Improving the Quality of Slant Stacks by Extrapolating Missing Offsets

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The quality of slant stacks is crucial for their use in imaging schemes. When certain offsets in a gather are absent, a slant stack of that gather may contain false noise events and misplaced actual events. Techniques published in recent SEP reports have been used to extrapolate near, wide, and in-between offsets to greatly improve the quality of slant stacks.

Missing Data Artifacts

Schultz described missing data artifacts in SEP-8. The synthetic example in figures 1 to 4 exhibit the following types of artifacts:

(1) Linear streaks due to cable truncation.

(2) Event limbs appearing at wrong times due to missing near and wide offsets.

(3) Linear streaks due to aliased offset sampling.

On a conventional 48 trace slant stack gather (figure 7), aliasing noise is often the predominant artifact. When such noise is reduced by interpolating offsets (figure 8), then misplaced event limbs can be a major problem.

Extrapolation Techniques

Figure 5 is the 47 trace source gather. (It is the same one used by Schultz in his 1980 SEG talk on slant stack velocity estimation.) Various techniques were used to extrapolate a 231 trace gather (figure 6) from this dataset. The widest extrapolated offset is about ten per cent further out than the original gather. The techniques used were:

(1) Interpolating three offsets between each existing offset by tilting a one dimensional cubic spline along the event dip (Hale, SEP-25); The event dip was predicted

from depth variable rms velocity hyperbolas.

(2) Extrapolating extra near and wide offsets by autoregressive prediction (Clayton, personal communication; Thorson this SEP); A Burg algorithm predicts laterally after the data has been made more stationary by a time Fourier transform. (Near: 30 source offsets, 25 extrapolated offsets, 8 Burg coefficients; Wide: 50 source offsets, 40 extrapolated offsets, 15 Burg coefficients.) This method works well only with linear events. Normal moveout was used to linearize the near offset events, while an offset squared - time squared stretch (Ottolini, this SEP report) was used to linearize the wide offset events.

Results

Figures 7 to 9 are the slant stacks of Schultz's dataset for various degrees of extrapolation. Since there was no extrapolation done in the first case, figure 7 exhibits the various slant stack artifacts. Figure 8 was made from a gather with in-between offsets extrapolated. Aliasing noise is greatly reduced. However, event limbs appear at wrong time values for low p values because of missing near offsets. This problem is mostly rectified in figure 9 where near and some far offsets had been extrapolated in the source gather. Also the cable truncation streaks going from the lower left to upper right in figures 7 and 8 have been attenuated in figure 9.

Discussion

Schultz's remedy (SEP-8) was to apply tapered weights to the gather before slant stacking to mask out aliased offsets and cable truncation effects. This strategy reduces the amount of data entering the slant stack process. When strong tapering is necessary some of the events in multi-velocity or multi-dip regions may be selected against. On the other hand, my strategy is to preserve all of the original data and extrapolate additional offsets to reduce artifacts. It must be conceded that the normal moveout and event dip prediction parts of my extrapolation techniques may introduce velocity bias, but these can be replaced by other more velocity independent methods.

