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## Short Note

# The effect of binning on data from a feathered streamer

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In a recent paper (Levin, 1983), I derived the common mid-point (CMP) time-distance relations for reflection from a plane of arbitrary orientation when the streamer carrying the hydrophones was feathered by currents. The streamer was assumed to be straight but deviated at a constant angle $\gamma$. This assumption corresponds well to what is observed during marine exploration. I considered two cases: first, the CMP points chosen to be what they would have been in the absence of feathering and second, the CMP points selected to lie along a line perpendicular to the profile direction. The second choice is the one normally made and the only one I'll consider in this short note.

In the paper, I assumed the CMP points were allowed to extend from the origin, which was the point of coincident source and detector, to whatever distance from the line corresponded to the maximum source-to-detector separation. While this is a possible choice, it is not the choice of many of those who must process marine 3-D data. Instead they demand that all CMP points fall within a bin centered on the profile line. I shall call this choice "binning."

The algebra required to investigate binning is essentially the same as that laid out in the 1983 paper. There are minor differences, which are given in the Appendix. Here I shall simply show results. When the profile lines are shot in the dip direction, binning need not be considered, since, by my choice of points perpendicular to the profile direction, all the CMP points fall along strike and are the same distance from the plane reflector. Figure 1 is an example for rather large feathering (30 degrees) and a 15 degree dip. Only for large values of source-to-detector separations $X$ does the time-distance hyperbola differ appreciably from what it would be if there were no feathering.

For profiles not shot in a dip direction, the effects of binning become apparent. The maximum distortion of time-distance plots due to feathering is seen for lines shot in the strike direction. Hence, they are data recorded for strike profiles we consider here and in the Appendix. When the 3-D lines are strike lines, binning tends to chop up the data. In order to have CMP points for all source-to-detector separations fall within a bin, traces must be pulled from different lines of the survey. For a survey shot in the strike direction, different lines of the survey are at different distances from the reflector: binning assembles data selected from time-distance hyperbolas having different $t_0$

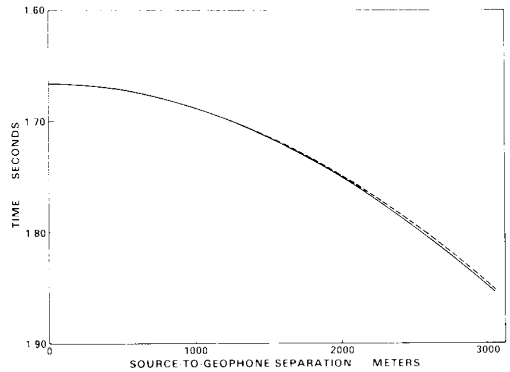


FIG. 1. Time-distance plots for a dip line. The dip is 15 degrees; the feather angle, 30 degrees. The depth to the reflector is 3048 m (10 000 ft) and the velocity is 3657.5 m/s (12 000 ft/s).

values. The results for a specific choice of parameters are shown in Figures 2 and 3. Bins were selected to extend to half the separation of the survey lines. The data were broken into pieces by binning with those points of a given piece corresponding to CMP points that fell within the bin limits. No restriction was placed on the in-line extent of a bin, the requirement that bins extend to half the line separation being sufficient. Depths to the reflector increased from 3048 m (10 000 ft) for a source-to-detector separation of zero to 3246 m (10 648 ft) for a source-to-detector separation of 3048 m for Figure 2 and decreased to 2989 m (9806 ft) for Figure 3.

Superimposed on the data of Figures 2 and 3 are the time-distance hyperbolas corresponding to no feathering and a depth to the reflector of 3048 m. In an average sense, the data fall around the hyperbolas. As shown in the Appendix, those points that lie at the center of the bin differ from the non-feathering values by amounts that are nearly proportional to the source-to-detector separation but are very small until that separation becomes large.

A reader may remark on the smoothness of the points com-

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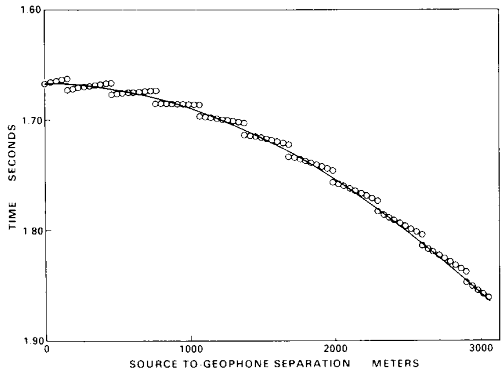


FIG. 2. Time-distance plots for a strike line. The dip is 15 degrees; the feather angle, 30 degrees (updip). The depth to the reflector is 3048 m (10 000 ft) and the velocity is 3658 m/s (12 000 ft/s).

