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are filed in Supplemental
Lecture Notes II, under
the same title, "Snell Waves"

MIGRATION OF SLANT-MIDPOINT STACKS:
FIELD DATA EXAMPLE

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Introduction

A field data test verifies the theory of slant-midpoint imaging. In slant-midpoint migration slant stacks are made for several slant values, migrated by the double square root equation, and then all summed together. Velocity analysis can be performed before or after migration. Important results include:

1) Slant-midpoint imaging is valid for angles to 90 degrees and any velocity depth function.
2) Pre-migration velocity analysis has the signal enhancement advantage of stacking. Or slant stack sections may be migrated with a trial velocity function, post-migration velocities measured, and then remigrated, achieving the results of migration before stack.
3) The production of and multiple migration of slant stack sections are more economical than their counterparts of normal moved out CDP stacks and migration before stack.

Digicon kindly provided the CDP gathers used in this study. Deconvolution was not applied due to the lack of steep dip algorithms, field dataset software, and the pressing need not to deconvolve. A boxcar AGC was applied to the gathers.

Production of slant stack sections

The weighting scheme illustrated in Figure 1 was applied across the slant-sum trajectory to inhibit cable end artifacts. The weighting scheme is a triangular window whose peak corresponds with the apex of the slant hyperbolic event and goes to zero when the curvature of the hyperbola has covered a specified Fresnel zone time width (see Gray, Estevez, and Schultz, SEP-13,12,9).

As a consequence of slant stack formation-inversion theory (Thorson, SEP-14), a frequency domain ramp filter compensates for event width broadening and reverberation. Figure 2 contains slant stacked sections. Figure 3 is a five-fold slant gather of ten adjacent midpoints demonstrating slant moveout of events.

Migration of slant-midpoint stacks

Two depth-variable algorithms have been considered for migration -- a Stolt type (see Ottolini, SEP-14) and a projection operator. The very economical Stolt-type algorithm is

$$P_{mig}(k_x,k_z) = P(k_x,\omega') \tag{1}$$

$$\omega' = \frac{vk_z}{2}\left[\frac{k_y^{\,2} + k_z^{\,2}}{k_z^{\,2}(1 - p^2v^2) - k_x^{\,2}p^2v^2}\right]^{1/2}$$

[where p is the slant stack moveout parameter $t' = t - (p * \text{offset})$.]
Since the slant variable velocity stretch has not been adequately implemented yet, an alternative projection operation will be used when the array processor memory is expanded in the near future.

$$P_{mig}(k_x,\ z=n\Delta z,\ t=0) = \sum_{\omega} P(k_x,\ z=0,\ \omega)\ \exp\left[i n\Delta z\left\{\left[\left(\frac{\omega}{v(z)}\right)^2 - (k_x + \omega p)^2\right]^{1/2} + \left[\left(\frac{\omega}{v(z)}\right)^2 - (k_x - \omega p)^2\right]^{1/2}\right\}\right] \tag{2}$$

(the double square root equation of Claerbout, p. 73, with H and Y in wave numbers). Figure 4 shows slant migrated sections compared with conventional 45-degree wave equation migration of a CDP stacked section. Figure 5 is the migrated five-fold slant gather of ten adjacent midpoints of Figure 3. Migration with the correct depth-velocity function transforms slant stack sections into their earth images. Slant (and offset) moveout is thus removed and the migrated slant sections may be summed together to, first, combine the events which differing slants selectively enhance and, second, improve signal to noise. Even sections which have been migrated with incorrect velocity functions may be moveout corrected and summed to provide a result which has some improvements over conventional migration.

Velocity analysis

The moveouts of the slant gather in Figure 3 are a function of velocity and slant according to

$$t' = \int_0^{\tau} [1 - p^2 v(\tau)]^{1/2} \, d\tau \qquad (3)$$

(where t' is slant moved-out time, a function of migration time τ.) Residual migration moveouts may be analyzed by

