DMO applied

Shuki Ronen

Introduction

DMO is the operator that should be applied, in addition to normal move-out, to extrapolate non zero offset seismic data to the data we would record, had we performed a zero offset experiment. It was shown that the DMO affects the spatial resolution of the stack (Rocca and Ronen, 1982). The resolution is improved by compensating for under sampling in the mid-point direction with the redundancy in having some offsets while only one is needed to describe the earth. This report gives intermediate results of applying DMO to land data with some statics and strong velocity variations. The DMO that was applied used a finite differencing algorithm. (Bolondi et al, 1983; Salvador and Savelli, 1983; Ronen, 1983)

Accuracy of DMO by finite differencing

The impulse response of the finite differencing operator (Ronen, 1983) was found to be

$$t_f = t_n \exp\left(-\frac{x^2}{2h^2}\right) \tag{1}$$

Where t_n is the NMO time:

$$t_n^2 = t_h^2 - \frac{4h^2}{v^2} \tag{2}$$

t_h is the time before NMO. The exact response of DMO, (Deregowski and Rocca, 1981), is

$$t_e = t_n \left(1 - \frac{x^2}{h^2}\right)^{1/2} \tag{3}$$

The error in travel time is controlled by x/h. To find an upper bound to this quantity, x/h, differentiate (3)

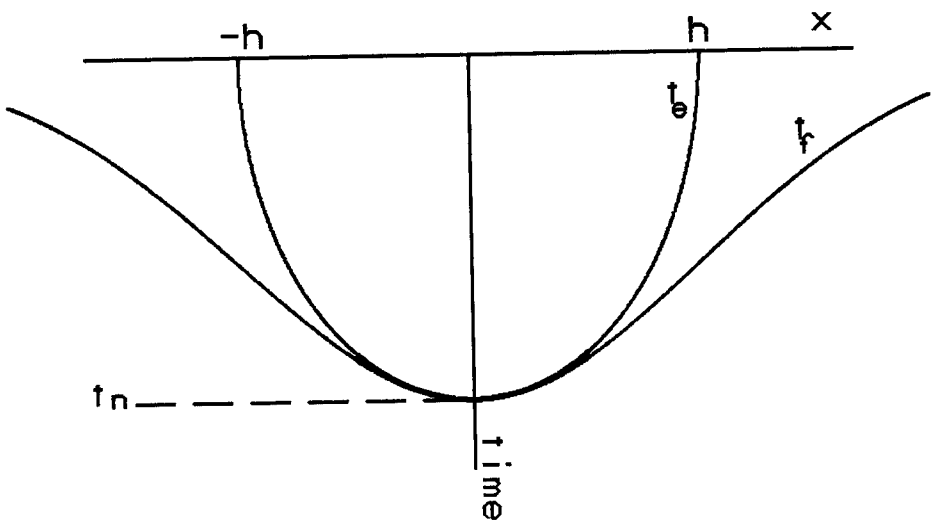

FIG. 1. Exact and approximate impulse responses.

$$\frac{dt_e}{dx} = -\frac{xt_n^2}{t_e h^2} = -\frac{xt_n}{h^2}\left(1-\frac{x^2}{h^2}\right)^{-1/2} \tag{4}$$

Hence,

$$\frac{x^2}{h^2} = \left[1+\left(\frac{dx}{dt_e}\frac{t_n}{h}\right)^2\right]^{-1}$$

Substituting $t_n(t_h,v,h)$, from equation (2),

$$\frac{x^2}{h^2} = \left[1+\left(\frac{dx}{dt}\frac{t_h}{h}\right)^2-\left(\frac{2}{v}\frac{dx}{dt}\right)^2\right]^{-1} \tag{5}$$

If the dip of the reflector is θ, then the reflector on the zero offset section has arrival time with $dx/dt = v/2\sin\theta$. The smile (3) has the dip of the reflector at the midpoint x, given by

$$\frac{x^2}{h^2} = \left[1+\left(\frac{vt_h}{2h\sin\theta}\right)^2-\frac{1}{\sin^2\theta}\right]^{-1} \tag{6}$$

