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How Can The Inverse Scattering Method Attenuate All Multiples (Including Converted-Wave Internal Multiples) With A Propagation Model (Water) That Doesn't Support Shear Waves?

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Abstract

We review the inverse scattering multiple attenuation method, describe the current state of field data application, and provide an impression of anticipated future developments. In addition, we describe in detail the fundamental and intrinsic difference between prediction mechanisms that derive from forward modeling, and the prediction capability that reside within a task-separated direct inversion procedure. This analysis scrutinizes the logic behind the inverse scattering multiple attenuation methods and thus sheds light on how multiples can be predicted and subtracted from seismic data without any subsurface information (e.g., absolutely no velocity analysis) or interpretive intervention.

INTRODUCTION

There has been a rejuvination of interest in multiple attenuation methods due to the industry trend towards ever-more complex, costly, and challenging exploration plays. For example, a dipping ocean bottom in deep water and/or subsalt or sub-volcanic targets raise the technology bar and can cause serious problems for the assumptions behind traditional multiple attenuation techniques.

The inverse scattering methods for attenuating free-surface and internal multiples are specifically designed to address these challenging circumstances. To date, it is the only method for attenuating all multiples in a multi-dimensional earth that requires absolutely no information about velocity or structure below the hydrophones, nor iteration nor interpretive intervention. These methods derive from the multiple elimination apparatus that reside within the only multi-dimensional direct inversion methodology: the inverse scattering series (see e.g., Weglein et al., 1997, Carvalho et al., 1992, Coates and Weglein, 1996).

Weglein (1999a) provides a perspective of all current multiple attenuation methods and a view of the road ahead. In addition, the inverse scattering method is placed within the context of the tool-box of multiple attenuation procedures. Weglein (1999b), Berkhout (1999), Matson et al. (1998), Verschuur et al. (1998) describe, illustrate and explain the differences and relative strengths and limitations of the inverse scattering multiple attenuation method and the feedback loop (free-surface-interface) procedure pioneered by Berkhout (1982) and developed by Berkhout and Verschuur (see, e.g., Berkhout and Verschuur, 1998).

CONCEPT

To understand how it is possible to predict and subtract all multipes in a multi-dimensional earth without any subsurface information, it is useful to recognize a fundamental difference between processing through direct inversion and forward modeling and subtraction. Modeling predicts data from a model and progresses from less to more data. The multiple prediction apparatus that resides within a direct inversion procedure starts with all of the data (as a given) and seeks to separate these data into categories: first, free-surface multiples are separated from primaries and internal multiples, second, internal multiples are separated from primaries.

These are fundamentally different prediction operations with distinct objectives and requirements for a-priori information. We will present further analysis, examples and discussion of the logic and mathematics (see e.g., Weglein and Matson, 1998) behind the inverse scattering multiple attenuation methods. This increases both the plausability and understanding of these procedures.

STATUS OF 2-D, AND 3-D ALGORITHMS

The free-surface multiple attenuation algorithm has provided added value over conventional procedures in a significant number of 2-D and 3-D field data examples. The first application of the 2-D internal multiple attenuation algorithm to a full line of field data was reported in Matson et al. (1999) with encouraging results. We anticipate progress in extrapolation/ interpolation and/or data acquisition to better satisfy the data requirements of a true 3D free-surface (and internal) algorithm. We expect 3D internal multiple attenuation algorithms to be realized in the near future. Field data examples will be presented that exemplify both the free-surface and internal multiple attenuation algorithms.

1-D INTERNAL MULTIPLE PREDICTION AND IDENTIFICATION

A less ambitious but useful application of the inverse scattering internal multiple attenuation method is to use the 1-D post-stack version to predict and identify internal multiples as an aid to interpretation. The advantage of using the 1-D method is that it is much less computationally demanding than the 2-D code. It is applicable to stacked and/or near-offset data when the dips are small. Using this scheme, an interpreter can use the predicted multiple estimate to identify areas where internal multiples are likely to be a problem and exercise caution when interpreting fine detail proximal to that event. Since stacked data only approximates 1-D amplitudes and timing, there is more risk in subtracting multiples using the 1-D estimate as opposed to the 2-D estimate. Nevertheless, the 1-D estimate can still be a valuable qualitative tool and can indicate where application of the 2-D method is required (i.e., when full-prestack multi-offset internal multiple attenuation is needed or when the structure becomes complex).

In Figure 1, we show a data example from the Mississippi Canyon area in the Gulf of Mexico. This data set was used for the Multiple Attenuation Workshop at the 1998 SEG meeting in Dallas. On the left panel in Figure 1, we show a near offset gather of these data after the free-surface multiples and source wavelet have been removed. The source wavelet is a by-product of the free-surface multiple removal method (see, e.g., Ikelle et al. 1995) and was used to deconvolve the source signature from the remaining primaries and internal multiples. Unlike the free-surface case, the wavelet cannot be easily estimated after computing the internal multiples; hence, it is important to remove the source wavelet beforehand. In the center panel of Figure 1, we show the internal multiples estimated by applying the 1-D algorithm to the near offset gather on the left. In the right panel, we show the internal multiple estimate computed using the full 2-D pre-stack algorithm.