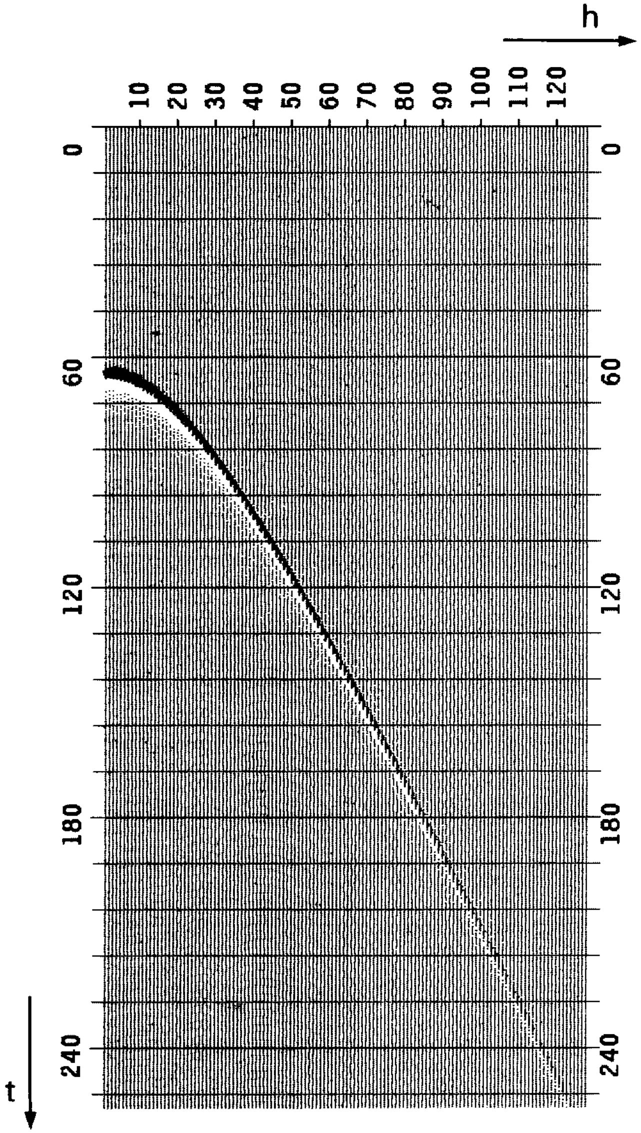

FIG. 1. Synthetic source gather for examining slant stack artifacts. Parameters are: nt=256 nx=128 dt=1. dx=1. v=1. event time=64.

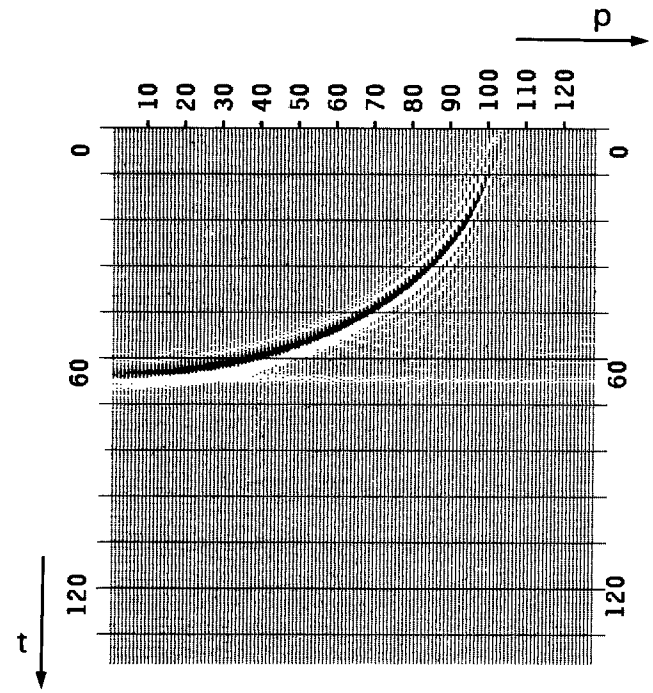

FIG. 2. Reasonably good slant stack of gather in figure 1. Horizontal streak and fainter diagonal streak are truncation artifacts. Parameters are: p1=0. dp=.02