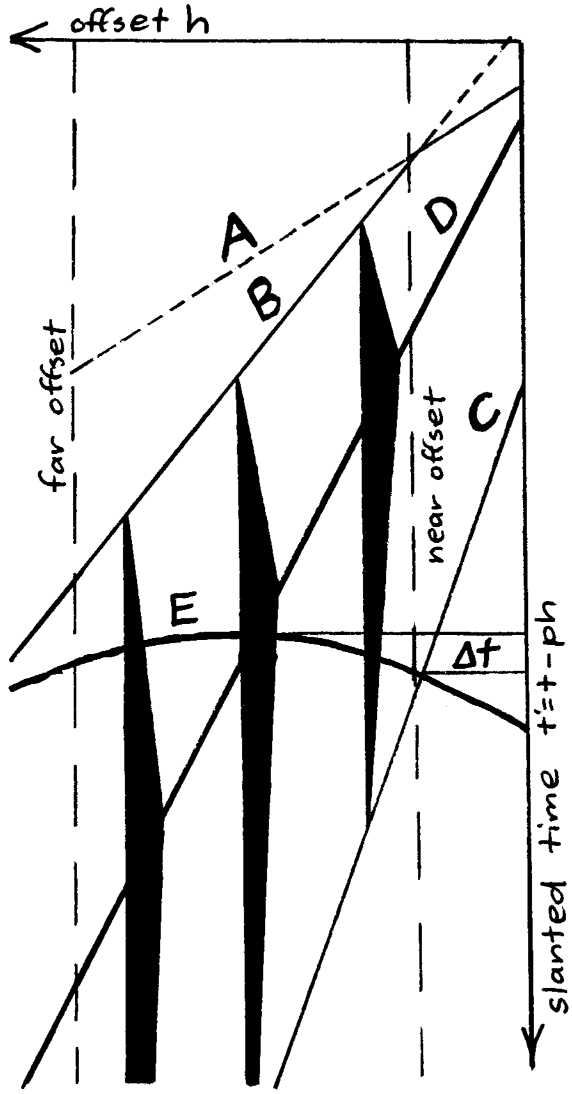
$$\frac{\cos\theta}{\sin^2\theta} \frac{\Delta\tau}{t} = \frac{\Delta\hat{v}}{\hat{v}} \qquad (4)$$

[from Equation (9) of Claerbout, page 92 of this report, where $\sin\theta = pv$]. Semblance techniques may be used on these equations. Analysis of migrated slant gathers has the advantages of migration before stack; those being collapsed diffractions, better located events, and enhanced signal. A medial constant velocity is usually sufficient as a trial function for migrated velocity analysis.

Future directions

The final results are not yet in. The theory is sound as proved by the initial results. Future work lies in refining the computer software and parameters to perform the above processing. Improved results are expected by the time of the 49th SEG meeting in San Francisco.

FIGURE 1.--Slant stack weight scheme: moved-out CDP gathers before sum.



1a.--Schematic. Blackened triangles illustrate trace weighting scheme before stack according to Schultz (SEP-9). Curve D is the computed peak of moved-out flat-lying events (E) according to

$$h_p(t') \;=\; pt_0v^2\,(1 - v^2p^2)^{1/2} \qquad \text{(Gray, SEP-13)}$$

where h_p is peak offset and p is slant moveout parameter $t' = t + ph$. Fresnel window mutes, B and C, are found at a specified rise (Δt) of the moved-out hyperbola E.

$$h_w(t') \;\approx\; h_p(t') \pm v(\Delta t * t' + \Delta t^2)^{1/2}$$

where h_w are the window offsets. Curve A is a seafloor mute. Figure 1c shows weighted data.

