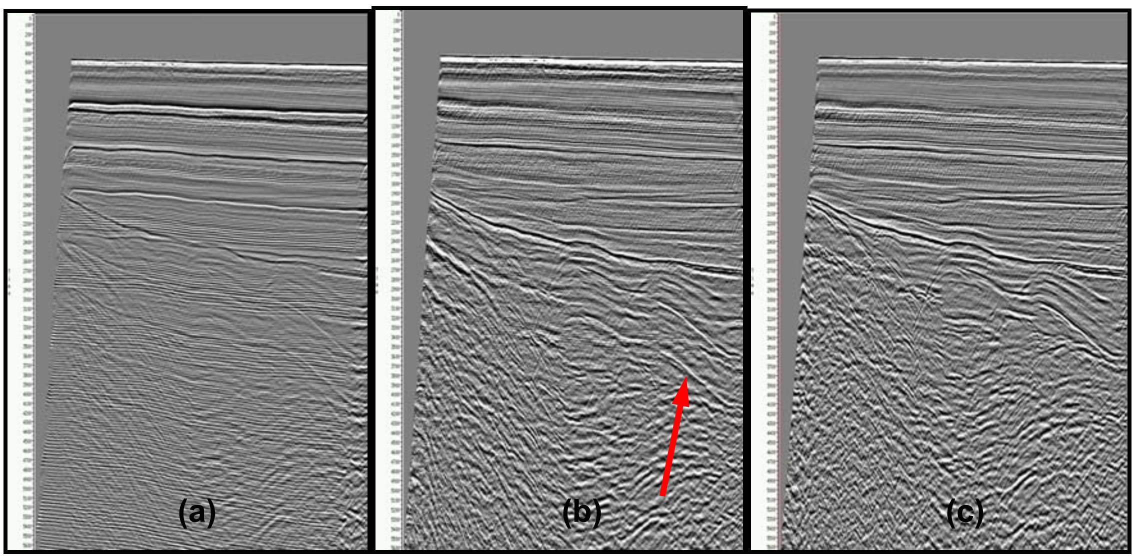

Fig. 3: (a) Stack of input traces, (b) stacked traces after one pass of Radon demultiple, (c) stacked traces after two passes of Radon demultiple. First pass Radon with conservative velocities removes the water bottom multiple allowing for more accurate velocities and targeting of highlighted peg-leg multiples.

Tau-P Deconvolution Methods

Deconvolution in the tau-p domain falls under a classification of demultiple techniques that rely on the periodicity of the multiple wavefield. However, perfect periodicity in the time-space domain occurs only for plane wave propagation or small apertures. Since limiting the aperture is generally not an option, the best alternative is to compute the tau-p transform of common shot point or common midpoint gathers, which simulates plane waves. The multiple then becomes more periodic and susceptible to attenuation using predictive deconvolution (Figure 4). Standard mono-channel, first order gap deconvolution is effective for short to medium period multiples in areas where the waterbottom is not structured or overly hard. When the waterbottom becomes harder, multi-channel, second order operators are usually applied. One successful example of second order tau-p deconvolution is the 'REMUL' program created within Norsk-Hydro (Lokshtanov, 1995). Second order operators, however, require more accurate water bottom estimates and limit themselves to water bottom multiples and peg-legs. With tau-p deconvolution methods in general, if the data is poorly sampled spatially, the frequency content of the far offsets can be adversely affected.

