The effect of low frequencies on seismic analysis

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ABSTRACT

In this study, we consider some of the effects of recording high-fidelity, broad-band seismic data. We are especially interested in the effect of low-frequencies on seismic analysis. Such broad-band data may considerably augment existing bands and provide invaluable information for producing high-quality subsurface images. Low-frequencies have a great effect on seismic inversion and may considerably broaden the useful band of P-S data.

INTRODUCTION

In the past, low-frequency seismic recordings have been shunned in the exploration industry, largely because of their overwhelming contamination with noise. Surface waves or ground roll have been especially problematic. Ground roll can overwhelm other reflected events, especially at near offset from the source (Sheriff and Geldart, 1982; Yilmaz, 1987). Low-frequencies are attenuated in the field using arrays or in the processing centre using low-cut filters. The question is, if we can otherwise suppress low-frequency noise without wasting good information?

In fact, for converted waves, it is sometimes difficult to record data until a substantial offset was reached (Fig. 1). However, with the advent of 24-bit recording systems, it is possible to record signal in the presence of high-amplitude noise. It may be realistic to record signals at least 80 dB down or 10,000 times smaller from the noise (Bertram, 1991). Recovery of this very broad-band signal may provide more compact wavelets, more focused migrations, and improved estimation of long-wavelength velocity trends from seismic inversion. This will be extremely useful for conventional as well as shear-wave data. Low-frequency geophones are used in crustal seismology and earthquake. The characteristics of a 1-Hz geophone are shown in Figure 2.

The objetive of this current study is to determine if recording high-fidelity, broad-band seismic data can produce better P-wave and P-S wave seismic sections. We are interested in the effect of broader band recordings on: wavelet character (length, compactness), time resolution, smart interpolation, velocity analysis, statics, deconvolution, S/N, lateral resolution before and after migration, and long-wavelength velocity estimates from inversion.

LOW-FREQUENCIES AND SEISMIC PROCESSING

Vertical Resolution

One of the basic challenges in seismic processing is to obtain the most compact wavelet to give the sharpest subsurface image for interpretation. It is well known that

the time duration of a wavelet is inversely related to its bandwidth. Then we generally want to acquire and preserve maximum broad-band. The Fig. 3 shows some zero-phase wavelets and its relation with the bandwidth. By other hand, the importance of the low-frequencies in the vertical resolution.is shown in the Fig. 4 In (a) is shown a reflectivity time series that consist on two spikes at 0.09 s and 0.11 s, respectively. The convolution of this reflectivity pair with two zero-phase Ormsby wavelets of 1-2-50-60 Hz and 10-15-50-60 Hz are indicated in the Figs. 4(b,c). There is not a huge difference in the results. However, a detailed inspection shows that the convolution in (c) gives well defined troughs near 0.08 s and 0.13 s. An interpreter or sparse spike operator could easily find a solution such as shown in (d).

Deconvolution

Figure 5 shows an example of the effect of the low-frequencies on spiking deconvolution. All the deconvolution test used the same operator length, 80 msec. In (a) is shown the spike time section that represents the modeled reflections, while (b) represents the convolution of the reflectivity with a zero-phase Ormsby wavelet (1-2-50-60 Hz). The Figs. 5 (c-e) show the deconvolved sections using different frequency spectra for this zero phase-wavelet : 1-2-50-60 Hz, 10-15-50-60 Hz and 20-25-50-60 Hz, respectively. The associated autocorrelations are displayed just below. It is evident from these Figures that when the low-frequencies are lost, spiking deconvolution tends to create amplitude deformations on the deconvolved wavelet, In particular, the reflection at 150 ms on the input section appears now as strong as the reflection at 110 ms. In all cases, spiking deconvolution failed to distinguish the two most shallow reflections. The autocorrelograms reveal that the deconvolution on a time section obtained with a zero phase wavelet 1-2-50-60 Hz represents the most clear autocorrelation. In fact, the last autocorrelogram shows a strong autocorrelation near to 35 msec that would be interpreted as some type of noise on the input section (Yilmaz, 1987).