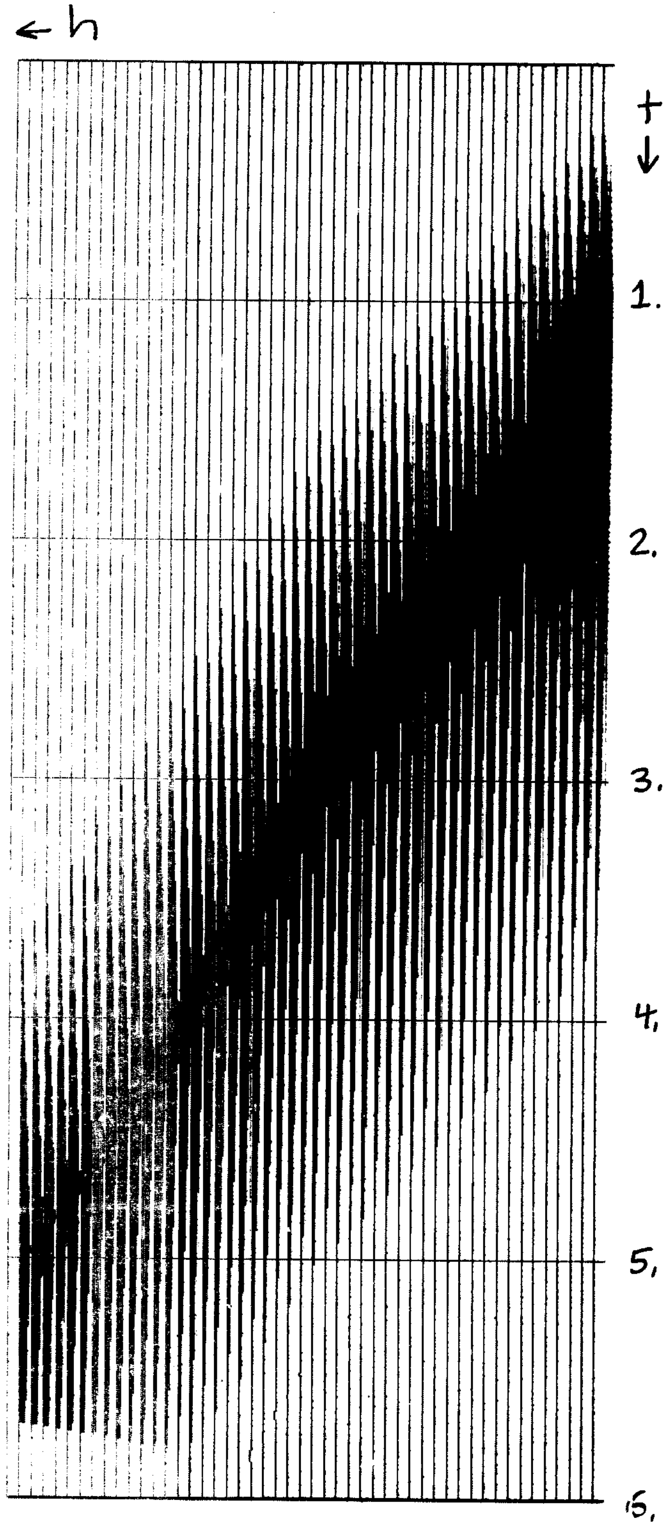


FIGURE 1b.--Sample weighting scheme used on Digicon gathers.