This is consistent with the familiar cutoff (Deregowski and Rocca, 1981) of the smile operator, that allows dips up to $\theta = 90°$

$$\frac{x}{h} = \frac{2h}{vt_h} \tag{7}$$

The ratio h/t_h is bounded by the mute, that does not allow NMO stretch above a certain value $s \approx 1.5$. The stretch is the derivative of (2):

$$s < \frac{dt_n}{dt_h} = \left(1 - \frac{4h^2}{v^2 t_h^2}\right)^{-1/2}$$

Therefore

$$\left(\frac{2h}{vt_h}\right)^2 < 1 - \frac{1}{s^2} \tag{8}$$

Equation (8), substituted in (6), then in (1) and (3), provides an upper bound to the travel time error as a function of the dip θ and the NMO stretch s. This bound is plotted at Figure 2. This analysis deals with the travel time and not with the amplitude of the impulse response. Also, equation (9) is obtained from the differential equation and not from the finite difference equation. So, there are other errors, not covered by this analysis.

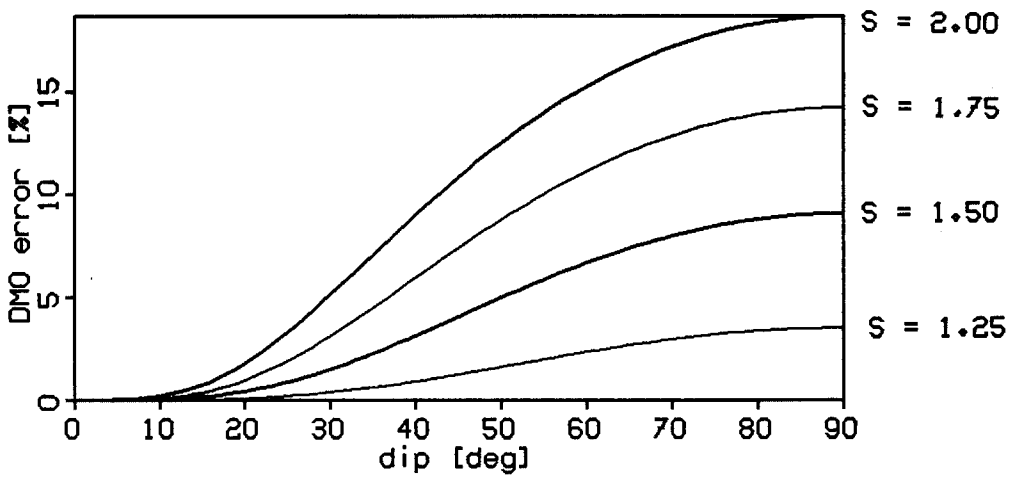

FIG. 2. Relative error in finite difference DMO, as a function of dip and mute.

The cutoff (7) is done by dip-filtering. Here the gaussian shape of the response is problematic, since the tails of the gaussians have small dip although they should be cut off. Dip-filtering before DMO, as Fabio Rocca suggested, seems to take care of this problem, (Figure 5).

DMO results

Field and residual statics were applied to the data. NMO with an estimated earth velocity profile was performed before DMO. The dipping events were over NMO-ed, but the DMO corrected them, (Figure 8). Because of the geometry of the survey, three zero traces are between each two data traces on every common offset section input to the DMO, (Figure 6).

Conclusions

(1) The zero traces, on every common offset section, are interpolated. There is noise resulting from the midpoint under-sampling of the section, this noise will mostly stack out.

(2) The finite differencing DMO is accurate for moderate dips and below the mute.

(3) Dip-filtering prior to DMO is better than after DMO.

REFERENCES

Bolondi, G., Loinger, E. and Rocca, F., 1982, Offset continuation of seismic sections. Geophysical Prospecting v. 30, p. 813-828.

