VARIABLE VELOCITY ANTI-ALIASING WINDOW FOR SLANT STACKING

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Slant stacking is applying a linear moveout correction to a common shot or geophone gather, then summing over all offsets. It is similar to beam steering in that it enhances energy from events with a given dip. Claerbout has found it useful as the slant stacked section can be thought of as the result of a physical experiment, one in which a plane wave propagates at a given angle from the shots, or by reciprocity, from the geophones.

Schultz, in SEP 9, demonstrated the usefulness of slant stacking for solving several problems in seismic exploration. He also investigated aliasing effects introduced by sampling the upcoming wavefield with a limited number of geophones. To reduce the aliasing, he derived an equation for a window over offset and time within which the slant stacking is performed.

The stacking window derived by Schultz assumes a spatially invariant velocity which can easily alias real events. In this paper, a window is derived which allows velocity to vary with depth. The velocity distribution is described by stacking velocities and their associated zero offset times picked from a velocity spectrum. These parameters define a set of hyperbolas in time and offset over which maximum signal coherence is achieved. Using these to design an anti-aliasing window should produce the best signal-to-noise ratio on a slant stacked section.

The equation of a hyperbola described by the stacking velocity V and zero offset time T_0 is:

$$T(X) = (T_0^2 + X^2/V^2)^{1/2} \qquad (1)$$

When slant stacking, each trace of a gather is given a linear shift in time which depends on the ray parameter P and offset X. In the slanted coordinate system, the equation for the hyperbola is:

$$T'(X) = \left(T_0^2 + \frac{X^2}{V^2}\right)^{1/2} - PX \qquad (2)$$

The Fresnel zone in the slanted coordinate system is a region extending half the period of the waveform from the top of the hyperbola $\hat{X}'$, $\hat{T}'$.

It can be shown

$$\hat{X} = PT_0V^2 \, (1 - (VP)^2)^{-1/2} \qquad (3)$$

and $$\hat{T} = T_0 \, (1 - (VP^2))^{-1/2} \qquad (4)$$

In the slanted coordinate system, the hyperbola top is at:

$$\hat{T}' = \hat{T} - P\hat{X} \qquad (5)$$

If the Fresnel zone duration is ΔT then,

$$T'(X) = \hat{T}' + \Delta T,$$

an equation that can be solved for the limits of the window. Both ΔT and $\hat{T}'$ are known, so substituting from equation (2) for $T'(X)$ gives:

$$\left(T_0^2 + \frac{X^2}{V^2}\right)^{1/2} - PX = \hat{T}' + \Delta T \qquad (6)$$

Squaring both sides gives a quadratic equation which may be solved for the horizontal limits to the window.

$$AX^2 + BX + C = 0$$

where

$$A = 1 - V^2 p^2$$

$$B = -2\,pV^2\,(\hat{T}' + \Delta T)$$

$$C = V^2\,(T_0^{\,2} - (\hat{T}' + \Delta T)^2)$$

The equation (7) is solved in the computer for each stacking velocity and zero offset time giving a set of horizontal limits describing the anti-aliasing window. The limits in time are computed from equation (1). The times within the anti-aliasing window for each offset are found by interpolating between points defining the window.

The anti-aliasing scheme was tested on two synthetic common shot gathers. The results, presented as "P gathers", show that the anti-aliasing window is effective when the velocity distribution is known.