Inversion

The final issue to test is the influence of the low-frequencies on a post-stack inversion. Figure 6(a) shows velocity information obtained from an actual productive well in Venezuela. The section between 2.1s-2.8s had abnormal pressures. The last portion of this well shows a calcareous formation used as seismic marker in this area. The reflectivity series generated from logs in this well is displayed in Figure 6(b). This reflectivity was convolved with two zero-phase Ormsby wavelets 0-0.1-75-80 Hz and 5-10-75-80 Hz. The associated post-stack inversions for recovering the velocity information contained in the input time section are shown in (c) and (d). The inversion method used was bandlimited inversion (or recursive) but similar conclusions can be obtained using other post-stack inversion methods. It is evident from both results that it is critical to include low-frequencies in the seismic signal. Although not shown here, the loss of 1 Hz in the low-frequency end is enough to eradicate the velocity trend in the pseudo-sonic estimate. This point is well known and most inversions have a procedure to include low-frequency data in their results. (Lindseth, 1979; Oldenburg and Stinson, 1984). But there are always limitations in these externally supplied trends.

CONCLUSIONS

This results some aspects that would be improved during the seismic processing if broad-band signals were acquired. Recovery of this very broad-band signal may

provide more compact wavelets, better vertical resolution and definition of the parameters involved in deconvolution, and more realistic pseudo-sonic estimates.

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Oldenburg, D.W., Levy, S., and Stinson, K.J., 1984, Root-mean-square velocities and recovery of the acoustic impendance: Geophysics, 49, 1653-1663.

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Window of resolution
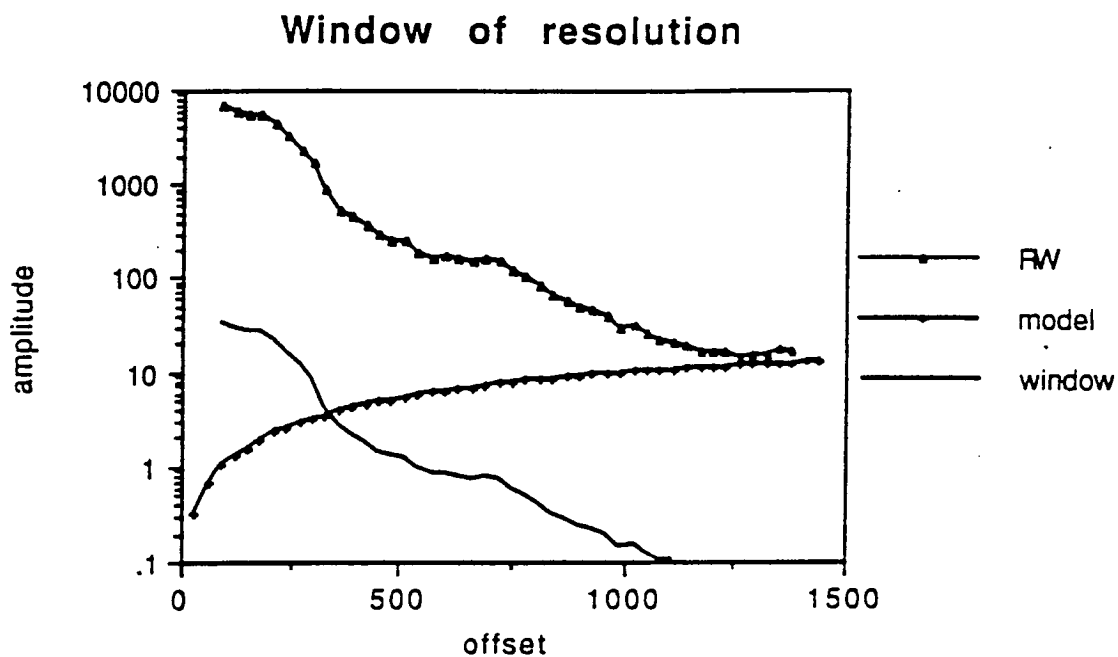
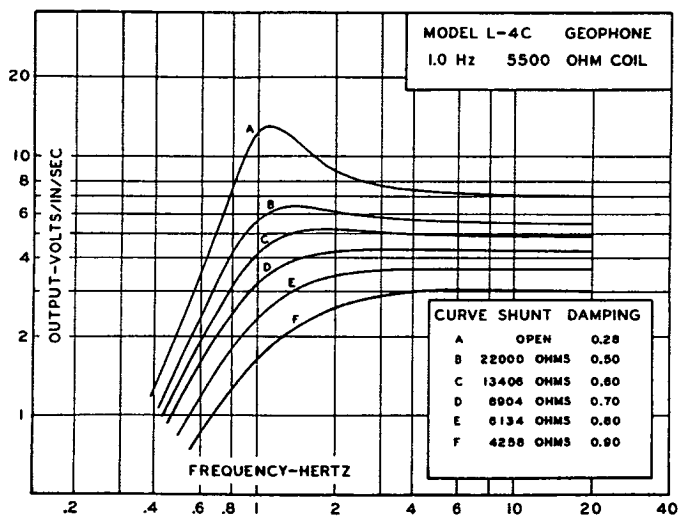FIG. 1. Window of resolution plotted against modelled P-SV amplitudes (From Bertram, 1991).