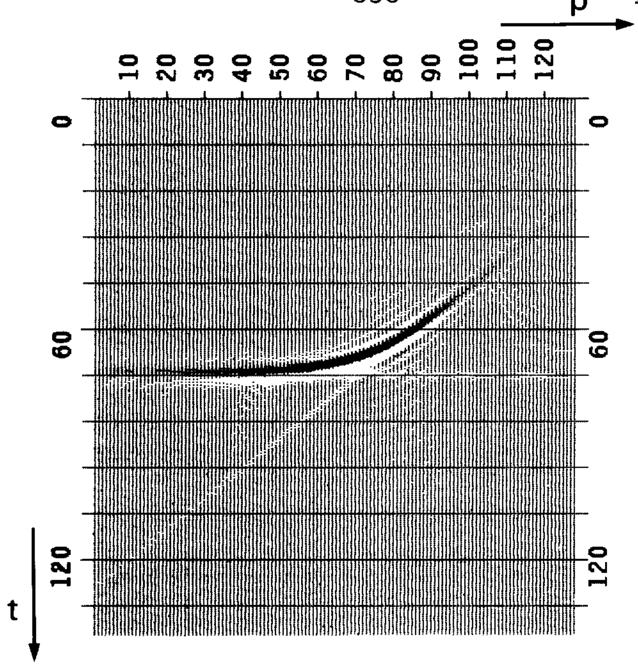

FIG. 3. Slant stack of offsets 15 to 55 from figure 1. Because near and wide offsets are missing, the event does not intercept the axes at the same place as in the superior slant stack of figure 2. Truncation linear streaks also visible.

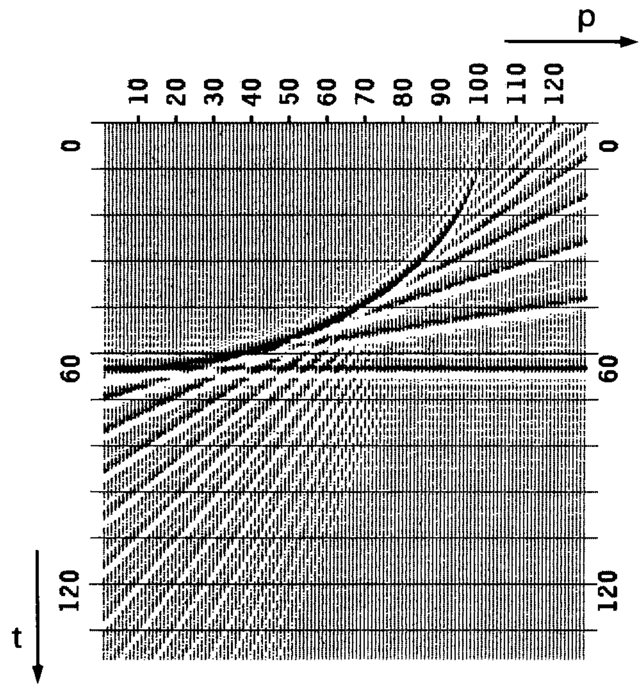

FIG. 4. Slant stack of every eight trace from figure 1. Offset aliasing artifacts are the various diagonal streaks.