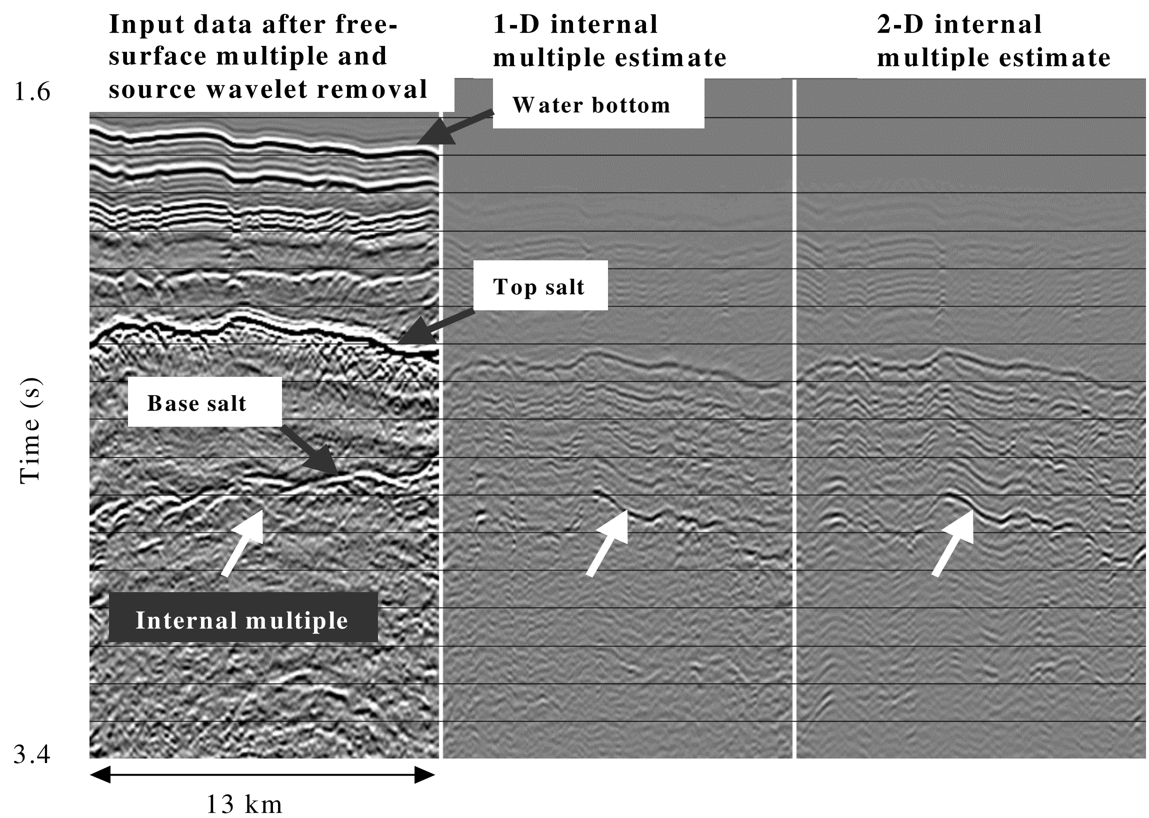

Figure 1: Near offset gather: Input data after free-surface multiple and source wavelet removal (left), 1-D internal multiple estimate, (center), and 2-D internal multiple estimate (right).

Comparing the 1-D and 2-D internal multiple estimates, it is evident that the 1-D estimate is a valuable tool for locating internal mulitples in time and space. Since diffractions are multidimensional, the 1-D algorithm views diffractions as noise; consequently, the predicted multiples appear less continuous than in the 2-D multiple estimate. The event labeled with a white arrow is a strong internal multiple that is predicted on both estimates and is clearly visible on the input data. This multiple reflects between the top of salt and the water bottom and arrives at the same time as the base of salt event.

CONCLUSIONS

We examine and further analyze the logic train and methods that allow us to predict and subtract all multiples from a multi-dimensional earth without any information about the subsurface or interpretive intervention. These inverse scattering multiple attenuation methods have matured to a point where production-strength 3-D free-surface and 2-D internal multiple attenuation algorithms are applied to field data and demonstrate significant added value. Practical 3-D data issues (e.g., crossline extrapolation/interpolation) are likely to progress and will allow these methods (that are designed to accommodate the most complex of multi-dimensional subsurfaces) to reach their full potential. Methods that permit better estimates of the required source signature will also continue to evolve and will further extend the regime of effective application.

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