Deregowski, S. M. and Rocca, F., 1981, Geometrical optics and wave theory of constant offset sections in layered media. Geophysical Prospecting v. 29, p. 374-406.

Hale D., 1983, DMO by Fourier transform, Ph.D. thesis, Stanford.

Rocca, F. and Ronen, S., 1982. Stacking smiles, SEP-32.

Ronen, S. and Rocca, F., 1982. Why dip move out, SEP-32.

Ronen, S., 1983. DMO by finite differencing. SEP-35.

Salvador, L. and Savelli, S., 1982, Offset continuation for seismic stacking. Geophysical Prospecting v. 30, p. 829-849.

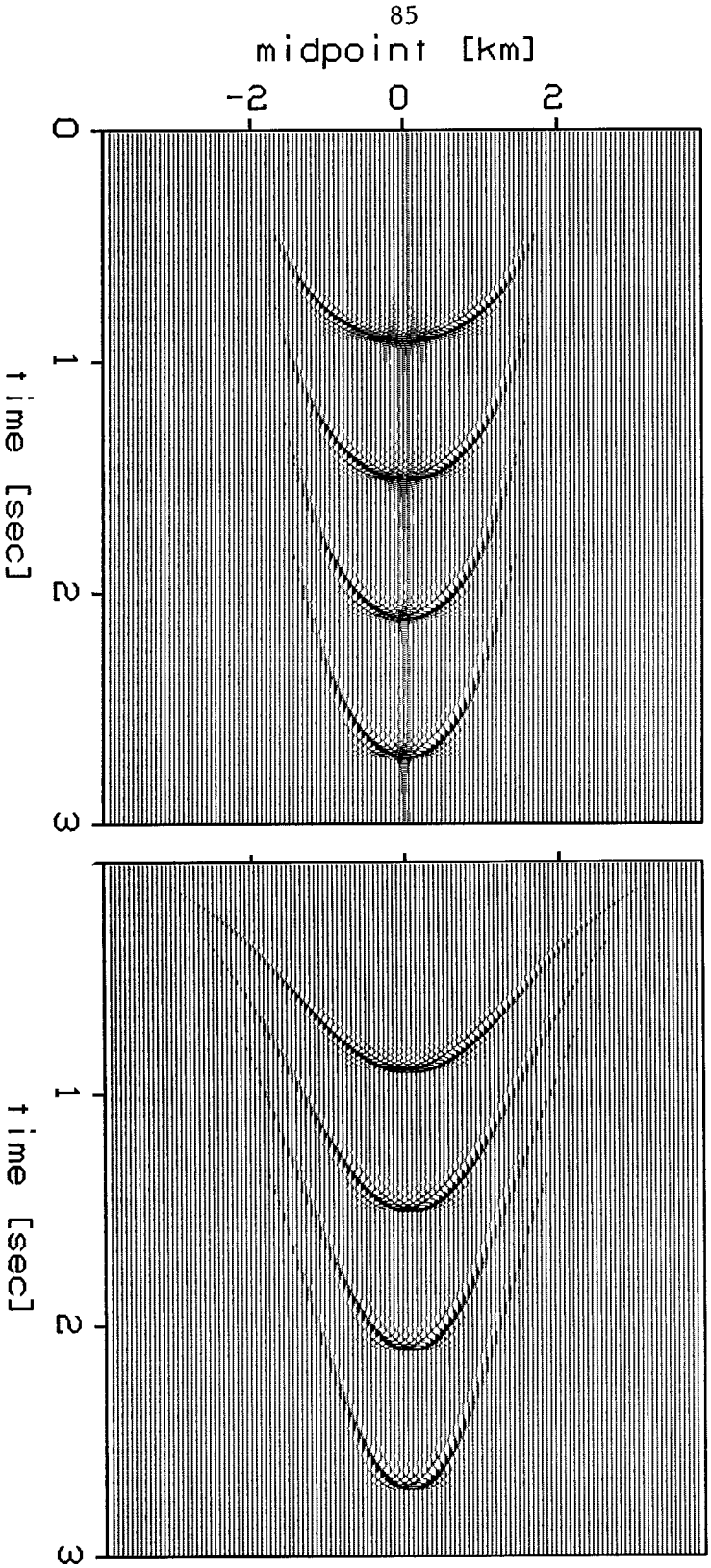

FIG. 3. Exact (above) and approximate (below) impulse responses. The offset is 3.84 km. No dip-filter was applied, to make the differences more visible. Generation of these examples took 300 seconds in the array-processor for the exact, and 40 sec for the approximate. The time of the approximate is much shorter for the near offsets. (The cost is square with offset). The exact DMO was done with Dave Hale's program, (Hale, 1983).