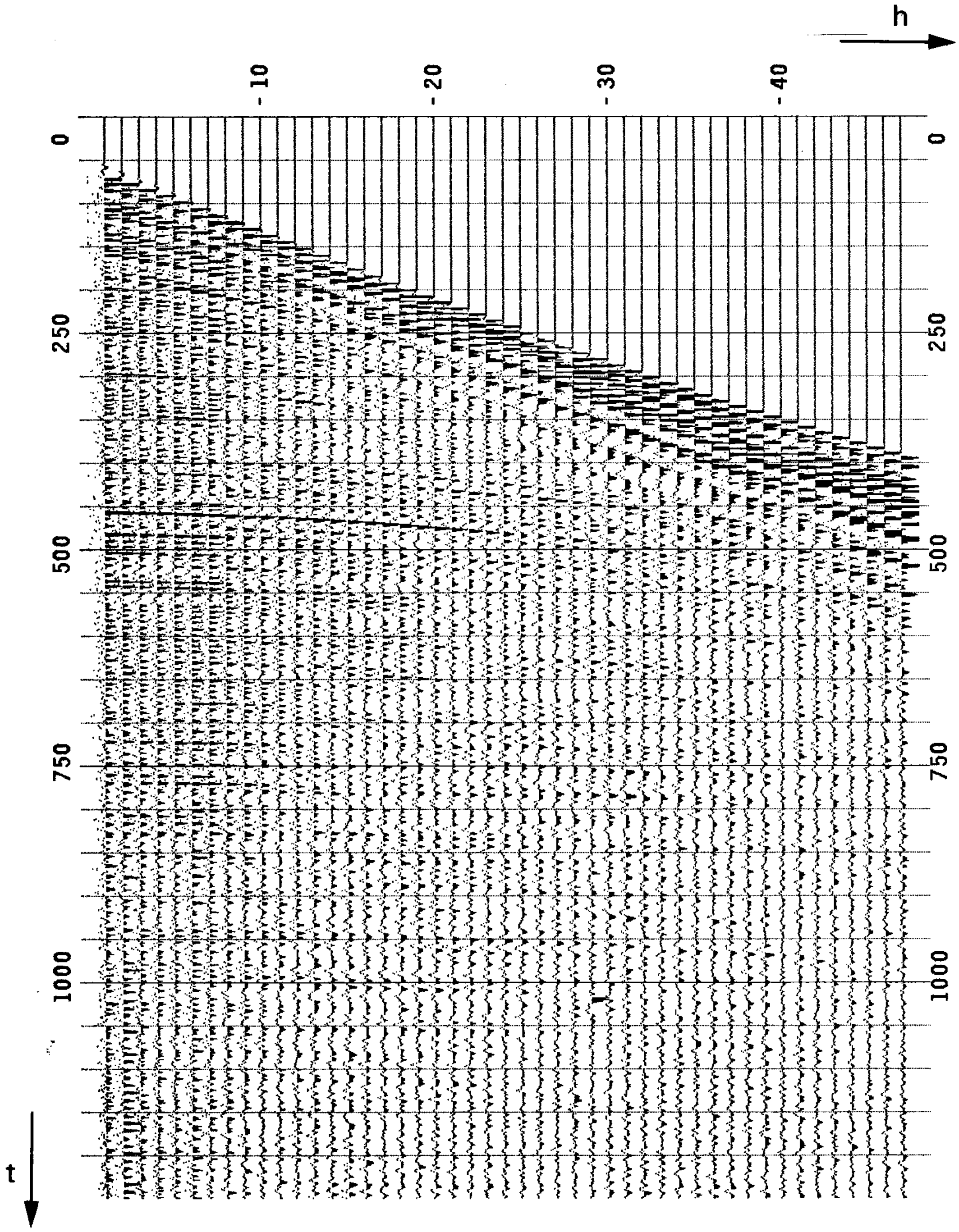

FIG. 5. 47 trace source gather for extrapolation experiments. This gather was given to us by Phil Schultz who used it in his 1980 SEG talk about direct estimation of interval velocities from slant stack gathers. Parameters are: nx=47 nt=1250 dx=.05 x0=.312 dt=.004 vmin=1.5 vmax=4.5