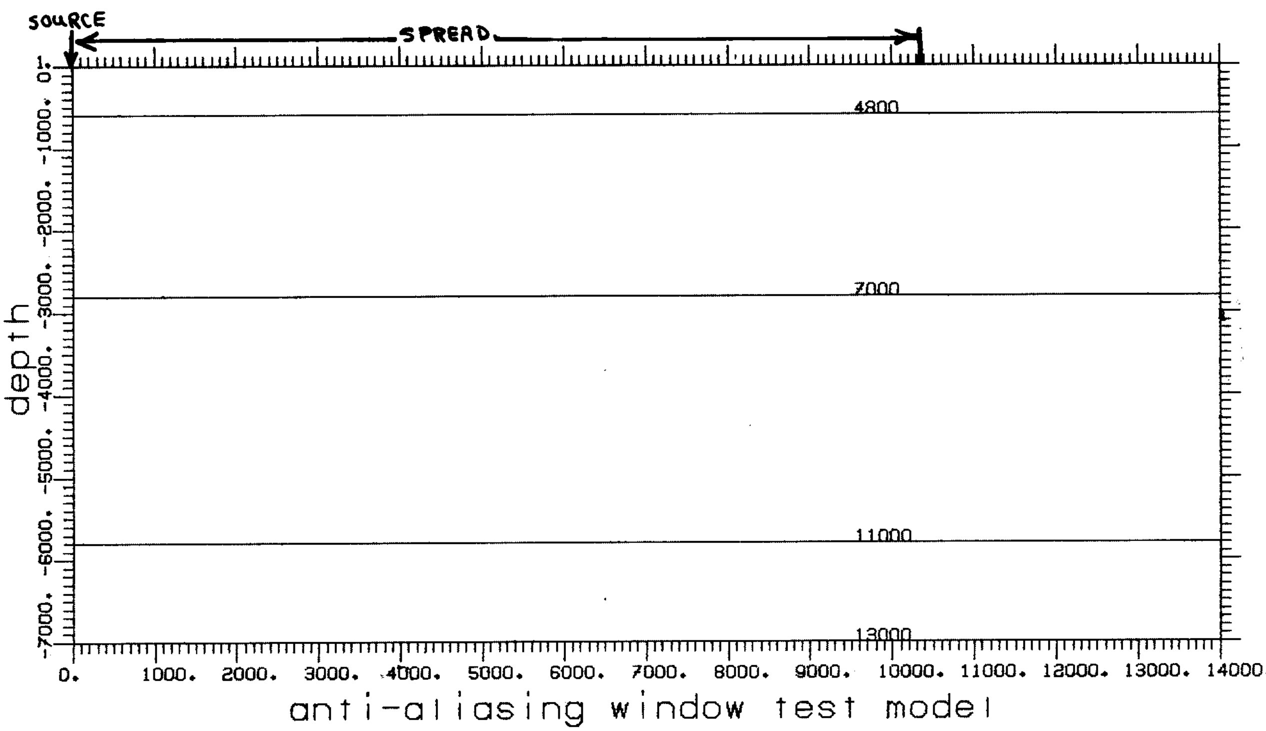

Figure 1.—Model 1: A water layer over sediments. The source and geophone locations are drawn in. The spread consisted of 48 geophones with a spacing of 220 feet.