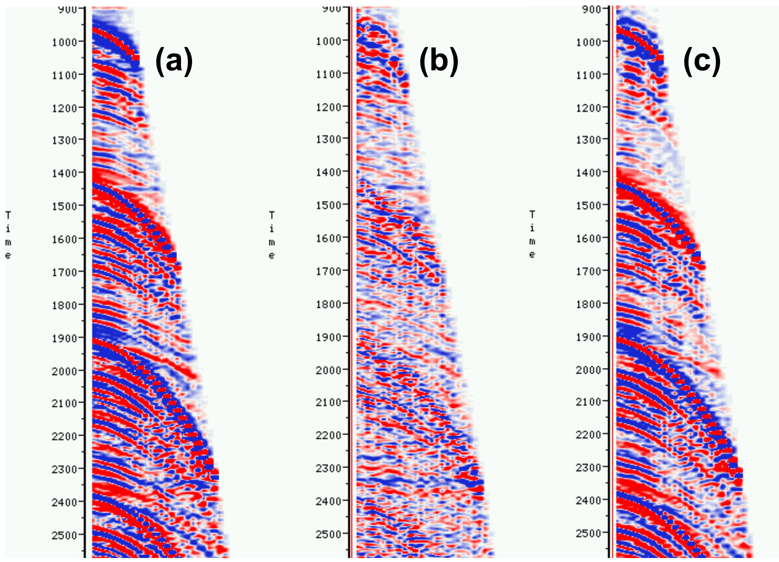

Fig. 4: (a) Input CMP, (b) input CMP with second order deconvolution operator applied in tau-p domain, and (c) difference between (a) and (b).

Frequency Discrimination

Frequency discrimination techniques rely on the simple observation that multiples in the deeper sections of data are generally more broadband than the surrounding primary energy. The multiples can be discriminated from primaries by their frequency content and, therefore, attacked (Figure 5). Long period water bottom multiples and near surface layer multiples are the most obvious targets for frequency discrimination techniques, since they retain the broadest bandwidth and appear coincidentally with lower frequency data. These methods can also be quite effective on diffracted multiples, as well as some forms of off-line noise (i.e. platforms and point diffractors).

Pattern Recognition

Any situation where the spatial pattern of the multiple differs from that of the surrounding primaries is suitable for application of a pattern recognition demultiple algorithm (Figure 6). Pattern recognition techniques target specific multiples through their predicted shape and time (Spitz, 1999). Attenuation in the frequency space domain is then performed. Pattern recognition algorithms are frequently used to attenuate peg-leg multiples without sufficient moveout differential to be removed with conventional Radon techniques. They also provide an alternative to adaptive subtraction for subtracting multiple models generated by other techniques, such as SRME methods. The algorithms are generally run post-stack but can also be used pre-stack on common offset planes. There are distinct advantages in applying a 3D algorithm in that primary and multiple shapes are less likely to be similar over a three dimensional area than over a two dimensional area.

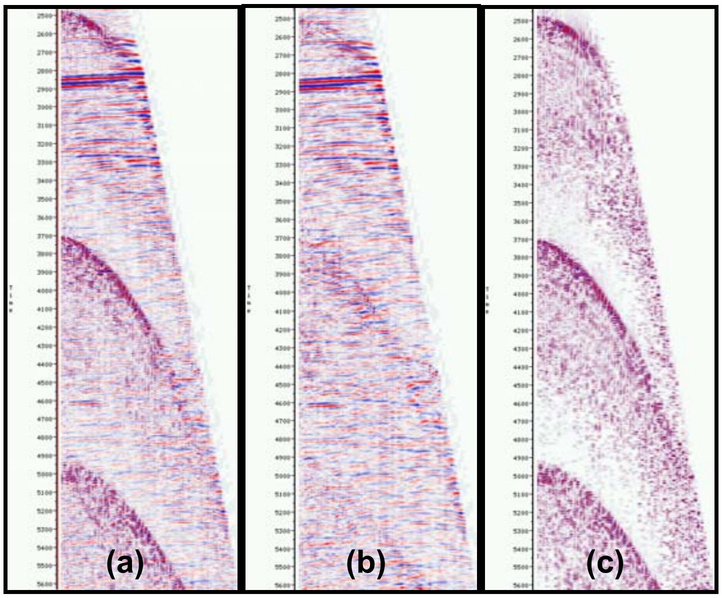

Fig. 5: (a) Input CMP, (b) CMP after frequency separation attenuation, and (c) difference between (a) and (b)