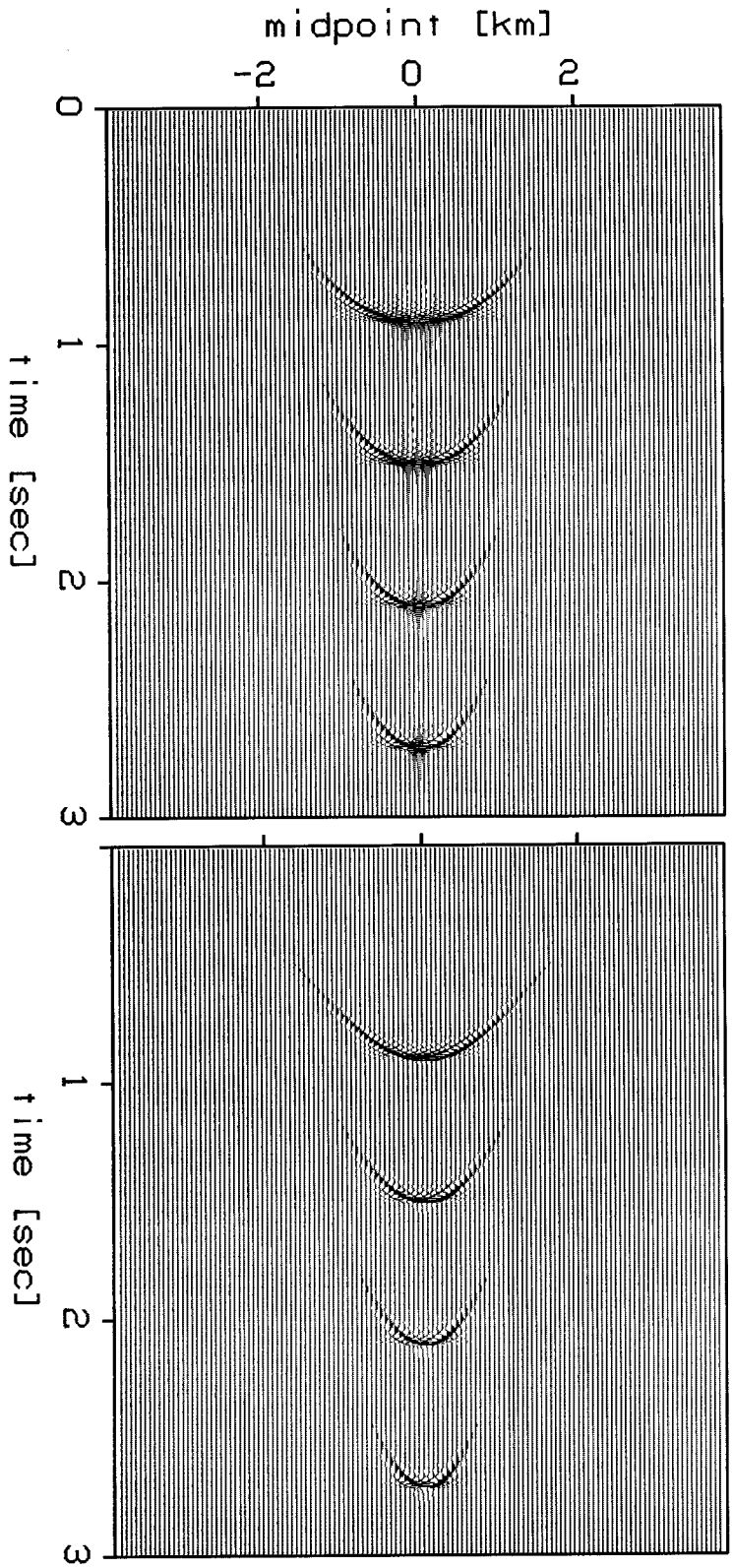

FIG. 4. Exact (above) and approximate (below) impulse responses. With dip-filter. The velocity is 2 km/sec.