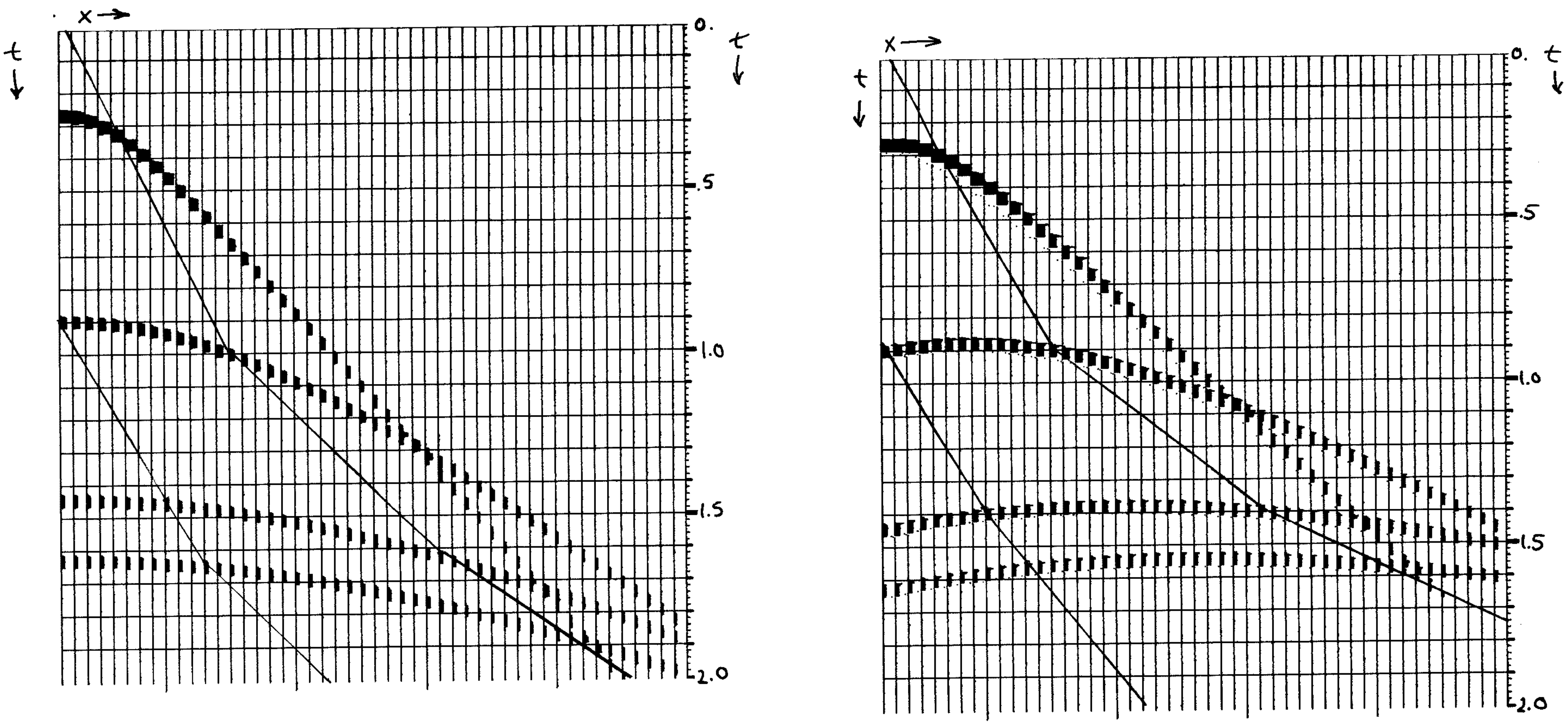

Figure 2.—On the left is the common shot gather computed from model 1. The wavelet is a .04 second rectangle with its amplitude weighted by the inverse of the travel time. The anti-aliasing window for P = sin 10°/4800 is drawn in. Figure 2b is the same gather in the shifted coordinate system for P = sin 10°/4800. The window is drawn in for a Fresnel zone duration of .02 seconds. Points defining the window intersect the hyperbolas .02 seconds from their tops.

