Improving seismic resolution by near offset multiple multiple supression

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Abstract

We present and discuss some results of a recently developed method to eliminate multiples in the near-offset range. The application of the method improves seismic resolution by preserving near offset information. The main steps of the application of the method are (a) simulation of multiples by means of a Kirchhoff-type summation applied to a common near-offset section; (b) application of an adaptive filter to adjust the simulated multiple and (c) subtraction from the original data. In this present form, it exactly reproduces the sea-bottom multiples and perform a good approximation to corresponding peg-legs. Combination of the method with a Radon filtering technique has been successfully applied to efficiently remove multiples in all offsets.

INTRODUCTION

Routine interpretation of processed seismic data is mainly focussed on understanding primary reflections. Multiples, however, also occur in all seismic reflection data, acquired in both land and marine environments. If not properly attenuated or removed, multiples can interfere with primary reflections, leading to difficulties in velocity analysis and attribute estimation.

In many land data cases, multiple attenuation can be adequately achieved by deconvolution and CMP stacking. Because of the presence of the strong reflections on the water-air contact (free surface), in particular sea-bottom multiple reflections, marine data most often require specific processing steps. In general, methods of multiple suppression can be divided into two categories, filtering and wavefield prediction and subtraction. Methods of the first group are based on the exploitation some difference between multiple and primary reflections. The popular Radon and *f-k* transform algorithms, generally applied in CMP domain, belongs to this category. The Radon multiple suppression technique requires the application of an internal mute on near-offsets, as the discrimination between multiples and primaries is more difficult in this range. Algorithms of the second group predict and subtract a given multiple type based on a wave propagation approach, These methods, in general, also fail in the near offset range, as they strongly depend on the use of traces up to zero offset. This information is not available in real situations and must be extrapolated from the input data.

The proposed method, designed to suppress multiples in the near-odffset range, has been applied in combination with the Radon filtering technique, better suited to eliminate multiples for large offsets. We recall that the application of Radon filtering to eliminate multiples require na internal mute on near-offset traces to anable a better discrimation from primaries. The main attraction of the present scheme is the novel use of the well-established machinery of Kirchhoff-type summations largely recognized by excellent results in migration and imaging. This methodology falls into the framework described by Hubral et al. (1996) as the unified approach to seismic reflection imaging. For a variety of seismic imaging problems, the unified approach leads to the construction of specific Kirchhoff-type stacking algorithms obtained upon the use of a suitable combination of Kirchhoff migration and demigration stacking lines.

The increasing use of seismic data in reservoir characterization, together with the large number of exploratory prospects on targets of stratigraphic nature, poses as a very desirable aim any improvement of resolution that can be achieved by seismic processing. In this context, the accurate elimination of multiple reflections in near-offset range within a target region may be crucial to correctly image, say, fine stratigraphic sequences or to derive reliable seismic attributes of a reservoir. In this work, we present real data results in which seismic resolution has been improved by preserving near-trace information.

DESCRIPTION OF THE METHOD

Theoretically, the simulation method is designed to effect a transformation of a given *input* section, supposed to be a reasonable approximation of a zero-offset section and containing all primaries and multiples, into an *output* section, which solely consists of the multiples to be suppressed. In this case, these are first-order, sea-floor and peg-leg multiples. In a Kirchhoff-type stacking algorithm, each sample of the output section is the result of a sum of samples collected along a uniquely specified curve in the input section. This curve is generically called the *stacking line*. In most cases, the input samples along the stacking line are multiplied by certain weights, also determined by the sample in the output section, where the resulting sum is to be placed. The terminology *weight function* is employed to refer to the choice of multipliers that are used in the summation process, which in turn is called a weighted Kirchhoff stack.