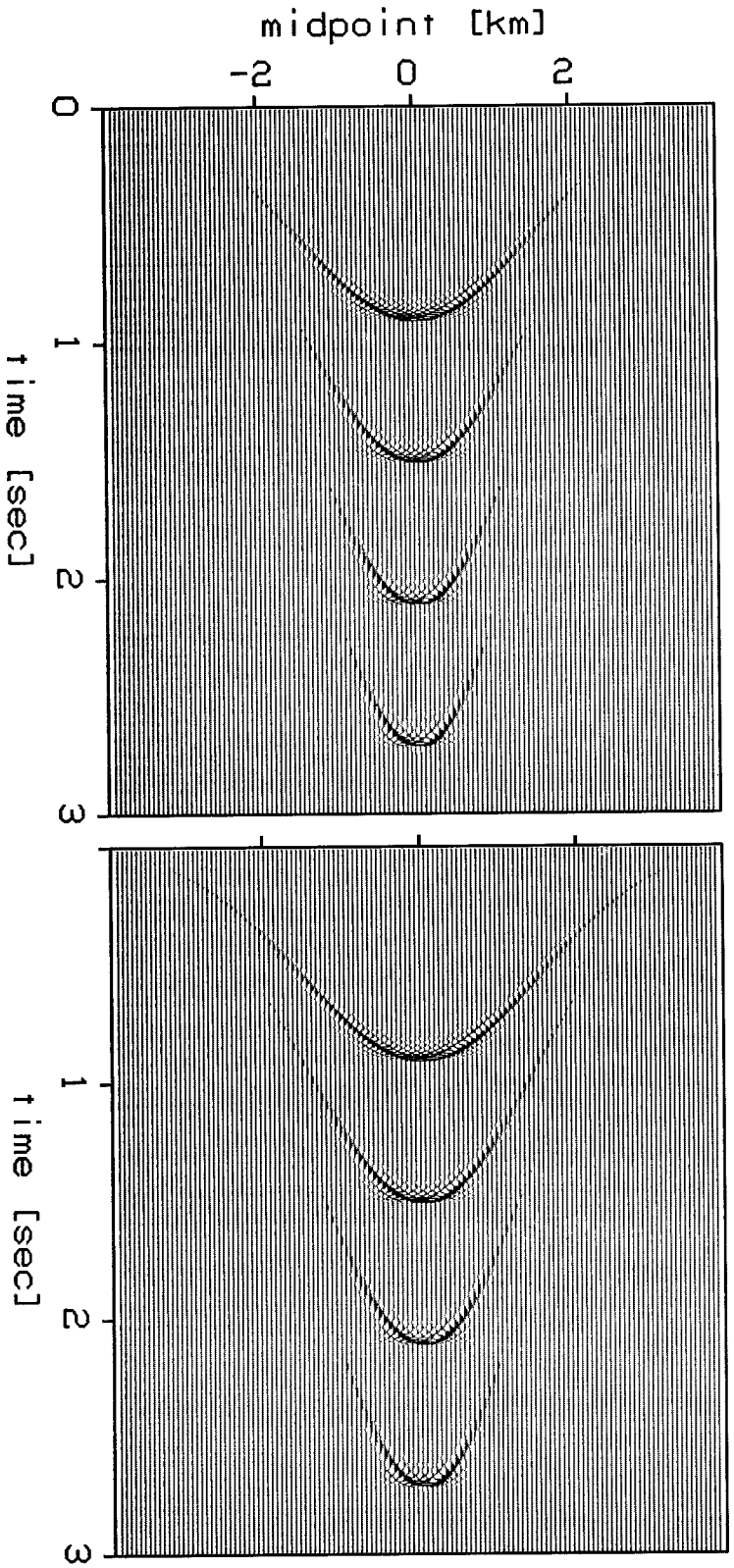

FIG. 5. Dip-filter before DMO (above) and after DMO (below). The velocity is reduced to 1 km/sec, to make the differences visible.