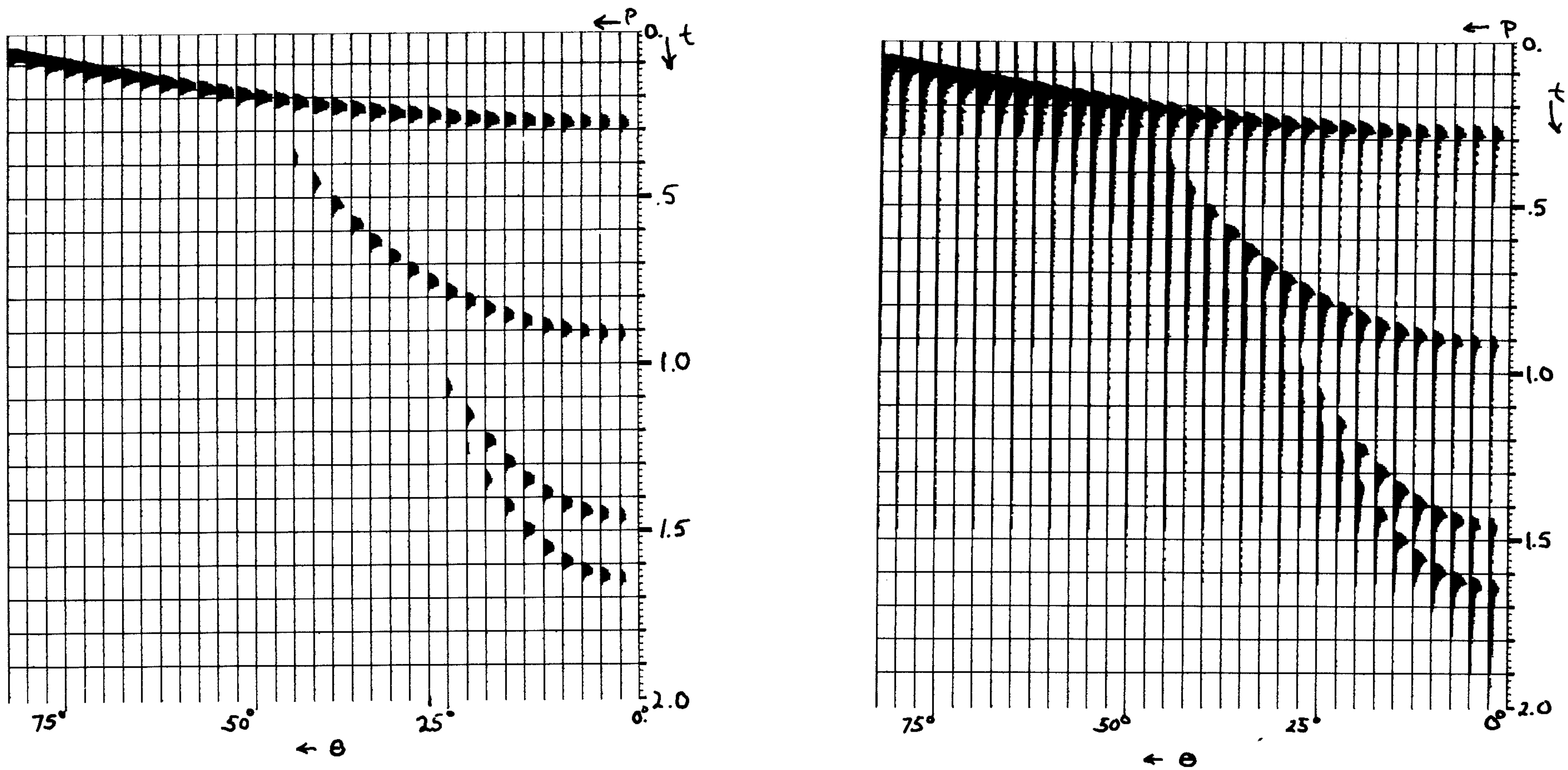

Figure 3.—On the left is a P-gather computed with the anti-aliasing window. To the right is a P-gather computed without the window. Note the tails caused by end effects and the varied shape of the wavelet. Each trace represents a slant stack for a different value of P where P = sinθ/4800. The truncated curves for the later events are caused by the window including only data outside the receiver spread and by the critical angle being exceeded.