The crucial step in any Kirchhoff-type summation algorithm is the construction of stacking lines and weight functions. This also applies to our simulation scheme, with the exception that weights are not so crucial due to the posterior application of the adaptive filter to adjust amplitude and phases. The use of adaptive techniques to math discrepancies between predicted and observed multiples is common procedure in multiple attenuation schemes. To obtain the stacking line in the input section that corresponds to a given sample point in the output section, we assume that the later pertains to a multiple reflection arrival. Being a multiple reflection, this signal must have been already detected as a primary-reflection arrival at some sample location within the input section. The sought-for stacking line will be nothing else than the locus of all sample points of such primary reflections.

The simulation of the correct amplitude and pulse shape of the multiples to be suppressed can be theoretically achieved by the introduction of weights in the Kirchhoff-type stacking integral. These weights depend, however, on the reflection coefficients and incident angles of the zero-offset reflection rays at the sea floor and reflector beneath. As these quantities are not known, it is much more practical to realize the necessary amplitude adjustments upon the use of adaptive filtering techniques. This procedure is also helpful in handling peg-leg multiples.

CHARACTERISTICS OF THE METHOD

The proposed method shares the typical characteristics of a 2.5-D, Kirchhoff-type, weighted summation algorithm. Similar to its 2.5-D counterparts. e.g., MZO and migration schemes, the seismic traces need to be half-differentiated with respect to time prior the stacking. This operation accounts for the distortions on the signal shape that comes into place due to the stacking process. The stacking process also introduces some stretching in the output pulse, which is highly undesirable in multiple simulations. In order to remove this effect, an inverse correction (compression) is to be performed at all input traces.

The method is expected to work well on any seismic section that can be a reasonable approximation of a zero-offset section. For small dips, near common offset sections after NMO correction can be good approximations for input zero-offset sections. For steeper dips and/or greater offsets, a further DMO correction is also necessary. CMP-stacked sections can be also easily used as input sections for the proposed method. Better results are obtained in deep water situation because the traveltimes for sea floor and peg-leg multiples can be well approximated under the assumption of the constant-velocity medium of water, see Filpo and Tygel (1999). The use of the adaptive filter permit us apply the method under different stages of processing flow, even in stacked sections submitted to another process of multiple suppression.

APPLICATION ON REAL DATA

The present method has been successfully applied to an offshore 2-D seismic line recorded at the Brazilian continental margin. At first, a multiple attenuation Radon filtering scheme has been applied to the data. This included an internal mute to remove the residual multiples left in the near-offset range. Figure1 shows the resulting post-stack, time-migrated section. In this section, no multiple reflections can be identified. Although this apparently good result, a question arises whether also valuable information on primaries in the near-offset range have been lost in the process.

To investigate this possibility, we have produced the alternative post-stack, time-migrated section of Figure 2, in which (a) for offsets up to 750 m, all traces resulting from the application of the conventional Radon multiple suppression method were replaced for their corresponding ones obtained by the application of present Kirchhoff method and (b) all remaining traces were kept. The improvement on seismic resolution can be clearly observed. Also near-offset events in the vicinity of the multiple are readily recognized in Figure 2. These are not seen in Figure 1 because the internal mute acts above the observed multiples. The particular high-amplitude event at trace 4380 and time 1900 ms, an interesting target for interpretation in the section of Figure 2, has been removed by the conventional seismic processing that lead to the section of Figure 1.

CONCLUSIONS

We have presented an algorithm to remove first-order, free-surface multiples designed to operate in the near-offset range, a region where most available methods fail. The method is based on the simulation of the free-surface multiples by means of a Kirchhoff-type, weighted summation applied on the original section. An assumption of the method is that the original section is a reasonable approximation of a zero-offset section, e.g., a short-offset or a CMP stacked section. Kinematics of the simulated multiples were excellent, an adaptive filter has been applied to match the amplitudes and phases of the observed and simulated multiples for optimal suppression. Very good results were achieved to remove first-order, free-surface multiples on deep-water seismic data in which primary events suffered severe interference from sea-bottom multiples. The contribution of the near-traces in the stacked section highly improves the quality of seismic reflections in the final post-stack, time-migrated section. As a result of the application of the new method, the final section is more suitable for interpretation. Lateral amplitude variations could be better observed after the application of the present method.