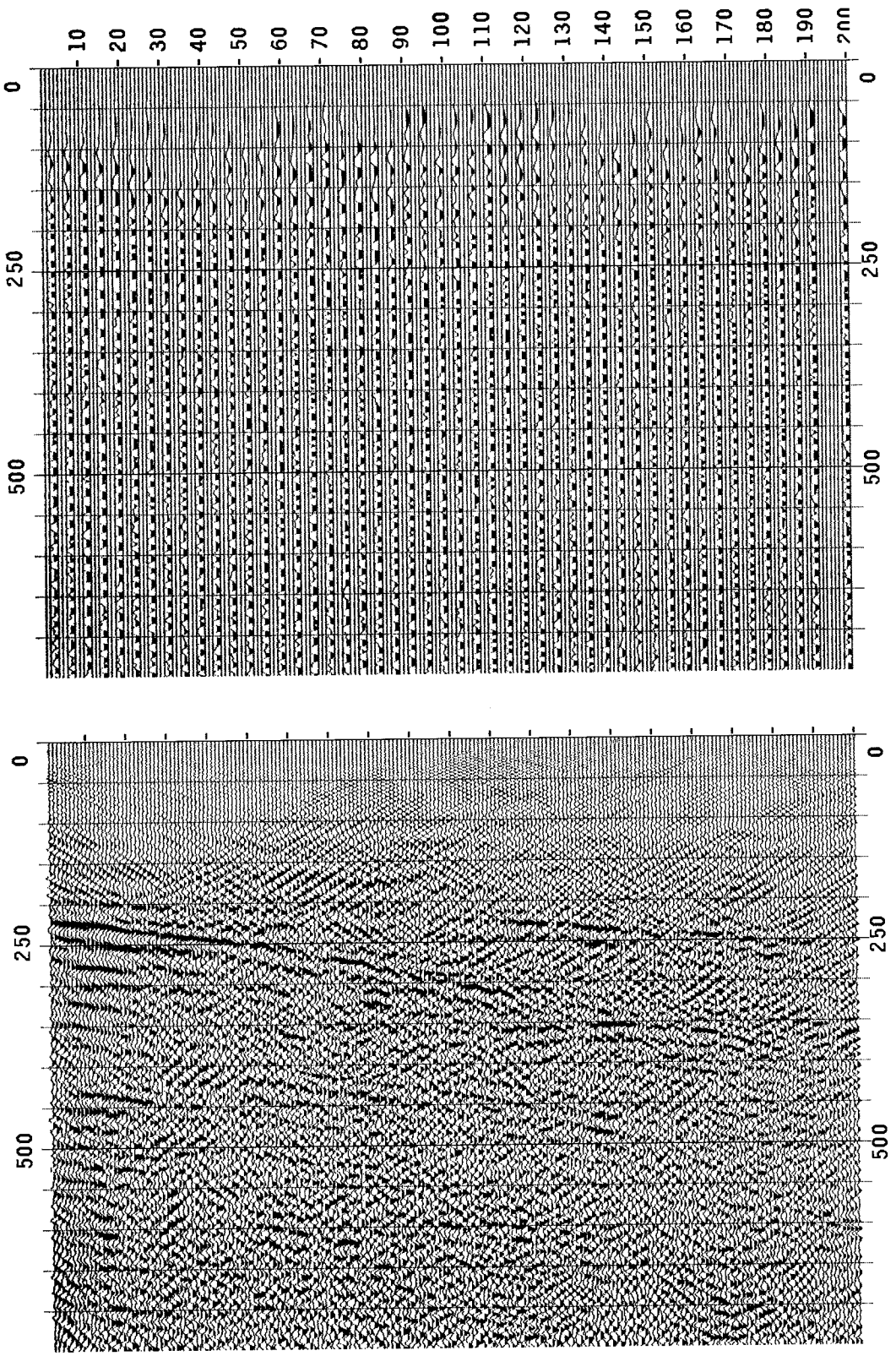

FIG. 6. One common offset section before (above) and after (below) DMO. The zero traces are interpolated. The noise