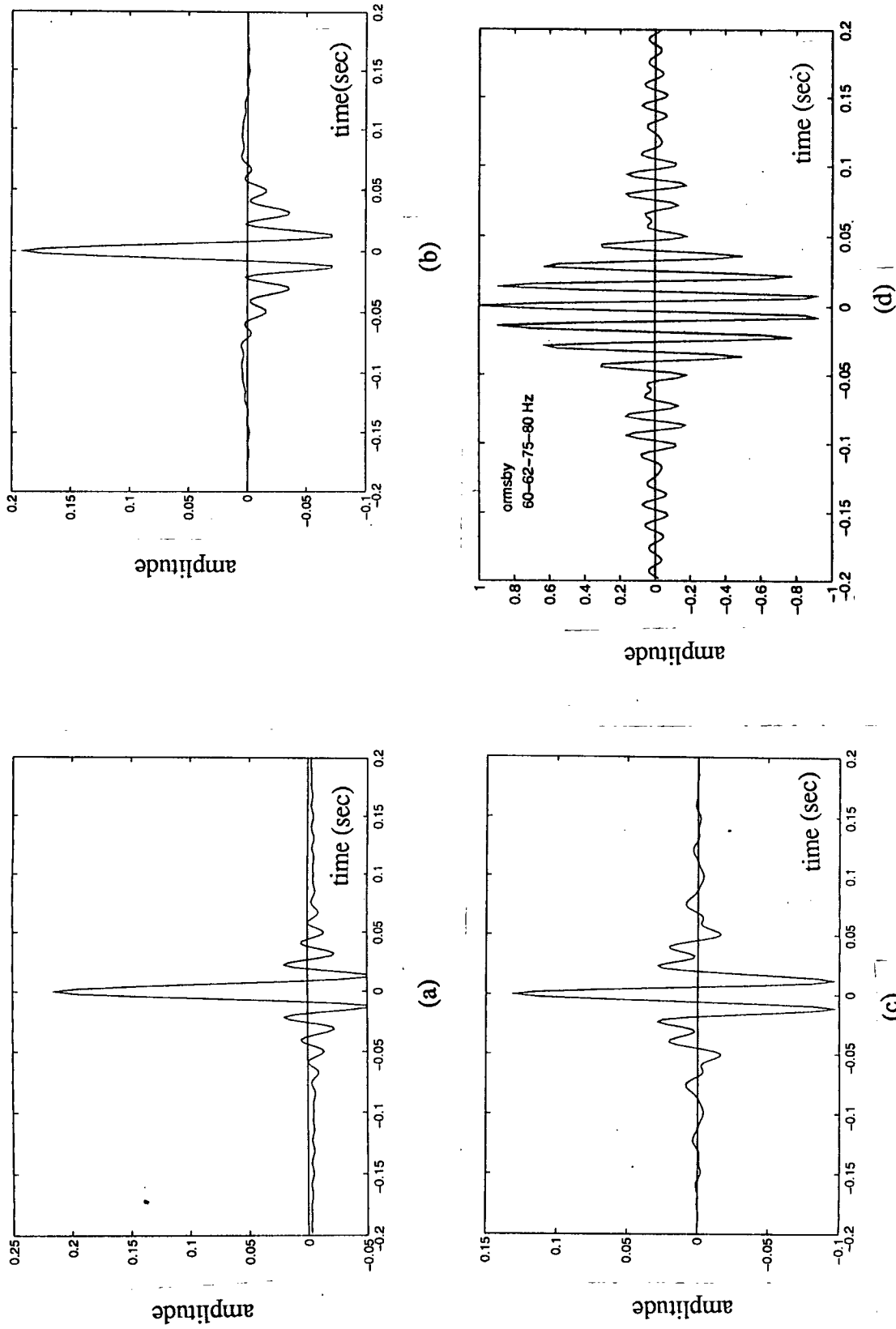FIG. 2. Curve shunt damping corresponding to a commercial 2Hz low frequency geophone.