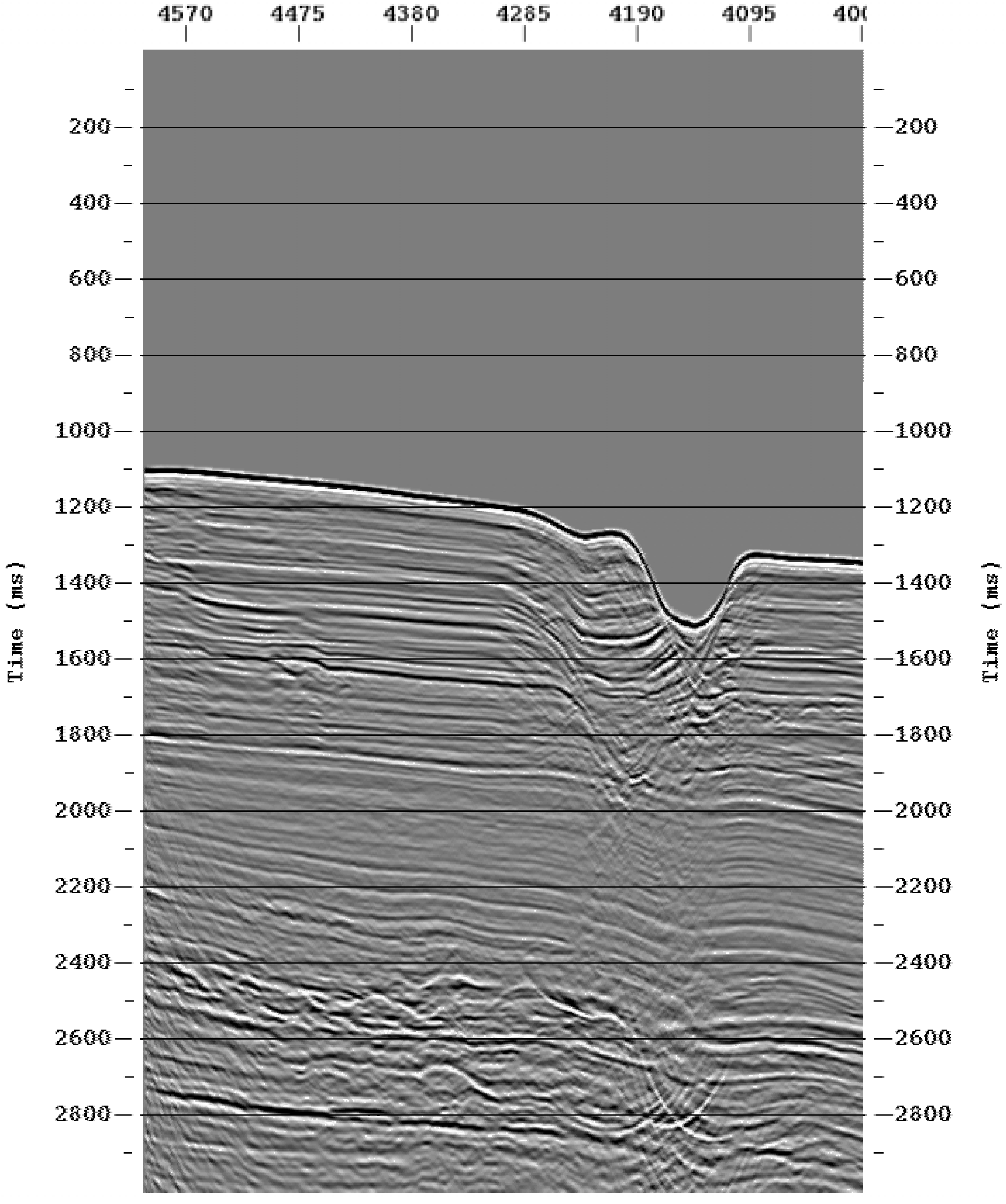

Figure 1 Stack time-migrated section with multiple suppression performed by Radon filtering associated with internal mute applied on the near offset range