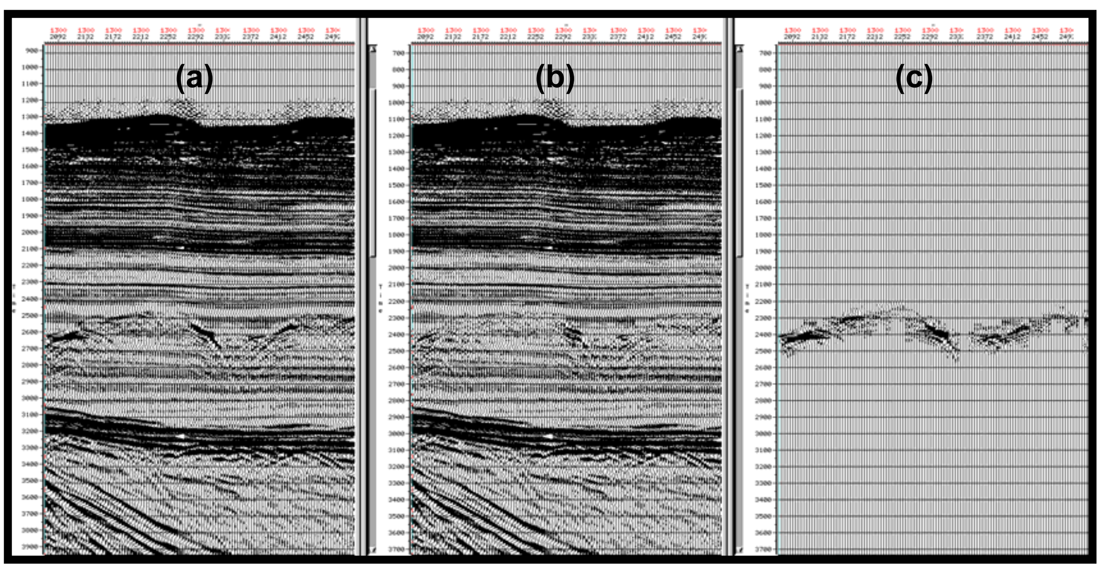

Fig. 6: (a) Input stack with residual dipping water bottom multiples overlain on a flat background, (b) result after application of pattern recognition algorithm, and (c) difference between (a) and (b).

Conclusion

There are theoretical and practical factors that make each approach unique and limits their effectiveness in certain situations. Understanding the principles behind some of these techniques can aid in choosing the most effective solution to a specific multiple problem. A variety of demultiple methods were combined on the test data in order to cope with several multiple types and the results, shown in figure 7, indicate the degree of success in attenuation of multiple energy. While exploring in frontier basins, where the unknown awaits, it is always prudent to recognize and avail oneself of all conceivable options.

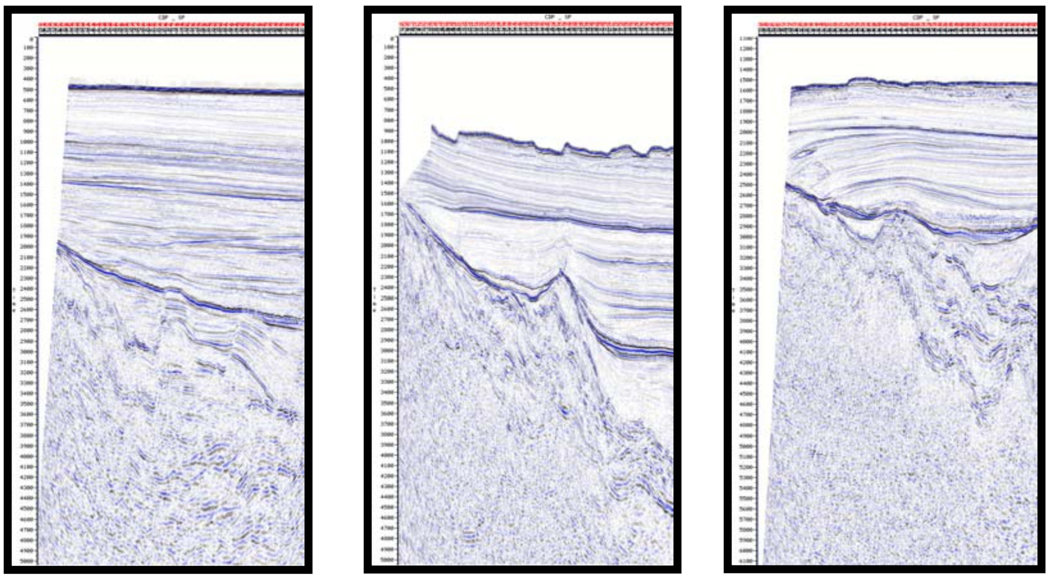

Fig. 7: Final migrated stacks of test lines after full demultiple application. See fig. 1 for comparison.

Acknowledgements

The authors would like to gratefully acknowledge EnCana Corporation for their assistance in both providing and analysing the test data.

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