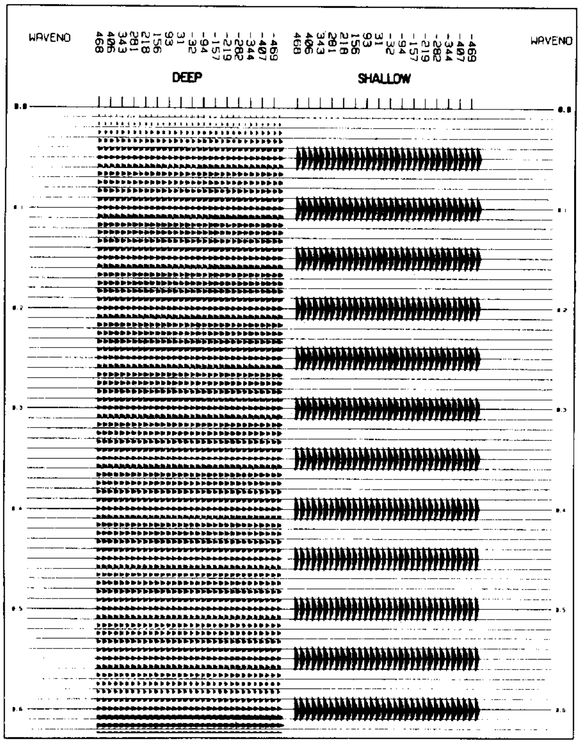

FIG. 6. Spectral records of spikes.

of the spectral traces of the appropriate spikes, then, the inverse transform of this spectral record would be the ideally focused record in *X-T*.

The moveout operation described by equation (2) is, in fact, only part of the correction to focus. There is an additional phase and amplitude spectral factor to be applied after moveout that is predicted from theory. Having applied moveout correction and the phase-amplitude factor, the entire spectral record could then be inverted. The result is similar in appearance to wave equation focused records. However, since the zero-offset trace is all that is required, it can be obtained by simply stacking the corrected spectral record then doing an inverse time transform. Thus, the spectral stack is an estimate of the time transform of the zero-offset trace.

Referring to Figure 4, the spectral stack outputs for records (R1–R4, $\overline{R4}$) are displayed as focused traces next to the near trace of the original records, the desired output. From right to left, trace 1 of R1 is the desired signal and trace 2 is the focused trace. Similarly, for R2, traces five and six are to be compared. For record R3, a time variant drop in amplitude is noticeable on focused trace 10. This is due to a divergence-like factor that varies as the square-root of event time which does not cause problems in application. Finally, the R4 traces show the result of the incorrect focusing velocity and $\overline{R4}$, the method of dealing with the problem of focusing variable velocity by the differential moveout technique in *X-T*.

Remarks

The description of hyperbolic events in *F-K* as presented here is exact for continuous, nonapertured sampling. Finite aperture and sampling requirements complicate the theoretical picture but do not significantly affect practical applications. In fact, practical experience has been very encouraging. The absence of the need for an *X-T* mute, the reduced spectral moveout at high frequency, and the independence of focusing on event time produces broadband, shallow data with good velocity directivity. Migrations of the spectral stack time section have shown substantial improvement in shallow data resolution, fault definition, and event truncation. The effects of non-zero phase data and other characteristics of the method are illustrated by synthetics. A number of spectral stacks of actual data and their migrations are shown.

Preprocessing of Nonhyperbolic Moveout Data in CMP Gathers

S3.2

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The subject presented in this paper is a wave theoretical approach to preprocessing CMP data from complicated geologic situations. By means of wave field extrapolation of CMP data, nonhyperbolic moveout curves are transformed into hyperbolic ones. The proposed process is called "velocity replacement" (VR), since an inhomogeneous overburden is replaced by a homogeneous velocity medium. After VR, conventional techniques can be applied such as interval velocity determination and CMP data stack. It will be shown with the aid of examples, that the quality of the results of conventional techniques after VR is considerably better than before VR.