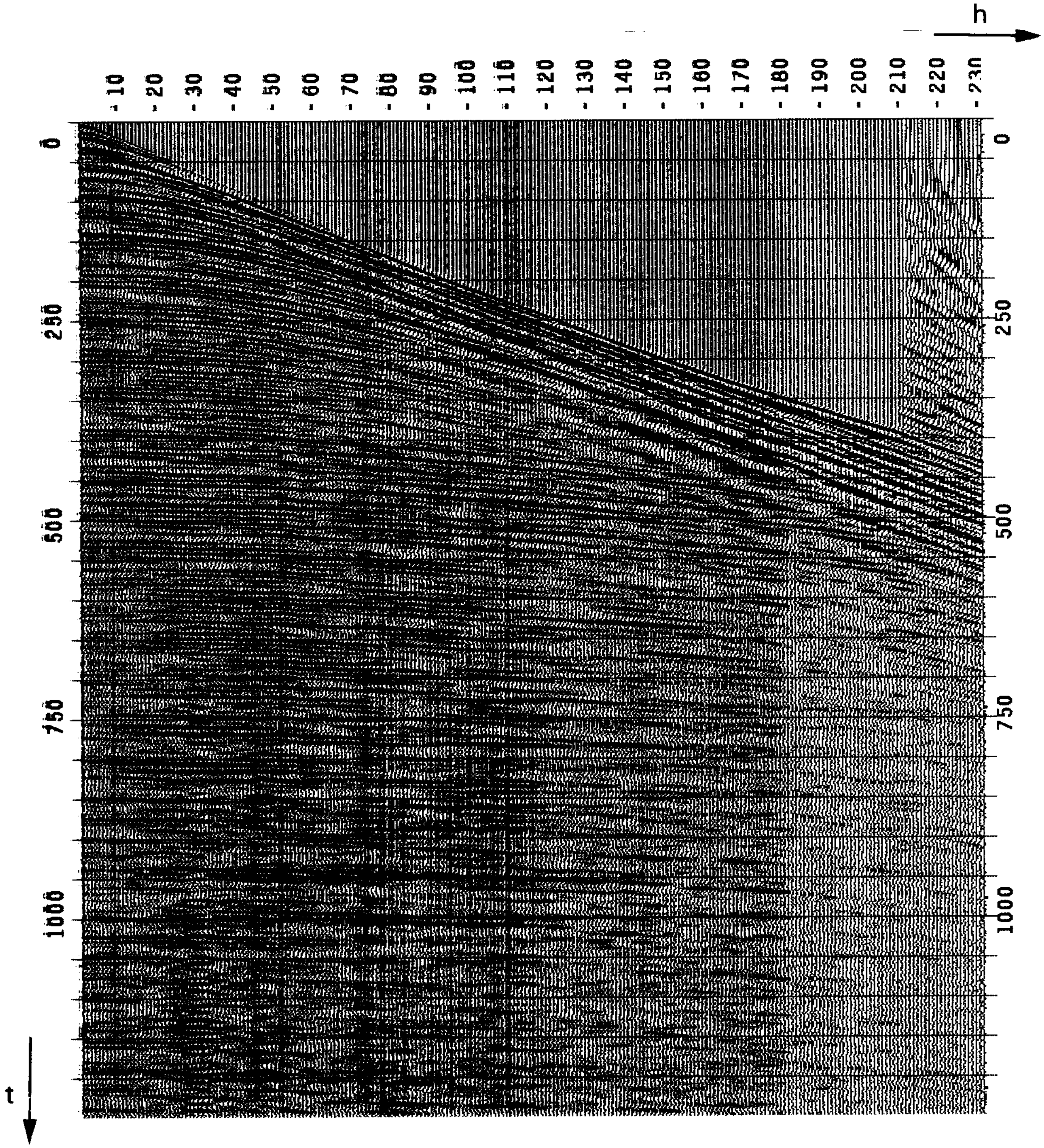

FIG. 6. Gather of figure 5 extrapolated to 231 traces. The original offsets are every fourth offset between 26 and 210. Three offsets were interpolated between each existing offset using tilted interpolation as described in the text. About 20 offsets were extrapolated off each edge using a Burg algorithm. As expected, these techniques do not extrapolate refractions as well. The upper right noise is a frequency domian wrap-around artifact. Parameters are: nx=231 x0=0. dx=.0125