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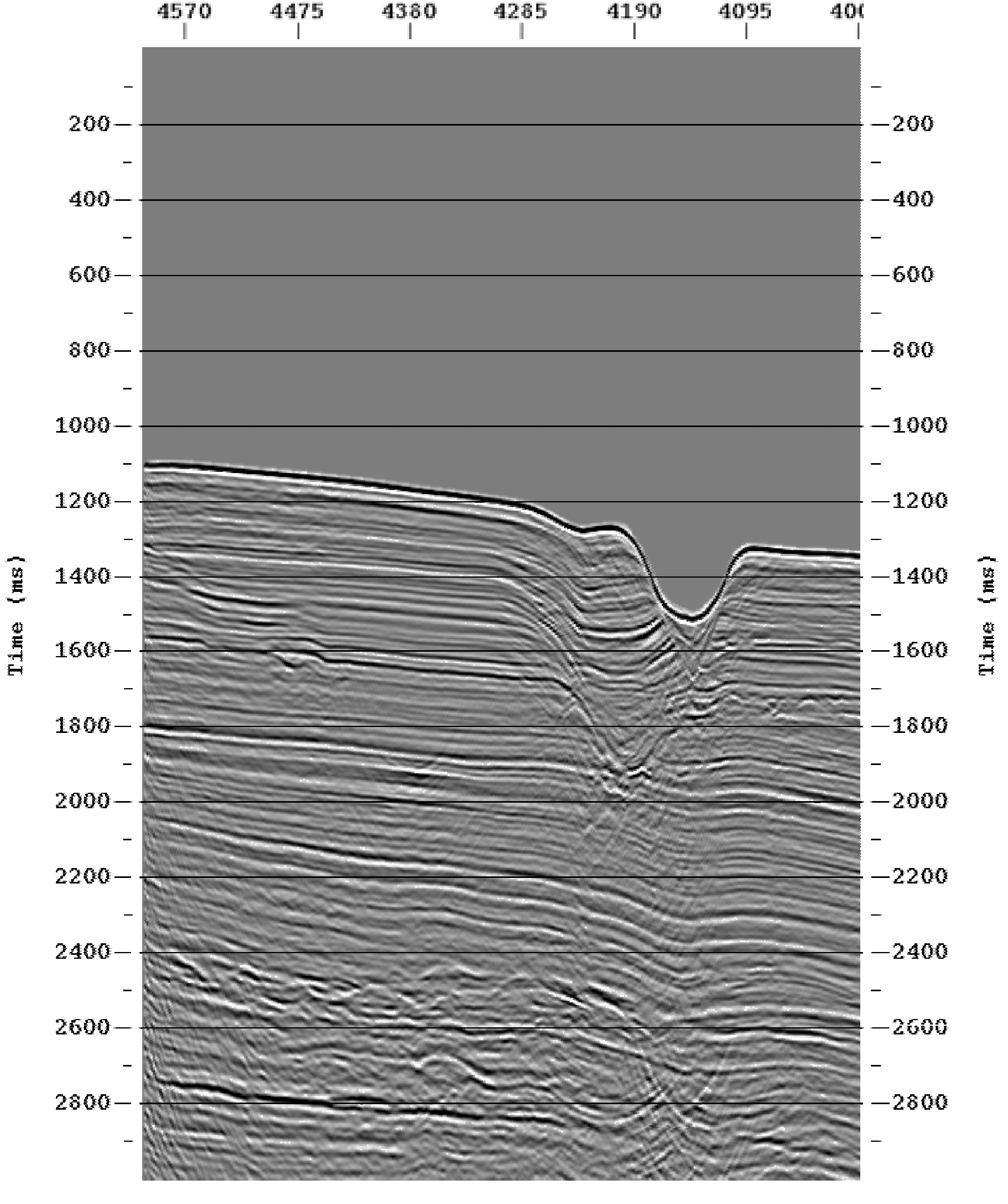

Figure 2 Stack time-migrated section. Multiple suppression was performed by Kirchhoff method up to offset 750 m and by Radon filtering from that.

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