Introduction

Most conventional prestack processing techniques are based on this hyperbolic assumption: The traveltime/offset relation for CMP data, being described by an infinite MacLauren series, is approximated by two terms only. This approximation is rather accurate in case of plane layered systems, even in the presence of dips. In layered systems with curved interfaces, only very small offsets and/or small velocity variations are allowed. As a solution for complicated configurations, the system can be made homogeneous by a wave-theory based velocity replacement (VR) technique. After application, the traveltime/offset relation can be described again by two terms only, without assuming serious restrictions on offsets and/or velocity variations. In this paper we assume 2-D subsurface configurations.

Velocity replacement (VR): General procedure

Consider a layered system with arbitrarily curved interfaces as shown in Figure 1a. In the following, we assume that the velocity problem is solved until interface $N-1$, and that we want to determine the interval velocity of layer N.

Distortions in the hyperbolic traveltime/offset relation of reflector S_N are due to two causes: (1) *Reflection* by a curved surface S_N. Since we make use of the CMP configuration, this effect will be small as the reflecting area, denoted d in Figure 1a, is small. In the following we will neglect this effect. (2) *Refraction* through curved interfaces $S_1 \ldots,$ S_{N-1}. Particularly when offsets are not small, this effect may influence the moveout curve significantly. It is obvious that when velocities $c_1 \ldots, c_{N-1}$ are replaced by velocity c_N,

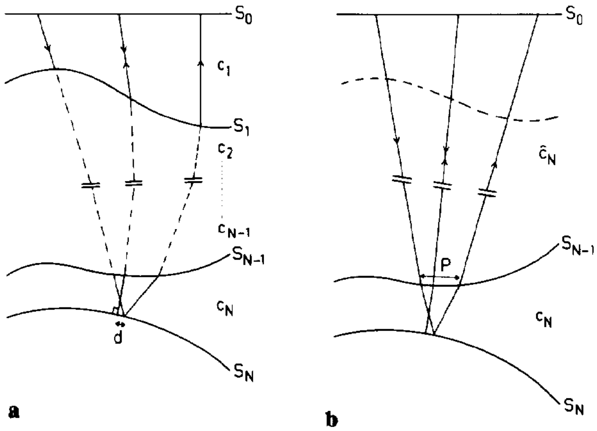

FIG. 1. With the aid of VR an inhomogeneous overburden is replaced by a homogeneous velocity medium.

the refraction effects of interfaces $S_1 \ldots, S_{N-1}$ are eliminated even for wide offsets, since the inhomogeneous overburden is transformed into a homogeneous one. Hence, by means of VR nonhyperbolic moveout curves are transformed into hyperbolic moveout curves. The VR process is based on forward and inverse wave field extrapolation of CMP data. The operator will not be derived here. For this, the reader is referred to Wapenaar and Berkhout (1982).

In order to perform VR on layer N, knowledge of the replacement velocity c_N is required. Since c_N is the unknown velocity, an iterative method must be used. Let us assume only a rough approximation is available. For instance, an estimate $\hat{c}_N$ can be obtained by applying a conventional method to the original data, which of course is inaccurate since the interfaces are curved. Replacing $c_1 \ldots, c_{N-1}$ by $\hat{c}_N$ yields a two-layer system with velocities $\hat{c}_N$ and c_N, respectively, as shown in Figure 1b.

Application of a conventional method to the two-layer system after VR in order to determine c_N again yields erroneous results since interface S_{N-1} is curved and $\hat{c}_N \neq c_N$. However, there are several reasons why we may expect more accurate results of the velocity analysis after the first VR step. (1) The inhomogeneous overburden (layers 1 through $N-1$) is replaced by a constant velocity medium with velocity $\hat{c}_N$, hence the refraction effects of curved interfaces $S_1 \ldots, S_{N-2}$ are eliminated. (2) Although $\hat{c}_N$ is a first estimate of c_N, we may expect that the velocity discontinuity at interface S_{N-1} decreases when c_{N-1} is replaced by $\hat{c}_N$ (compare Figure 1a with Figure 1b). (3) Particularly when the thickness of layer N is small, the refraction effects of interface S_{N-1} will be small since the refracting area, denoted by p in Figure 1b, is small.

