DISCUSSION

On: "Ground-roll suppression by the stackarray" by P. F. Morse and G. F. Hildebrandt (GEOPHYSICS, 54, 290-301, March 1989).

The stackarray approach proposed in Anstey (1986a) is a large improvement over seismic acquisition techniques with shot intervals that are 3 or 4 times as large as group intervals. The stackarray criterion (Anstey, 1986b) prescribes "an even, continuous, uniform succession of geophones across the CMP gather," and Morse and Hildebrandt (1989) illustrate the effectiveness of this regular spatial sampling, using some interesting experiments. However, the stackarray criterion does not explain the residual ground roll that remains even after a two-trace mix or simulation of overlapping geophone arrays as shown in Figures 14b and 13b, respectively, of Morse and Hildebrandt. Morse and Hildebrandt state that these events are not suppressed due to "the unusually low fold of the stack." In the following I will argue that Morse and Hildebrandt's argument does not satisfactorily explain the presence of residual ground roll and that the residual ground roll most likely results from not using a shot array in data acquisition. I put forward a hypothesis as to the nature of residual ground roll, and this hypothesis can be easily tested using the basic data recorded by Morse and Hildebrandt.

In the discussion the authors make the simplification that ground roll is only a function of offset x_o and not of midpoint position x_m. If midpoint-independent ground roll is not fully suppressed by the combination of geophone array and stack, then it should show up as a *horizontal* event in the stack. The residual ground roll visible in Figures 13 and 14, consists of *dipping* events, hence these events must stem from ground roll that is also a function of a midpoint position.

Midpoint-dependent ground roll may be generated by inhomogeneities in the near surface both in-line and off-line. The inhomogeneities act as secondary sources creating diffracted ground roll waves. A synthetic example showing the plane wave response of a two-layer medium with an irregular interface between the two layers is shown in Levander and Hill (1985). The example illustrates the midpoint dependence and also the *symmetry* of the secondary ground roll.

An important aspect of the residual ground roll present in Figures 13 and 14 is that it is *asymmetric* with right-dipping residual ground roll much more prominent than left-dipping. The most likely explanation for the presence of this ground roll is that it is created by side-scatterers that are close to the seismic line, but not on it. The suppression of side-scattered ground roll by the geophone array depends on the apparent velocity V_r with which it reaches the receiver position, with $V_r = V_R/\cos\alpha$, V_R is Rayleigh wave velocity, α is angle of raypath connecting scatterer and receiver. There is no suppression of ground roll by receiver array when the array is opposite the scatterer ($\alpha = 90$ degrees). The same reasoning applies to the raypaths connecting the shot array with the scatterer. However, the data set used in Morse and Hildebrandt was recorded with single hole dynamite, hence there is no shot array effect any place. As a consequence, when the receiver array is opposite the scatterer, there is no attenuation of the scattered ground roll by either shot or receiver, and aliasing of the ground roll occurs in all common receiver gathers for which the raypath from scatterer to receiver has an angle α close to 90 degrees with the seismic line direction. No aliasing occurs in corresponding common shot gathers, as this part of the ground roll is suppressed by the receiver array. This explains the presence and asymmetry of the residual ground roll in Figures 13 and 14 of Morse and Hildebrandt.

The solution to a better suppression of the side-scattered ground roll is to apply the criteria for symmetric sampling (Vermeer, 1990): equal shot and receiver intervals, and equal shot and receiver arrays. Compared to the stackarray criterion this symmetry criterion means an even, uniform succession of not only geophones but also of shots across the entire seismic line. Symmetric sampling is based on the principle of reciprocity that asserts properties of the wave field in the common-receiver domain are identical to the properties in the common-shot domain. Using symmetric sampling, even with the low fold, residual ground roll would not be aliased in the common receiver domain, and would not be so prominent in the stack. A more elaborate treatment of asymmetric and symmetric spatial filtering is given in Hampson (1987).

I request the authors confirm whether the dip direction of the residual ground roll in Figures 13b and 14b corresponds to the direction of the ground roll in the common receiver domain and not to the direction of the ground roll in the common shot domain. To test the hypothesis that the residual ground roll is due to aliasing of side-scattered ground roll in the common receiver gathers, I propose the following experiment: The data were recorded using 5 ft geophone arrays of 3 geophones each. Rather than summing 5 consecutive geophone arrays to simulate 25 ft arrays, it would be interesting to select every fifth trace, and stack the resulting subset of recorded data. With this subset symmetric sampling is simulated, however without alias protection from either shot or receiver arrays, so that the common-shot domain is almost ("almost" because of the short 3-geophone receiver array) as aliased as the common receiver domain. The stack now should also show strong aliased left-dipping ground roll. In this stack the in-line propagating ground roll would also be aliased, so there might be some subhorizontal residual ground roll in that stack as well. To investigate the effect of side-scatterers, it may help to apply a low-cut k-filter to remove the aliased in-line ground roll. It would be interesting if the authors could show these sections in their reply.