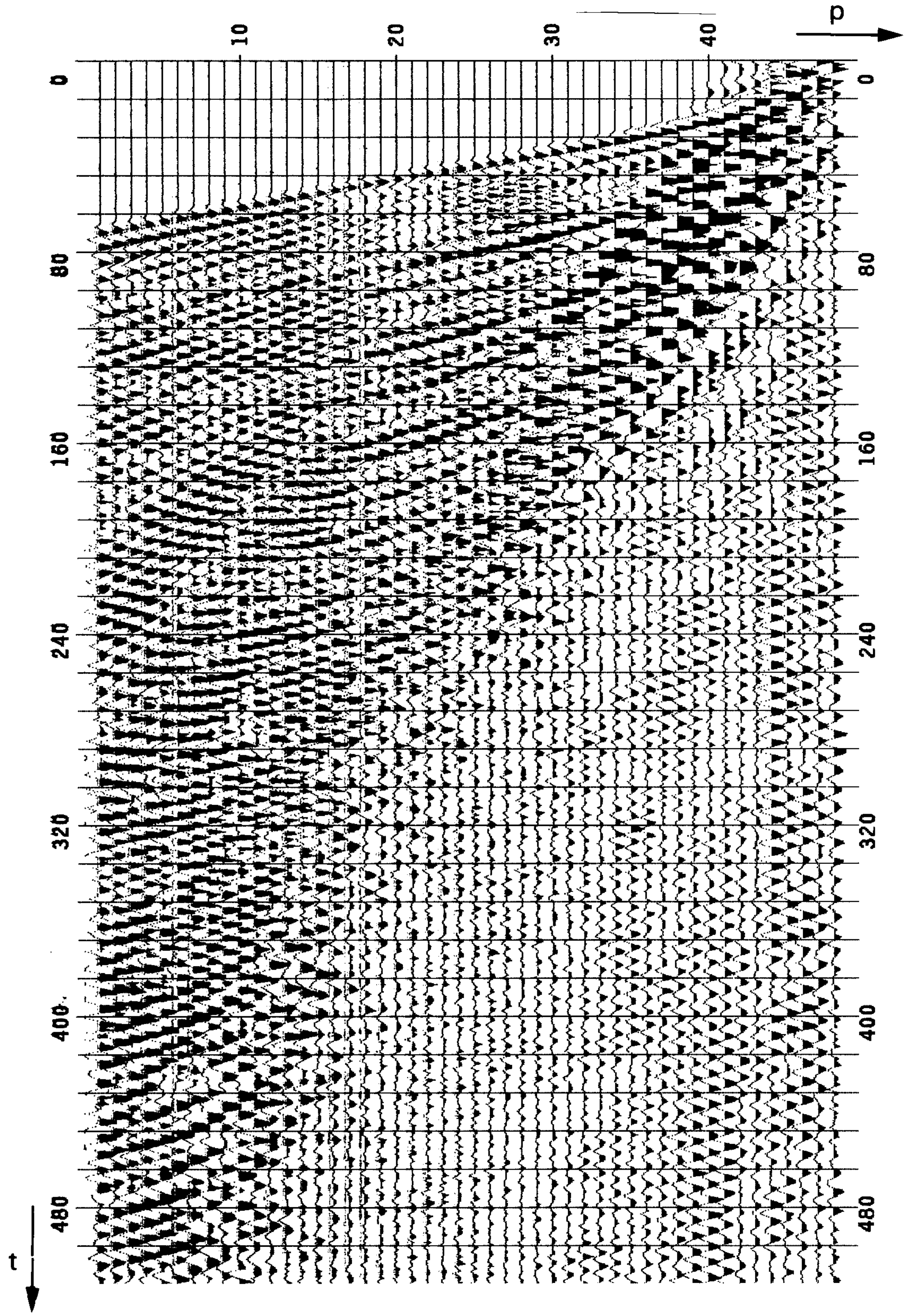

FIG. 7. Slant stack of gather from figure 5. No muting or tapering. Most of the upper left and lower right regions contain noise due to aliasing. Parameters: p1=0. dp=.015