FIG. 3. Some zero-phase wavelets as functions on band-width. In this order: (a) 1-2-50-60 Hz, (b) 10-15-50-60 Hz, (c) 20-25-50-60 Hz, and (d) 50-55-75-80 Hz.
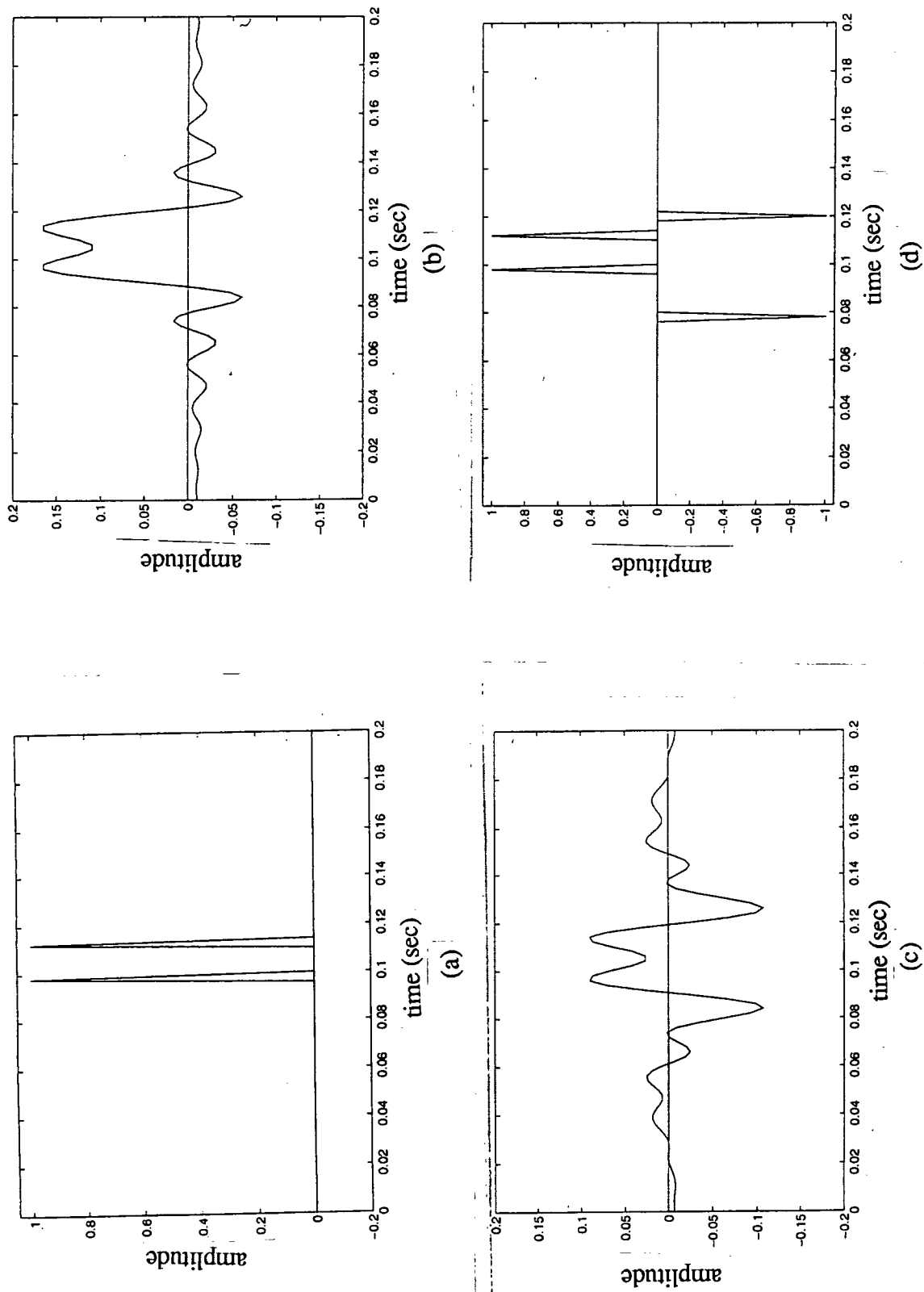
FIG. 4. Vertical resolution and band-width for two zero-phase Orsmby waveletes.