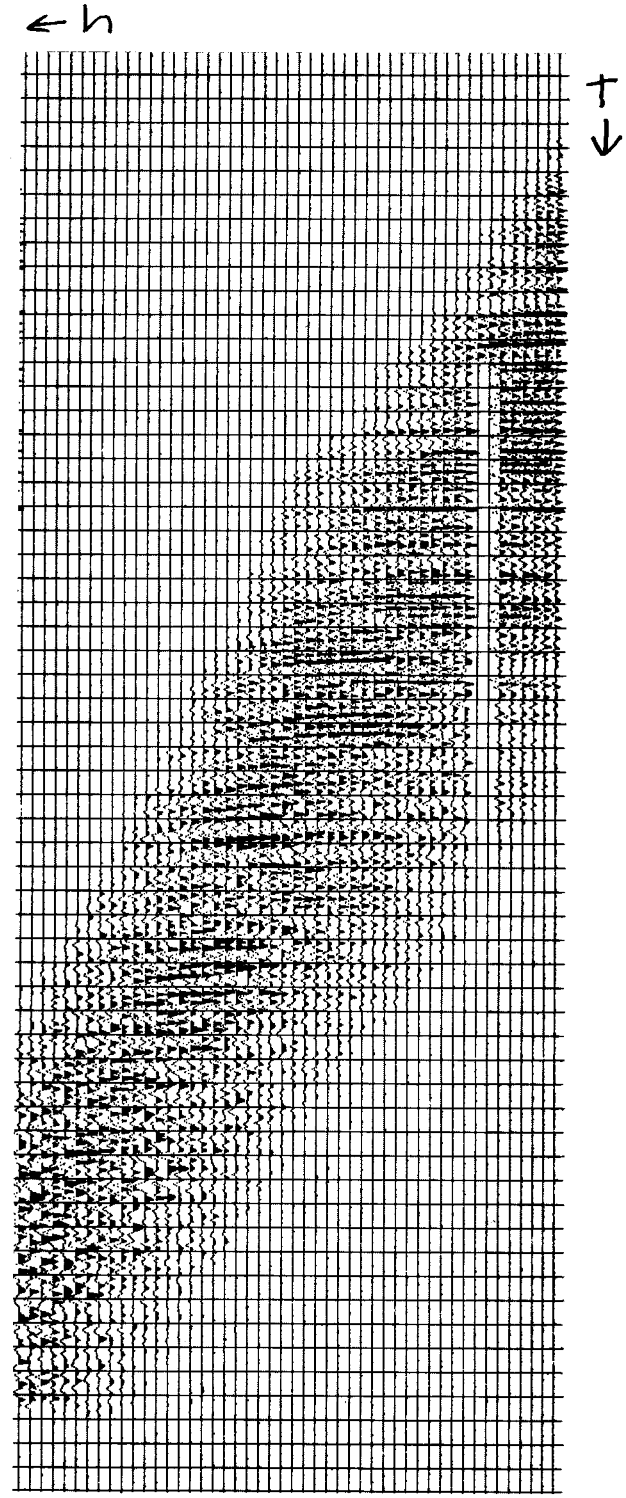
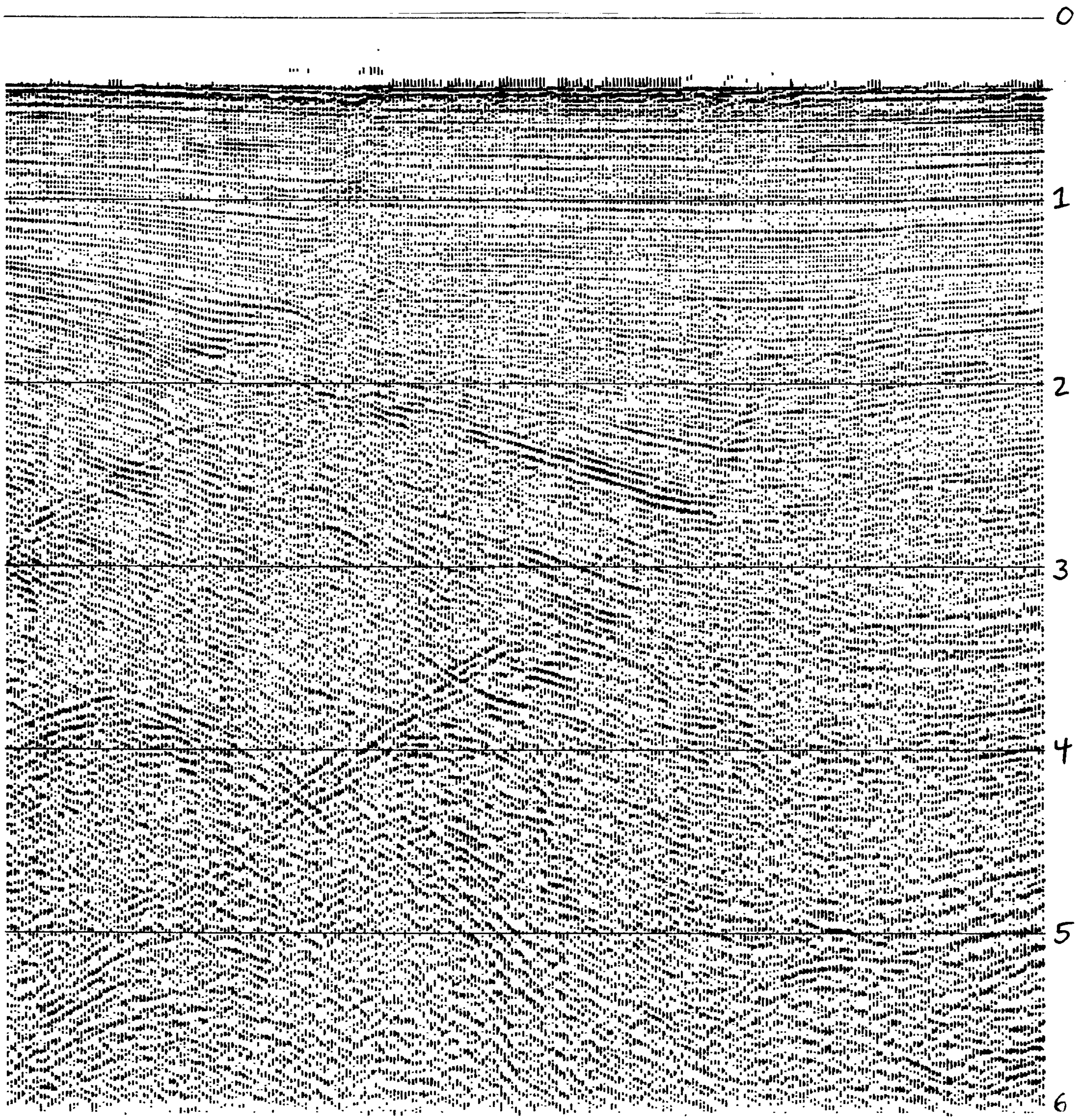