An extensive discussion of the total stackarray response, taking into account that there are two *independent* spatial coordinates in the prestack data set, can be found in Vermeer (1990).

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Reply by authors to G. J. O. Vermeer

We thank Gijs Vermeer for his interesting comments on our article. The focus of his discussion is to explain why residual ground roll remains on the stacked sections of Figures 13 and 14 even after using the optimal stackarray. He reasons that right-dipping residual ground-roll events can be explained by the presence of off-line scatterers. He further argues that symmetric sampling of the ground roll in both shot-and-receiver domains would mitigate this effect, and proposes a quick test involving reprocessing of our Humble data using only every fifth receiver group (which would result in symmetric sampling).

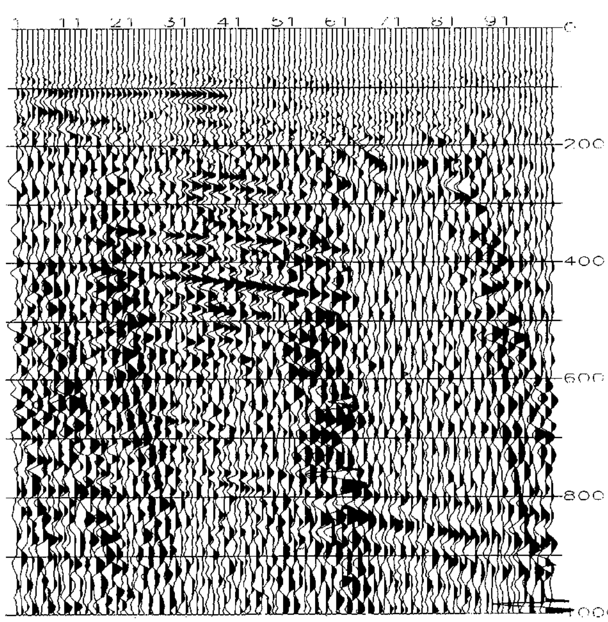

Fig. 1. Brute stack of data from Humble, Texas, that uses essentially no geophone array (actual array length is 5 ft).

The stacked section that results from selecting every fifth trace from each shot-record is displayed in Figure 1. The processing sequence used to prepare these data is identical to that used for the data shown in Figures 13 and 14 from our paper. As expected, the residual ground roll is stronger and some reflection events seen in the earlier figures have been obscured. Nonetheless, the residual surface energy is still clearly organized into strong right-dipping events, which would argue against the presence of off-line scatterers.

The field record from our Humble data that we showed in our paper as Figure 10 is typical of the data we collected. The surface energy is clearly linear (although strongly dispersive), and intercepts the time axis close to $T = 0$ at zero offset. The field data, therefore, show no evidence of any surface energy being scattered into the spread from the side. We would, in fact, be highly skeptical of any such hypothesis given the Gulf Coast geologic environment.

Considering the particular geometry used in this survey, we feel that the right-dipping events are probably due to variations in shot coupling. (Variations in geophone coupling would have resulted in residual ground roll that dipped to the left.) Lateral changes in shot environment that result in relatively minor differences in ground roll characteristics are far more likely to occur in this area than are sharp discontinuities that would scatter off-line energy into the spread.

If significant shot-coupling variations are, in fact, present, then a source array would definitely provide for a more stable ground-roll signature, and should be considered whenever operationally feasible. However, we would hesitate to recommend that symmetric source *and* receiver arrays be employed in all instances, since the simpler lateral-homogeneity assumption will fit most cases well enough. Moreover, in many of those cases where lateral amplitude variations are significant, the high fold of most modern 2-D surveys should provide sufficient statistical suppression of the ground roll to obviate the need for extraordinary source effort.

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Response by G. J. O. Vermeer to authors' reply

I am grateful to Peter Morse and George Hildebrandt for their illustrated reply to my comments. Obviously, shot-coupling variations are a bigger problem in this case than side-scatterers. I agree that both increasing the fold and using source arrays will reduce the effect of shot-coupling variations.

G. J. O. Vermeer