We may conclude that application of velocity analysis after the first VR step yields a new, improved estimate of the interval velocity of layer N. This value can be used as a more accurate replacement velocity for the next VR step. The process can be repeated, which means c_N is determined iteratively. Generally, application of two or three iteration steps per layer yields sufficient accuracy, although we must remark that significant improvement of the accuracy already occurs after one iteration step.

Application of VR: Elimination of near-surface anomalies

Apart from interval velocity estimation, VR can be used to solve the static correction problem in a dynamic way. In marine as well as in land data, nonhyperbolic moveout curves often occur as a result of near-surface anomalies. These anomalies are caused by a low velocity surface layer (seawater, weathered earth layer, etc.) limited by a curved interface (seabottom, base of weathered layer, irregular topography). Application of velocity replacement is a wave-theoretical approach to the correction of near-surface anomalies. By replacing the irregular low velocity layer by a new layer (velocity of which corresponds to the velocity in the next layer), the near-surface anomalies will be eliminated correctly. We show this by comparing some important properties of the CMP data before and after VR. Consider the configuration shown in Figure 2a. This configuration represents a seawater layer (velocity c_1 = 1500 m/sec) overlying horizontally layered sediments. The seabottom is represented by the first, curved interface.

The CMP data shown in Figure 2b were generated by modeling. The fourth moveout curve after NMO-correction is shown in Figure 2c, together with the stacked trace. The interval velocities were calculated according to Dix's relation. The results are shown in Table 1.

Apparently the hyperbolic assumption for moveout curves 2, 3, and 4 is too crude in case of curved near-surface anomalies. By means of wave field extrapolation on the CMP data, velocity in the first layer (c_1 = 1500 m/sec) is replaced by velocity in the second layer (c_2 = 3000 m/sec). The transformed CMP data are shown in Figure 2d. The same calculations as before VR are applied to the transformed CMP data. The results are shown in Table 1. The fourth moveout curve after NMO-correction is shown in Figure 2e, together with the stacked trace. From these results, we may make the following observations: (1) Coherence of the NMO-corrected traces after VR is high, (2) quality of the stacked trace is very good, and (3) accuracy of the interval velocities increased significantly. Obviously, the nonhyperbolic moveout curves have been transformed into hyperbolic ones.

Conclusions

By means of a wave-theory based velocity replacement technique, nonhyperbolic moveout curves in CMP data can be transformed into hyperbolic ones. The effect of VR has been shown with the aid of an example with synthetic data.

Table 1. Comparison of results obtained from CMP data before and after VR.

Before VR			After VR			Model
E	c(m/sec)	$\Delta c/c$	E	c(m/sec)	$\Delta c/c$	c(m/sec)
.595	1536	+ 2%	(.865)	(3016)	(+1%)	1500
.082	3367	+12%	.993	3016	+1%	3000
.070	2998	+50%	.992	2091	+5%	2000
.056	2926	−16%	.986	3684	+5%	3500

E: Coherency
c: Interval velocity
$\Delta c/c$: Relative error in interval velocity