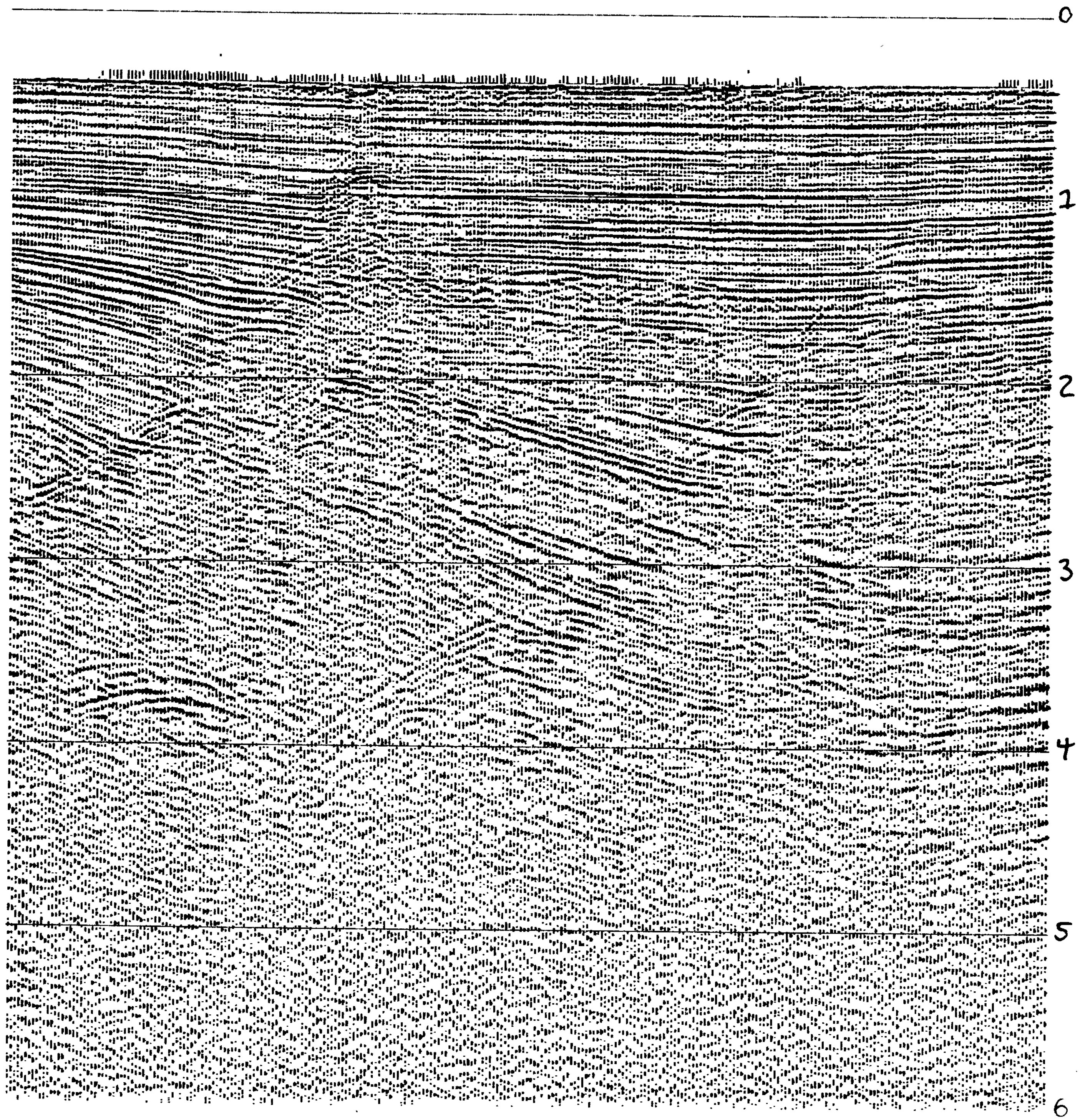