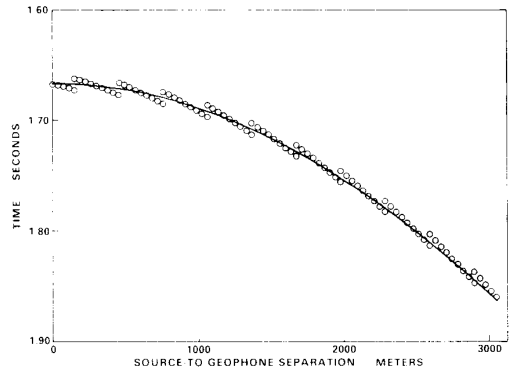


FIG. 3. Time-distance plots for a strike line. The dip is 15 degrees; the feather angle, −30 degrees (downdip). The depth to the reflector is 3048 m (10 000 ft) and the velocity is 3658 m/s (12 000 ft/s).

prising each piece of Figures 2 and 3. That smoothness stems from the assumption that any source-to-detector separation needed to let a CMP point fall precisely on the line perpendicular to the profile is available. In practice, only by chance would these assumed values be those allowed by a fixed arrangement of hydrophone stations and preassigned shot positions. We would expect deviations from the perfection of each small piece.

All the limitations laid out in earlier papers (Levin, 1971, 1983) are applicable to the results discussed here. The system being considered is unrealistically simple but is the one often assumed for velocity determination. To the extent that the behavior illustrated by Figures 1 to 3 corresponds to that found in the field, the moral is clear: if currents are expected to be strong, lay out your lines in a dip direction or be prepared to correct the recorded data.

## REFERENCES

Levin, F. K., 1971, Apparent velocity from dipping interface reflections: Geophysics, **36**, 510–516.

——— 1983, The effects of streamer feathering on stacking: Geophysics, **48**, 1165–1171.

## APPENDIX

The time-distance relation for reflection data collected along a strike line is

$$V^2t^2 = 4D^2(1 - \sin^2\phi \sin^2\gamma) + (X - 2D\sin\phi\sin\gamma)^2, \quad \text{(A-1)}$$

where $\phi$ is the dip angle and $\gamma$ is the feathering angle. There is a misprint in equation (8) of Levin (1983). $D$ is the perpendicular distance from the origin (CMP point) to the reflecting plane. $X$ is the source-to-detector distance SGD and $V$, the average velocity to the reflector. If instead of collecting data along the $x$-axis we collect data along a line parallel to the $x$-axis but displaced a distance $Y$, we replace $D$ with

$$D' = D - Y\sin\phi. \quad \text{(A-2)}$$

For CMP points chosen in a direction perpendicular to the profile line ($x$-axis), the CMP points have coordinates

$$[0, (X/2)\sin\gamma, 0]. \quad \text{(A-3)}$$

If we bin our data, points within a bin have coordinates

$$[0, Y + (X/2)\sin\gamma, 0]$$

and we select data from different parallel lines such that

$$|Y + (X/2)\sin\gamma|$$

is smaller than the half-width of the bin chosen. The center of the bin is at (0, 0, 0). This implies that at the center of the bin

$$Y + (X/2)\sin\gamma = 0. \quad \text{(A-4)}$$

Substituting from equation (A-4) into (A-2) gives

$$D' = D + (X/2)\sin\gamma\sin\phi \quad \text{(A-5)}$$

for the center of the bin.

We want to know by what amount the time for data at the center of the bin differs from the time we'd compute for the same SGD if there were no feathering. Write

$$\delta(V^2t^2) = 4(D')^2(1 - \sin^2\phi\sin^2\gamma) + (X - 2D'\sin\phi\sin\gamma)^2 - [4D^2 + X^2]. \quad \text{(A-6)}$$

Substituting from equation (A-5) into equation (A-6) gives

$$\delta(V^2t^2) = 4(D + X/2\sin\phi\sin\gamma)^2(1 - \sin^2\phi\sin^2\gamma) + (X - 2D\sin\phi\sin\gamma - X\sin^2\phi\sin^2\gamma)^2 - [4D^2 + X^2], \quad \text{(A-6a)}$$

$$\delta(V^2t^2) = -(X\sin\phi\sin\gamma)^2,$$

or (A-7)

$$\delta t^2 = -[(X/V)\sin\phi\sin\gamma]^2.$$

If we assume $\delta t^2$ is a continuous function, we can write

$$\delta t \approx \delta t^2/(2t). \quad \text{(A-8)}$$

Except for sign, equations (A-7) and (A-8) also hold for the differences between time squared and time for dip lines.