(a) Reflectivity serie,
(b) Convolution with a wavelet 1-2-50-60 Hz,
(c) Convolution with a wavelet 10-15-50-60 Hz, and
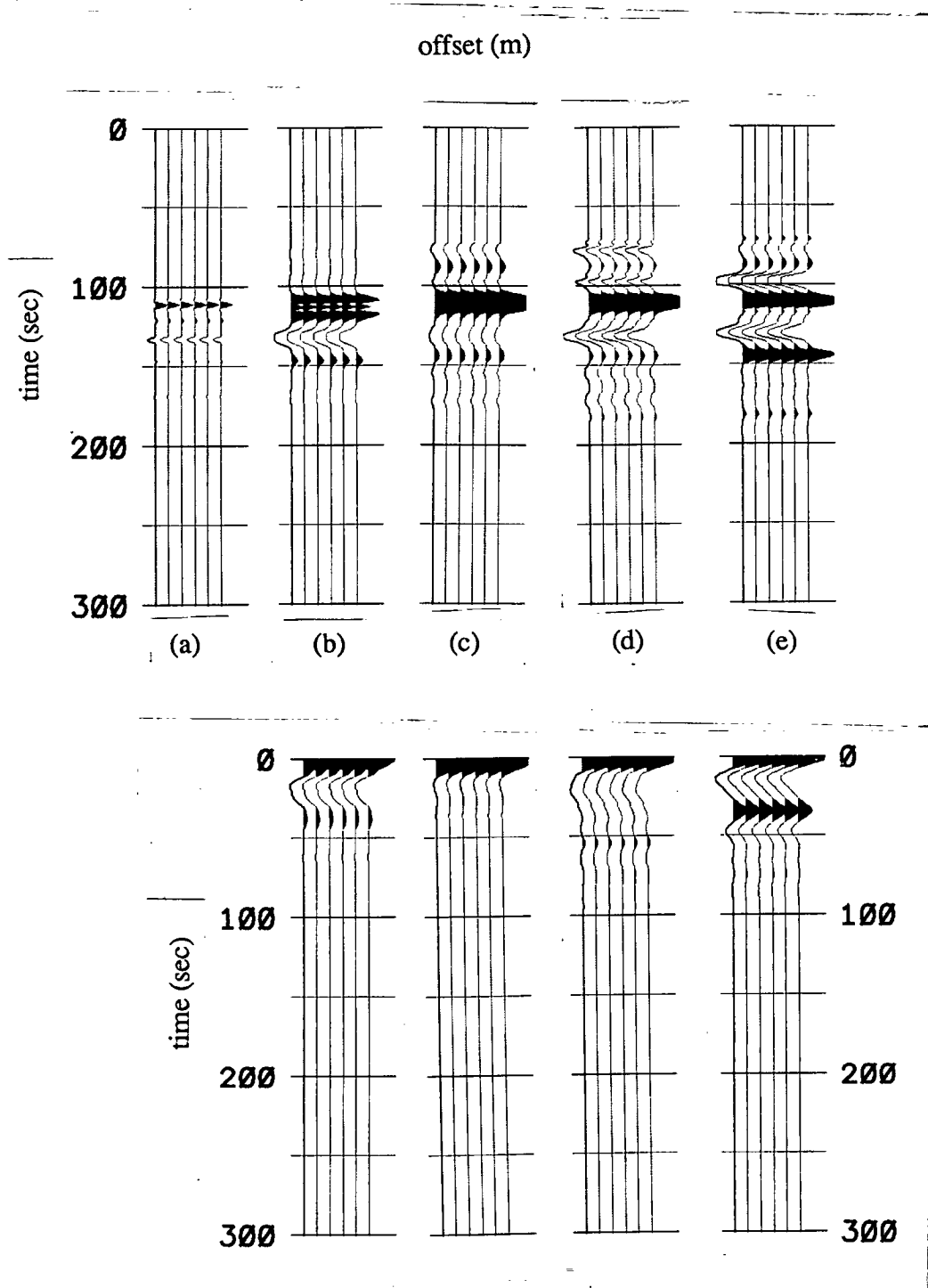(d) Wrong reflectivity series from interpretation on result in (c).