FIGURE 1c.--Moved-out and weighted gather. (The bends in the window are due to the fact that the 24 high offsets have twice the separation of the 24 low offsets.)

FIGURE 2.--Slant stack sections.



2a.--Slant stack section for low slant value which focuses shallow events. Fresnel windowing weighting not applied.



2b.--Slant stack section for high slant value focusing shallower events better than Figure 2a.

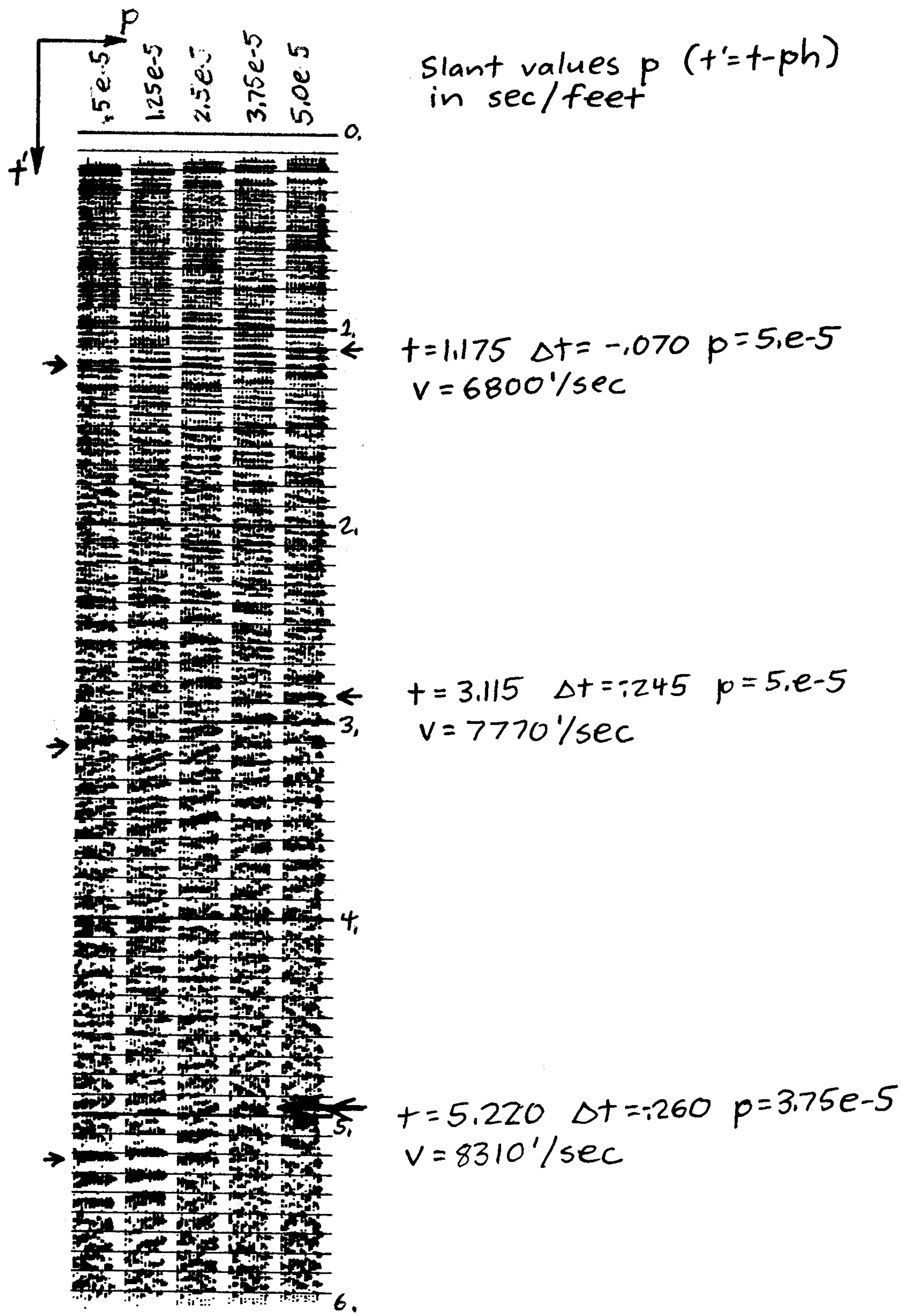
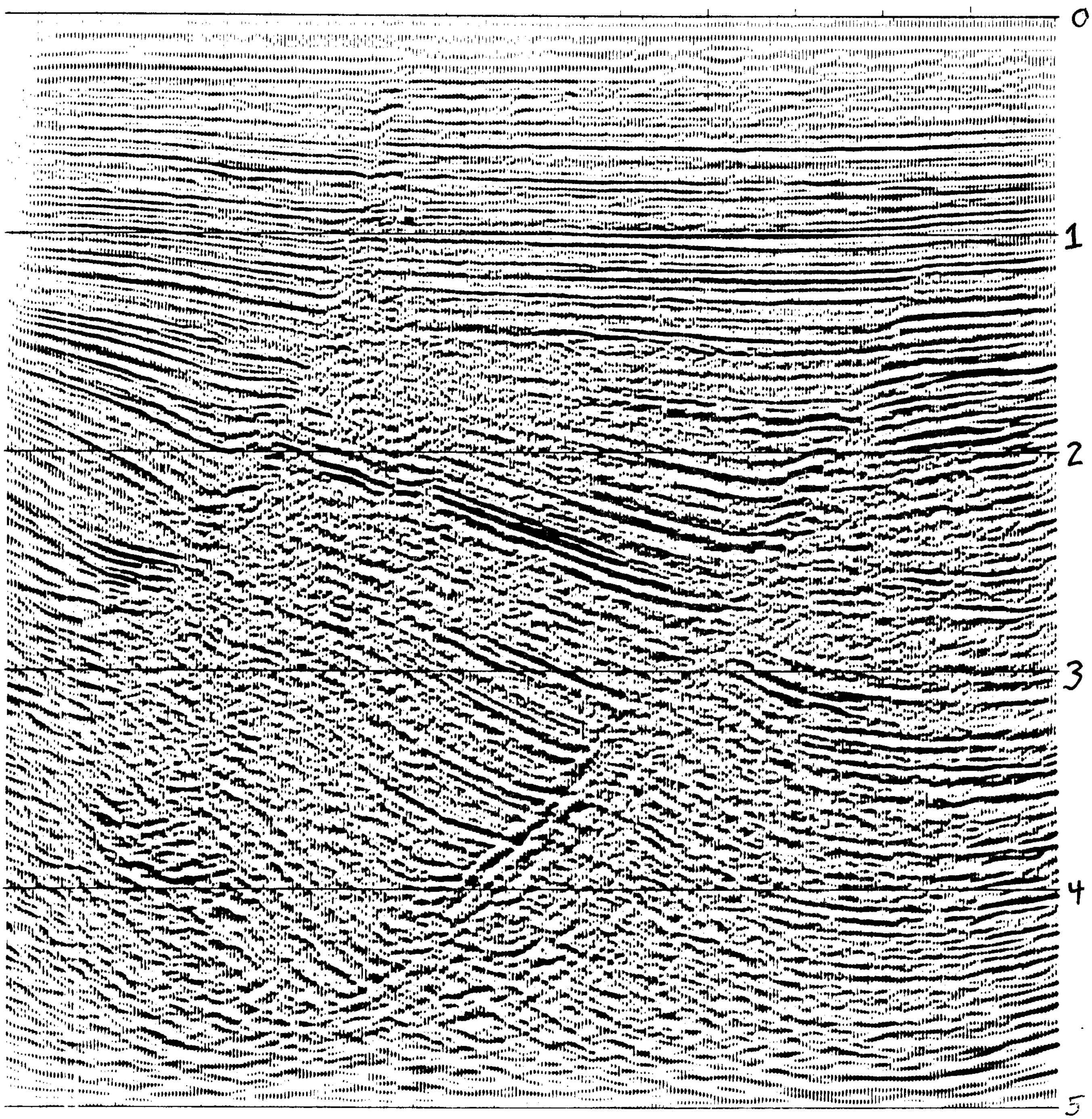
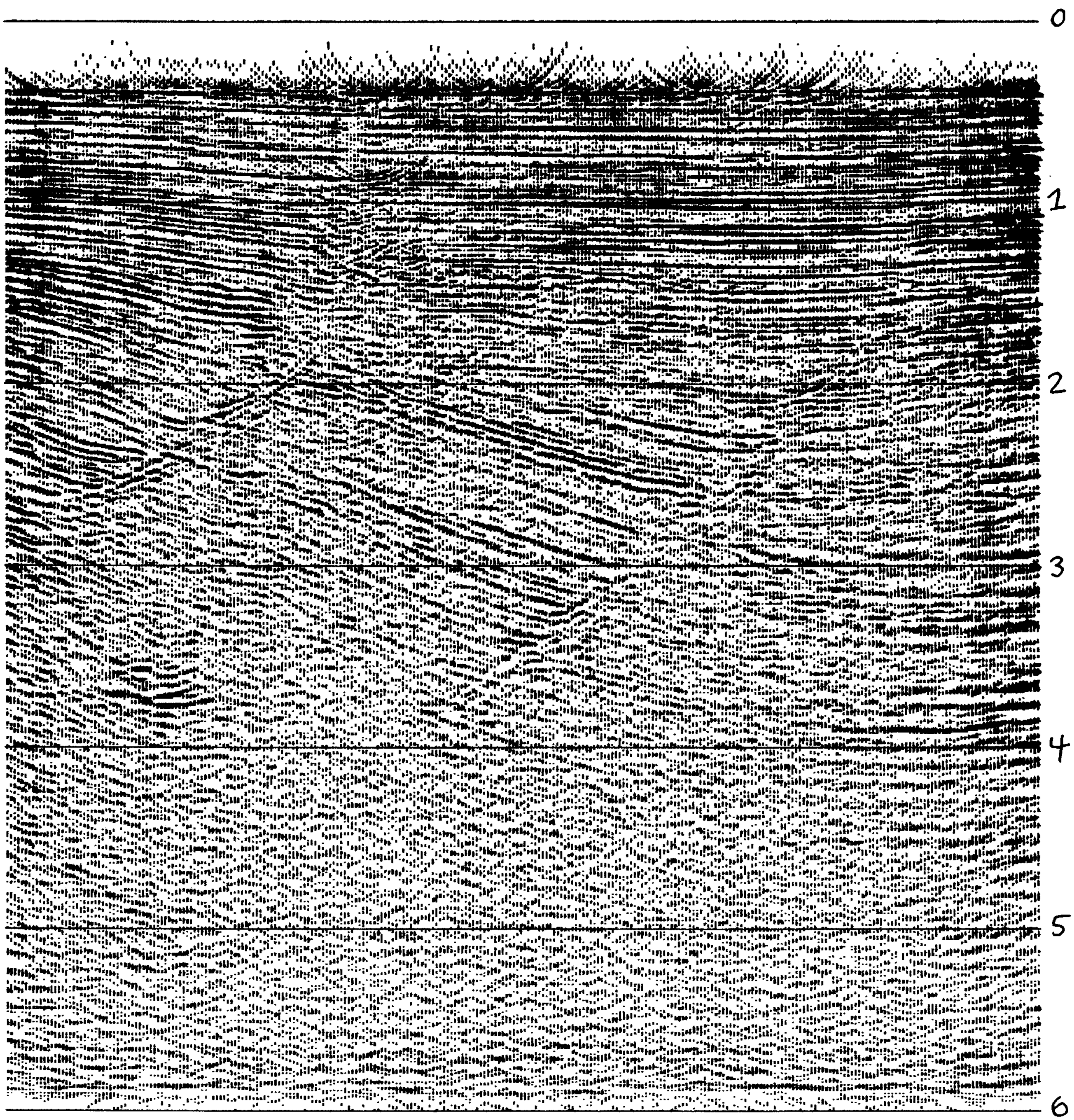