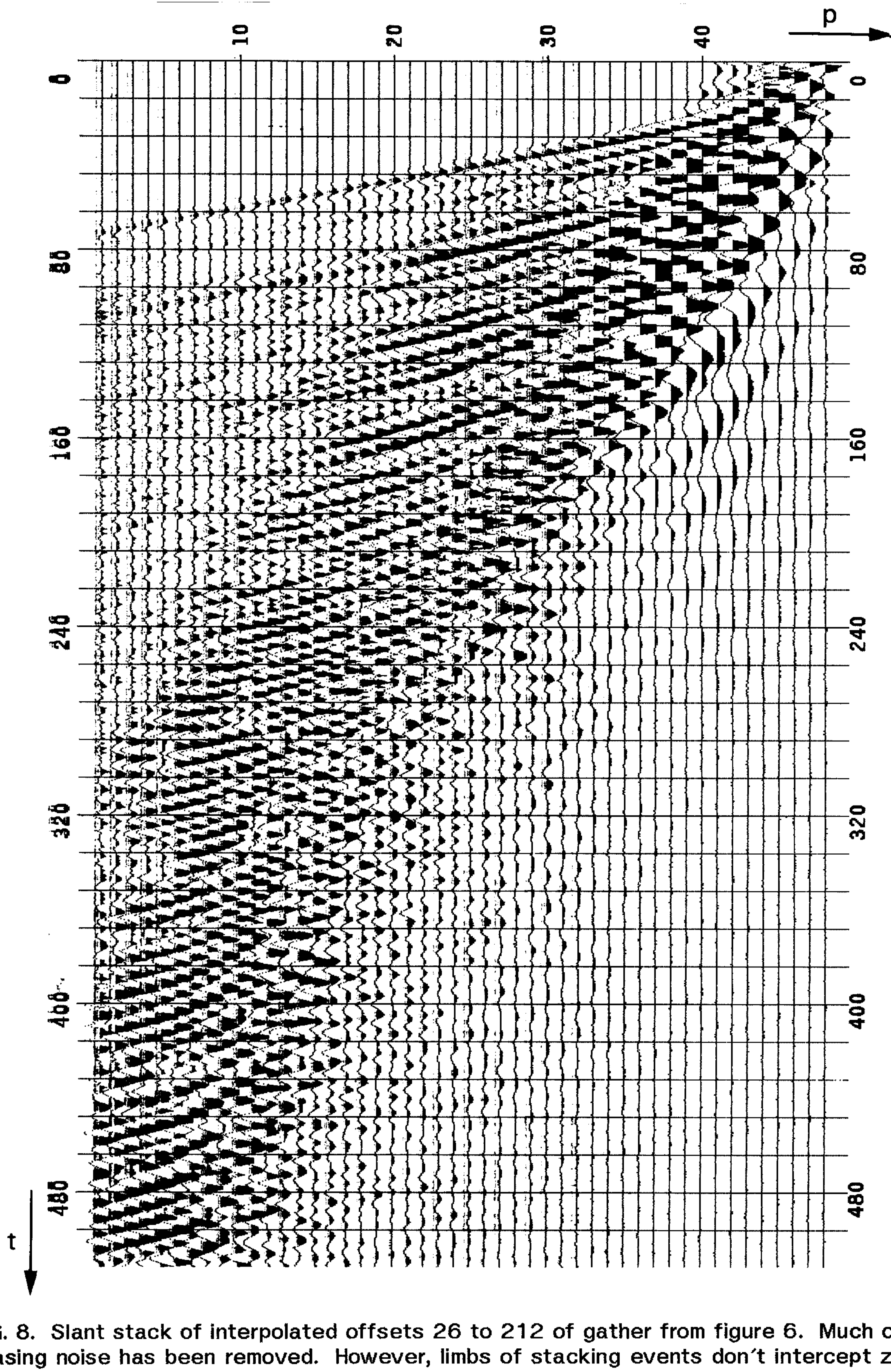

FIG. 8. Slant stack of interpolated offsets 26 to 212 of gather from figure 6. Much of the aliasing noise has been removed. However, limbs of stacking events don't intercept zero p axis at zero slope as they should because of missing near offsets. Looking at the stack edge on, diagonal truncation streaks can be seen going from the lower left to upper right corner.