is expected to stack out.

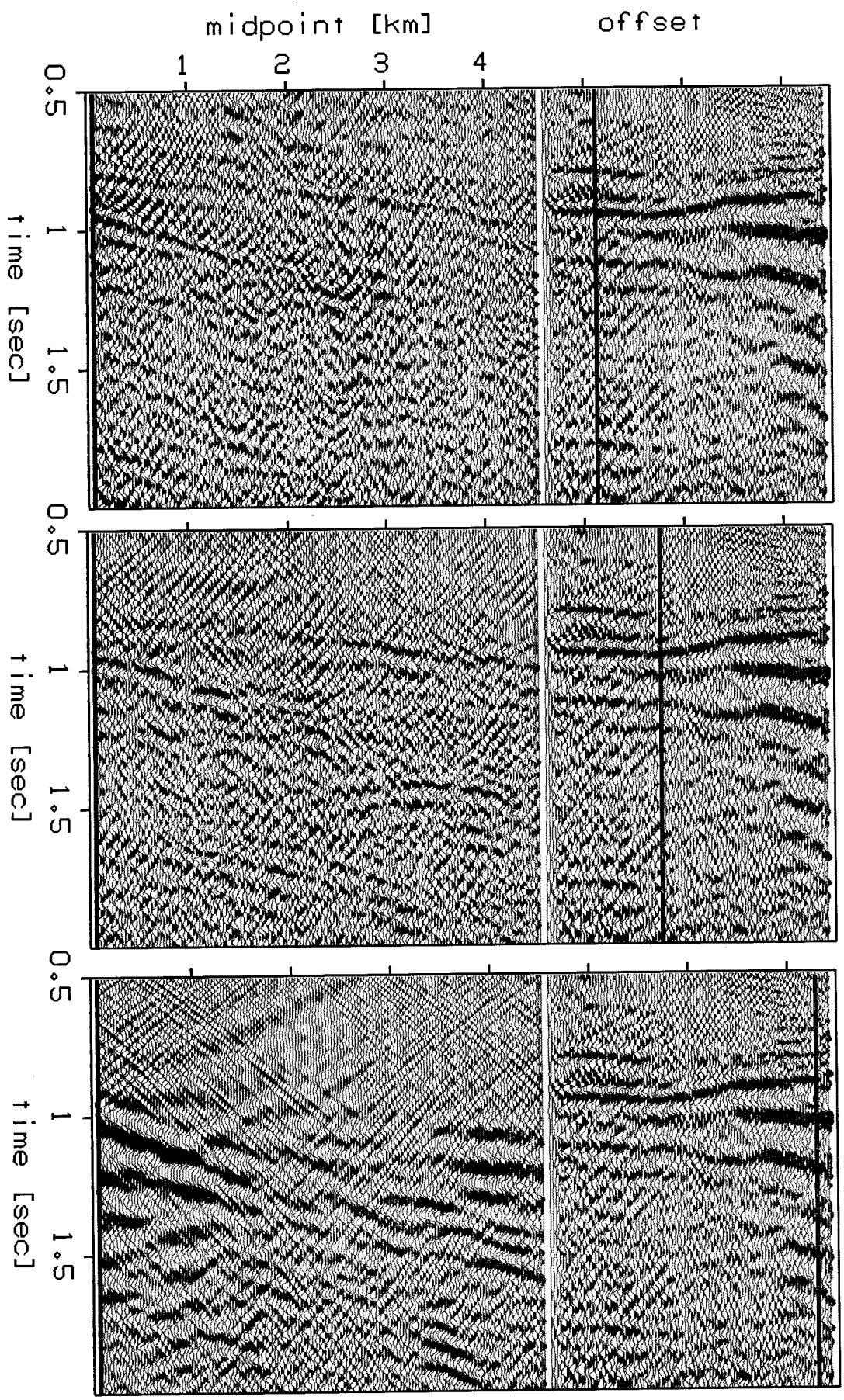
midpoint [km]
offset
1
2
3
4
0.5
1
1.5
time [sec]
0.5
1
1.5
time [sec]
0.5
1
1.5
time [sec]