FIGURE 3.--Five-fold slant gather of 10 adjacent midpoints. Three events identified by arrows with velocity calculation to the right. Slant moveout is upward for increasing p.

FIGURE 4.--Migrated sections.



4a.--Conventional wave equation migration of conventional CDP section (Figure 9 of Digicon's preprint, "Equalizing the Stacking Velocities of Dipping Events via Devilish").



4b.--Constant velocity fk slant-midpoint migration of the slant stacked section of Figure 2b. Note the improved imaging of the upper left fault plane. The slant value used in creating the stacked section focuses upper events better than lower events. A complete slant-midpoint migration would be the sum of several different slant values which focused events throughout the section. Depth-variable velocity migration would further improve the migration.

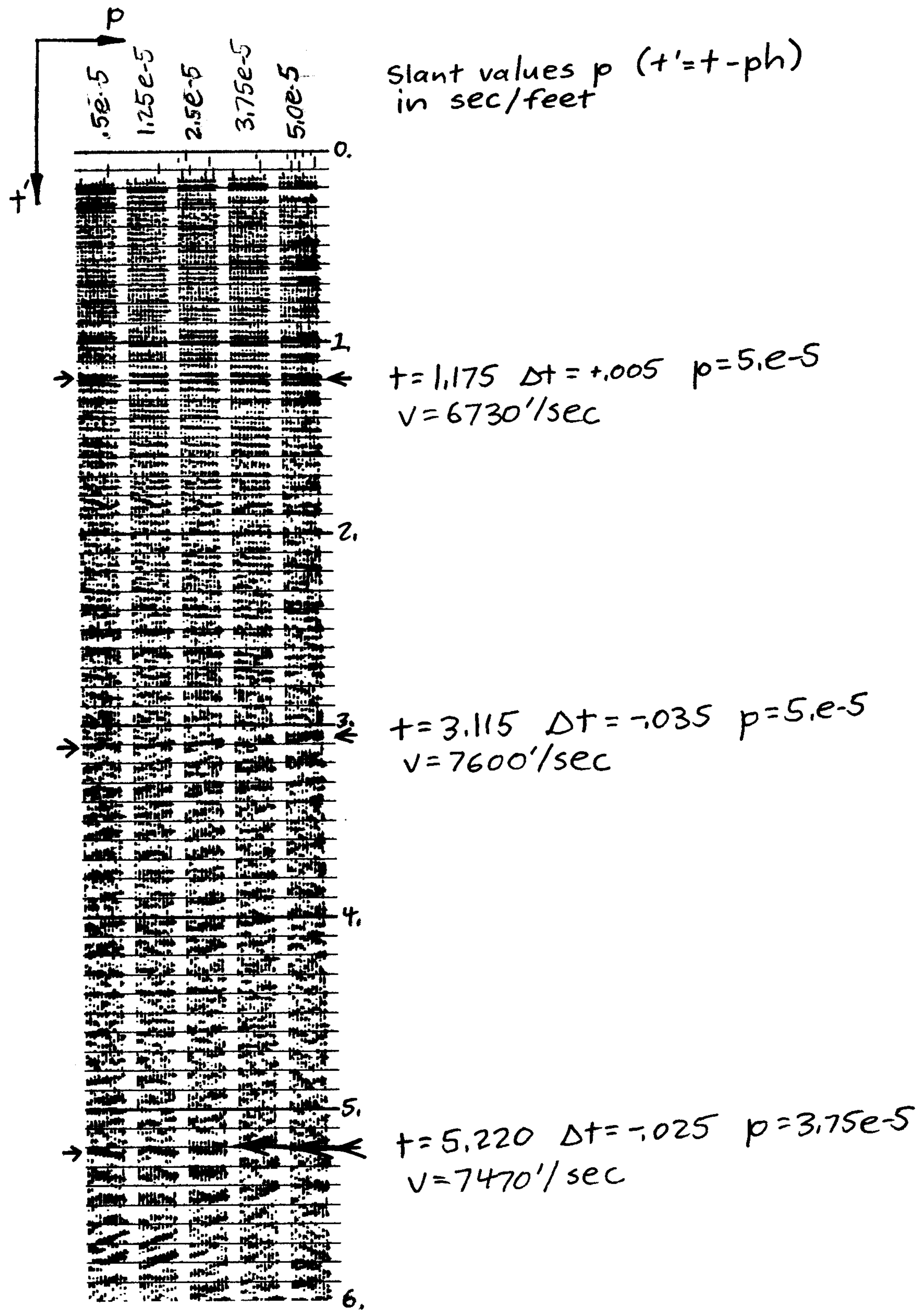


FIGURE 5.--Five-fold migrated slant gather of the same 16 midpoints in Figure 3. Constant velocity fk migration at 2 sec velocity (7000'/sec). Slant-midpoint migration using the correct velocity profile would remove all of the slant moveout. Residual moveout has been used in Equation (4) to give the velocities shown.