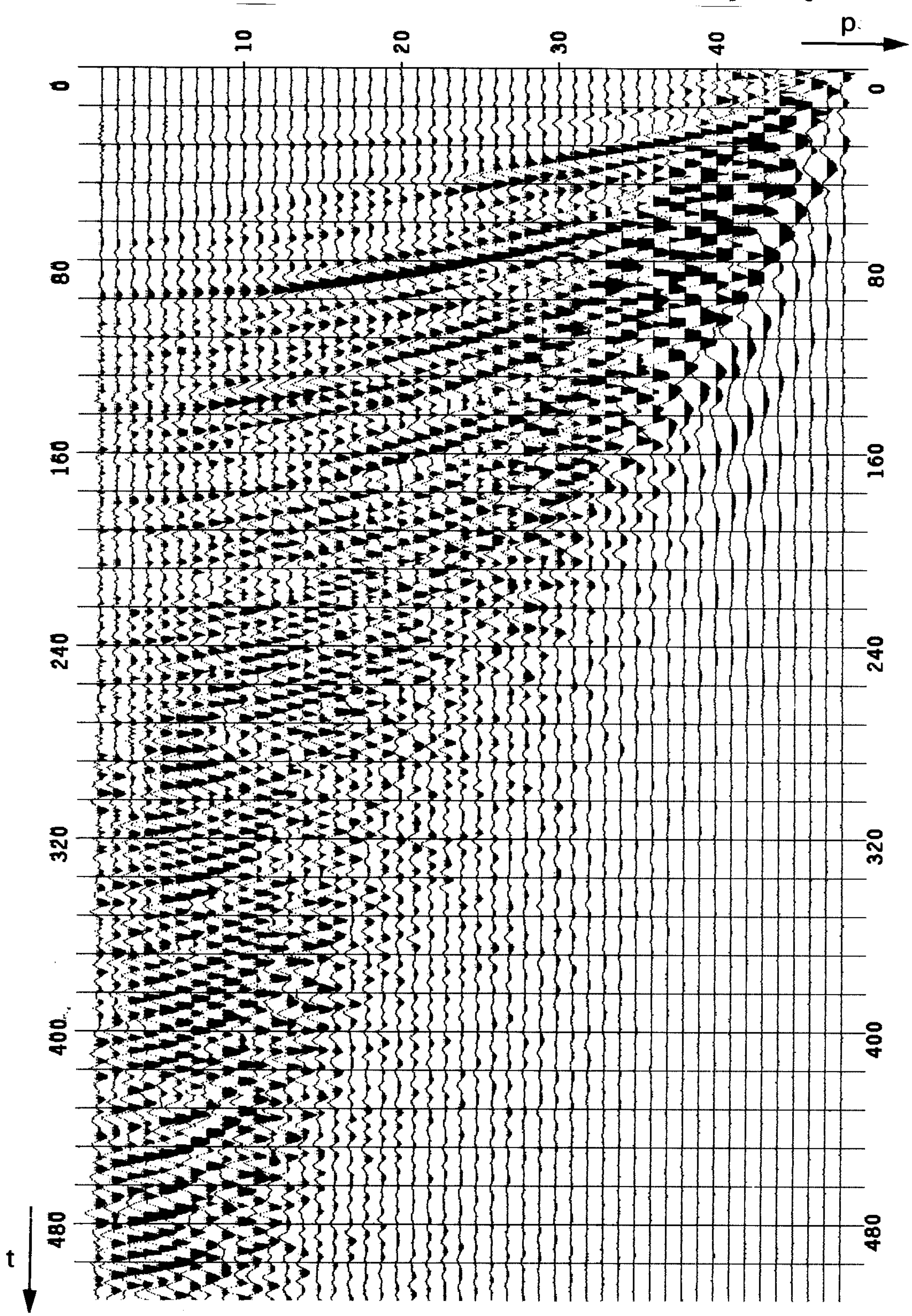

FIG. 9. Slant stack of entire gather from figure 6. Because near offsets have been extrapolated, the low p limbs of events stack at near their correct times. Because wide offsets have been extrapolated and then tapered, the truncation streaks of figure 8 are attenuated.

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