FIG. 7. (Opposite page) Near offset (above) to far offset (below). The mute zone will reach 1.5 sec at the far offset. The pinch-out is stationary except in the far offsets, where the upper event is a refraction and treated uncorrectly by the DMO.

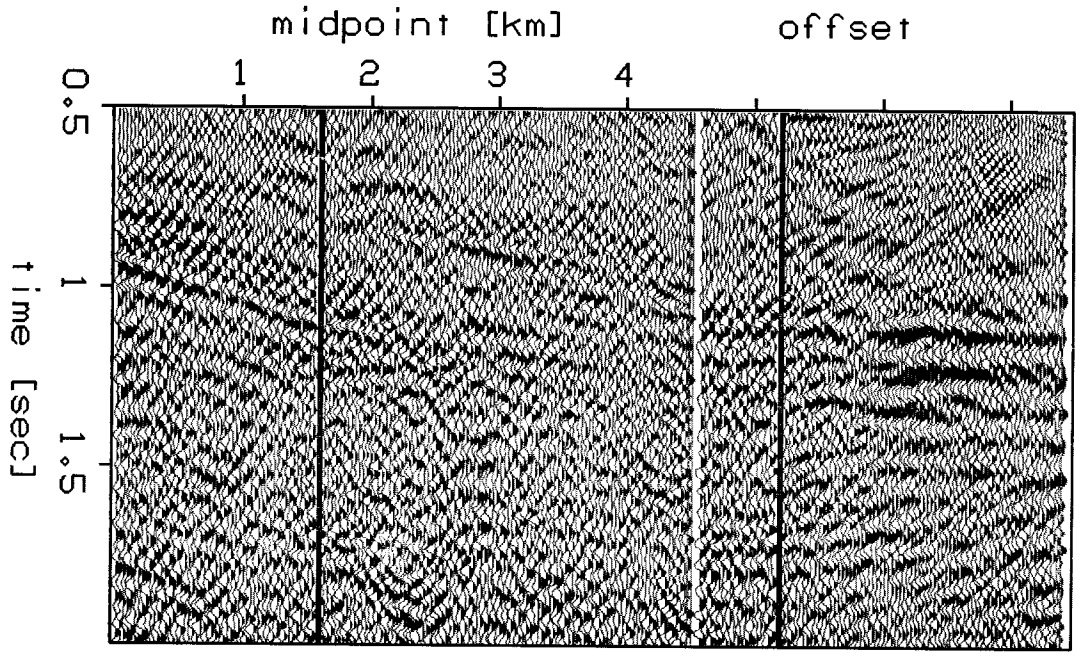

FIG. 8. Left: Common offset section. Right: Common mid point gather. The vertical black lines denote the intersection. NMO with an estimated earth velocity profile, then DMO were applied. The event at 1.1 sec on the gather was over NMO-ed but corrected with the DMO. Events at 1.7 sec are over NMO-ed because the estimated earth velocity was too low.