offset (m)

FIG. 5. Synthetic example that shows the improvement on spiking deconvolution if are includede low frequency information. Autocorrelograms are shown just below.
(a) Spike section,
(b) Convolution with a zero-phase wavelet 1-3-50-60 Hz,
(c) Deconvolved output obtained from (b), and
(d) and (e) Spiking deconvolutions for wavelets 10-15-50-60 Hz and 20-25-50-60 Hz, respectively.
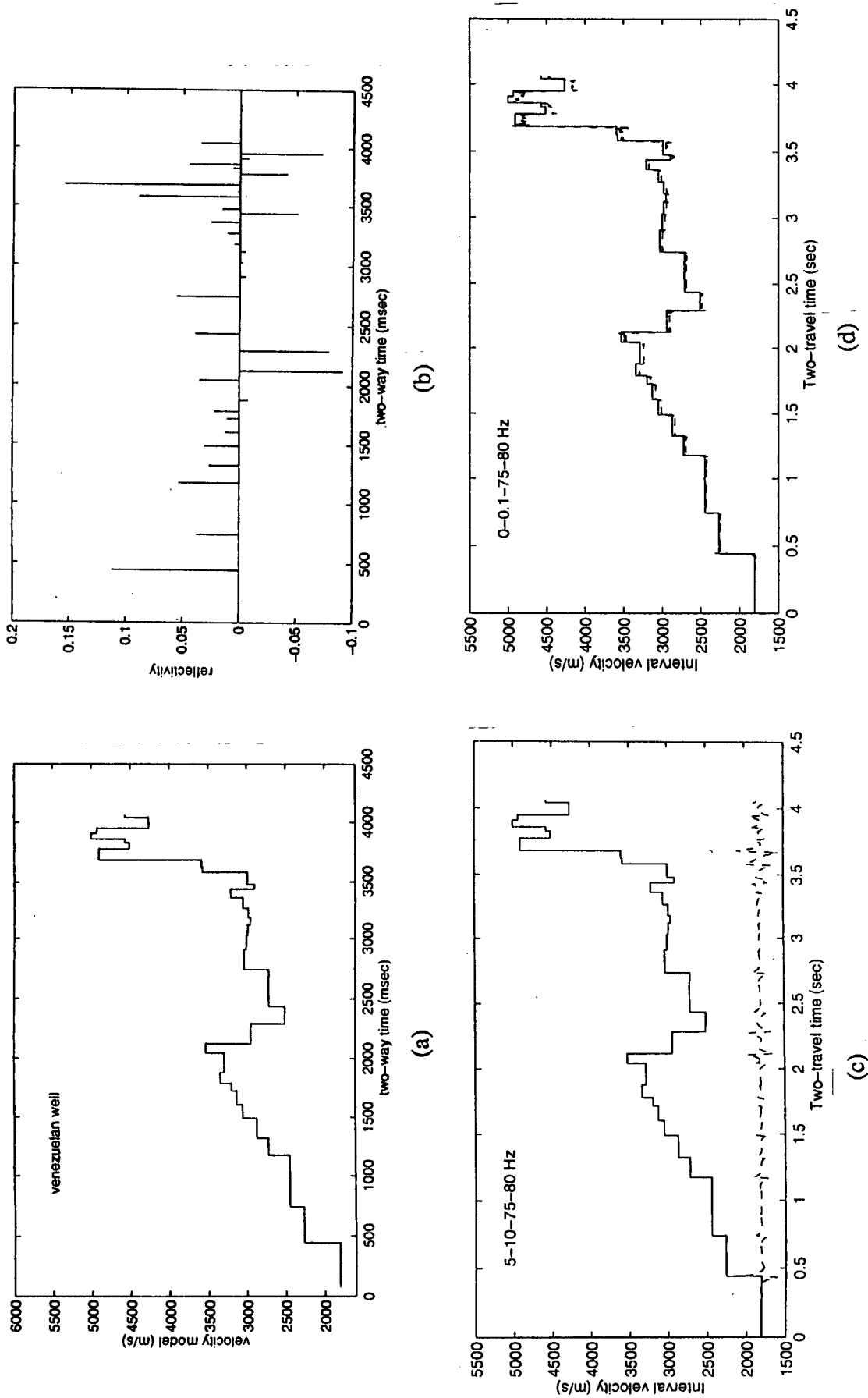
FIG. 6. Post-stack inversion seismic and low-frequency signals. (a) Velocity information from a well in Venezuela. (b) Refelctivity serie in time. (c) Pseudo-sonic estimated from convolution reflectivity with a zero-phase wavelet (5-10-75-80 Hz) as indicated in broken lines. (d) Inverted velocity using a wavelet 0-0.1-75-80 Hz.