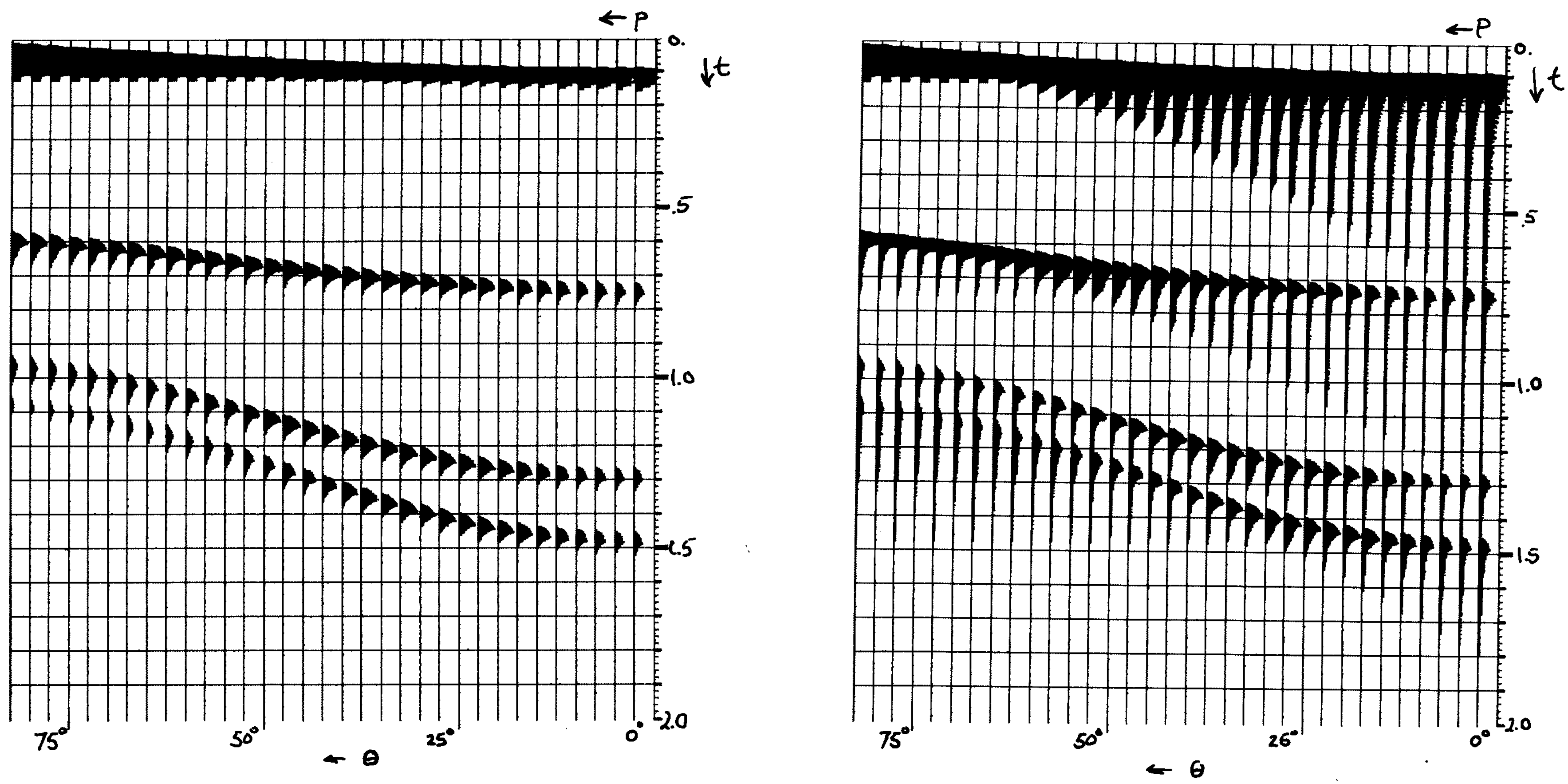

Figure 4.—The water layer of Model 1 was replaced by a 14000 ft/sec permafrost layer. The same field geometry was used to generate a common shot gather. The P-gather on the left was computed with the anti-aliasing window and shows a great improvement over that in the right. For these gathers, $P = \sin\theta/14000$. Note the non-elliptical shape of the gather, this is due to Snell's law effects.