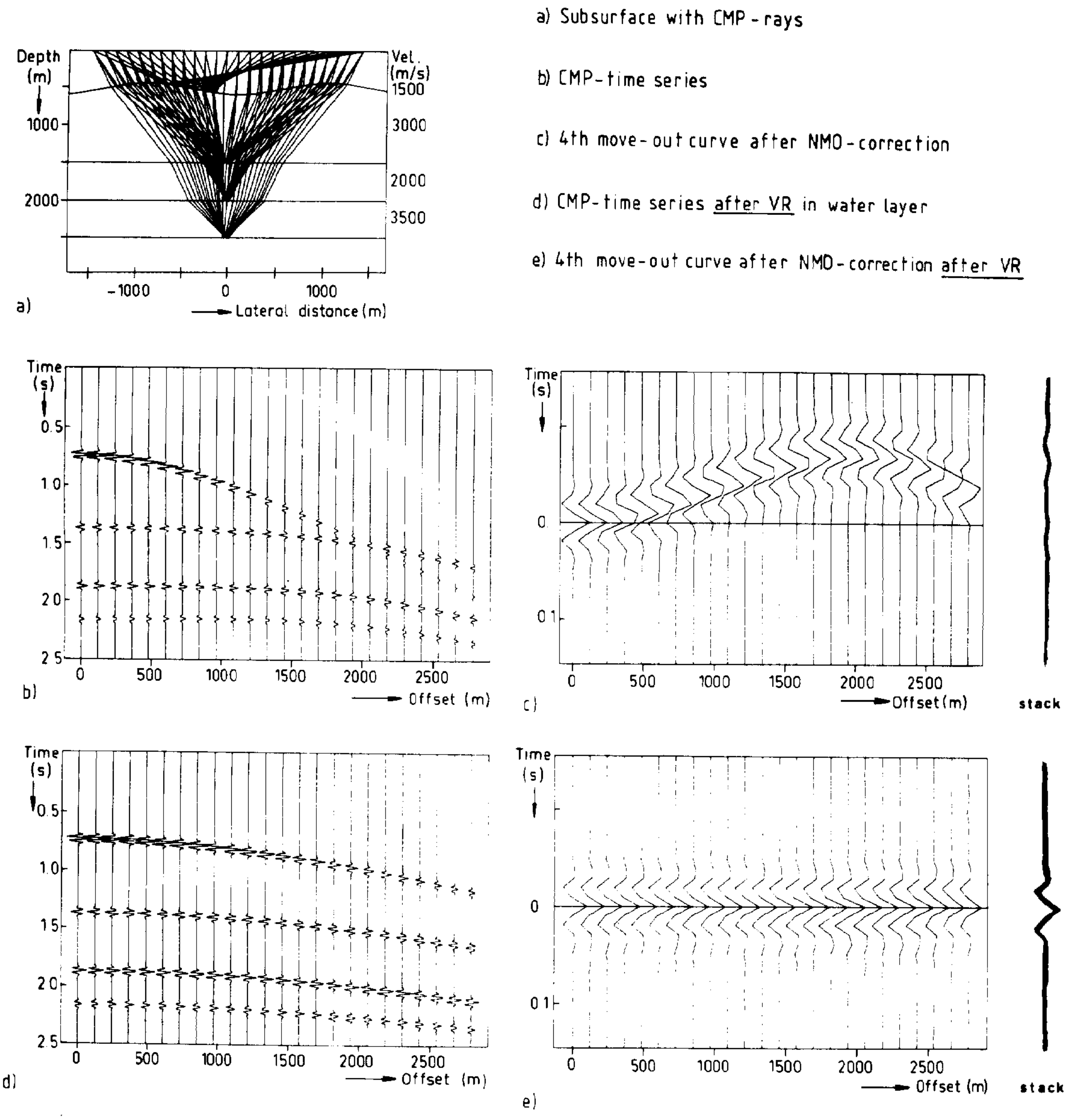

FIG. 2. Horizontally layered system overlaid by a water layer with a curved seabottom.

From this example we may conclude (1) application of conventional velocity analysis *after* VR may yield significantly more accurate interval velocities than velocity determination on the original data; and (2) quality of the CMP-data stack may be significantly improved by VR.

Acknowledgments

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Reference

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Dip-Moveout by Fourier Transform S3.3

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The conventional normal moveout (NMO) and stacking process enhances reflections having a particular moveout velocity, while attenuating events (e.g., multiples) having different moveout velocities. Unfortunately, this process also acts as a dip filter applied to the common-midpoint (CMP) stack. In other words, NMO and stacking enhances reflections in the CMP stack having a particular slope, while attenuating reflections having different slopes. NMO and stacking, like any dip filter, degrades lateral resolution. Fortunately, this dip filtering action can be suppressed by applying, in addition to NMO, a process known variously as "Devilish" (Judson et al, 1978), "pre-stack partial migration" (Yilmaz and Claerbout, 1980), or "dip-moveout" (Bolondi et al, 1982). As the latter term implies, dip-moveout