Statics estimation by stack-optimization of noisy data

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ABSTRACT

In a previous report (Ronen, 1984) I proposed to estimate surface-consistent time anomalies by stack-optimization, using a straight-ascent method. Because of local extrema of the objective function, it was not clear to what extent noisy data could be handled. Synthetic and field data examples shown here have low signal-to-noise ratio and were handled by the straight-ascent optimization program with a considerable success.

THE CHALLENGE OF NOISY DATA

When the signal-to-noise ratio (S/N) is high, reliable travel-times can be picked by hand or from cross-correlations; methods of least-squares model-fitting based on those travel-times (Taner et. al., 1974; Wiggins et. al., 1976) can be used even when the time anomalies are large, provided that the cross-correlation window is big enough. Only when the S/N is low do those methods have difficulties in recovering from incorrect (cycle-skips) travel-times that were picked in the cross-correlations stage; the estimated near-surface model is then based on unreliable data. Building pilot traces is a way to improve the reliability of travel-time picks but it might cost more than the stack-optimization method and is probably less robust.

SYNTHETIC DATA EXAMPLE

This synthetic data was generated by Dan Rothman (1984); it includes 100 midpoint gathers, 6 fold. Random noise was added. Shot and receiver consistent static shifts up to ±10 samples. Stacking without static correction produced the stack shown in Figure 1. A synthetically known set of 111 values for the 56 shot and 55 geophone statics would correct the data and produce Figure 2, whose power is probably the global maximum. An application of the straight-ascent program produced the stack shown in Figure 3, corresponding to a local maxima. The straight-ascent program was then run from 40 random initial points each run converged (in about 10 minutes) to a different maxima, none of which matched that of Figure 2. Different runs, however, produced reasonable results for different parts of the stack: the stack shown in Figure 4, for example, has a good solution on the sides. A different result was reasonable in the middle. From these results I composed an initial guess for yet another straight-ascent run that eventually produced the stack shown in Figure 5, whose power is 95% of the global maximum. The errors in the statics (Figure 6) are in long wavelength (cable length is 12) and in a few cycle skips.

How many local extrema are in this synthetic? At least 40, probably many more. If all of the maxima are equally probable, the probability of having 40 runs converging to 40 different maxima is

$$P(n,40) = \frac{\textit{ways to order 40 in n without repetition}}{\textit{ways to order 40 in n}} = \frac{\left(\begin{matrix} n \\ 40 \end{matrix} \right)}{\left(\frac{n^{40}}{40!} \right)}$$

$$= \frac{n}{n} \frac{n-1}{n} \frac{n-2}{n} \quad \cdot \quad \cdots \quad \frac{n-40+1}{n}$$

If there are 10,000 local extrema and we make 40 experiments then the probability of getting 40 different answers is $P(n=10000,40) = 0.92$. The likelihood of having n local maxima increases monotonically with n because P increases with n. If we want an estimate for n, that is better than "much more than 40", we should make more experiments; continue the random-start runs until some of them converge at the same point.

FIELD DATA EXAMPLE

A problematic line, which conventional statics programs had difficulties in handling was chosen: 194 shots and 194 geophones, split-spread, surface dynamite. Near-surface anomalies and a poor S/N (lightning bolts and an air wave are much stronger than the reflections) are the main problems.

The S/N was improved by a combination of automatic gain control * (AGC) and bandpass-filtering: the data came with soft AGC, I did hard AGC (saving the envelope),

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* Division by a smooth envelope. Soft AGC means very smooth envelope.

then bandpass, then multiplied by the envelope of my hard AGC, clipped in the 75th percentile. The statics program tried to correct the irregular near-surface. The improvement in the stacked section (Figures 8-9) was substantial for the upper 1.5-2 secs: the lateral coherency of events is improved inside and outside the estimation window which was 0.8 to 1.4 secs, and the shot and geophone statics are similar (Figure 7). Runs above 2 secs (from many starting points) were unsuccessful: no improvement outside the estimation window and no similarity between shot and geophone statics which (in a split-spread and surface dynamite data) shows that the solution is based on non-reciprocal noise. That is probably because of low penetration of the reflector that produced the multiples (Figure 9).

CONCLUSIONS

The stack-optimization method can estimate statics of data with low signal-to-noise-ratio. Extension of the signal-to-noise-ratio limit by many runs from different starting points worked for a synthetic example but not for a field data example.

ACKNOWLEDGMENTS

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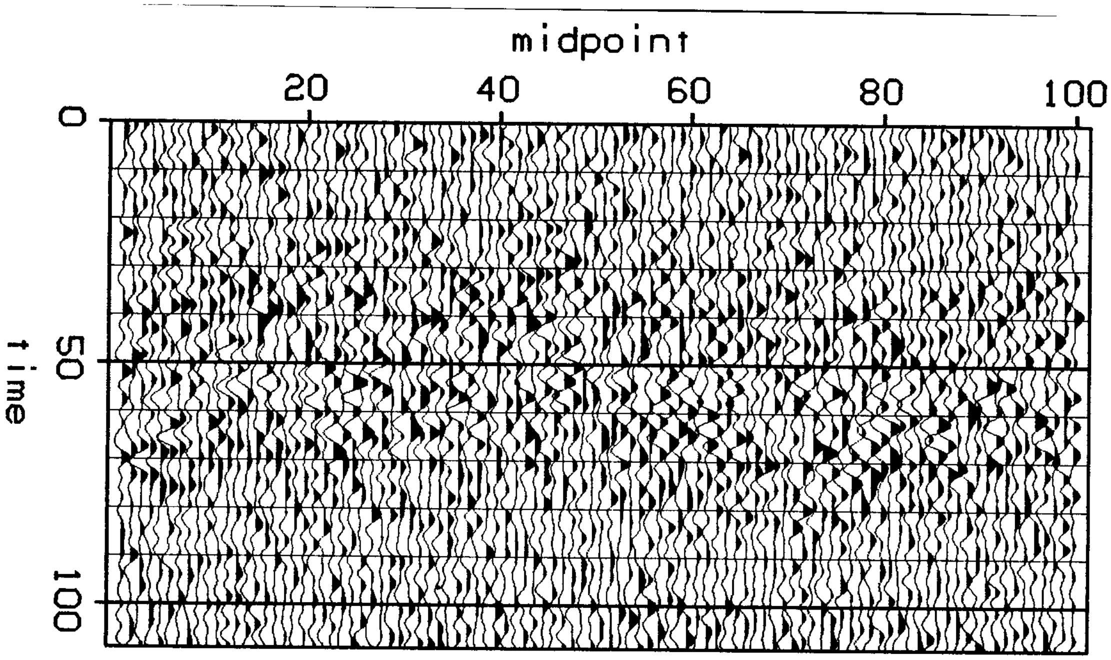


FIG. 1. Stack without static correction. (Synthetic).

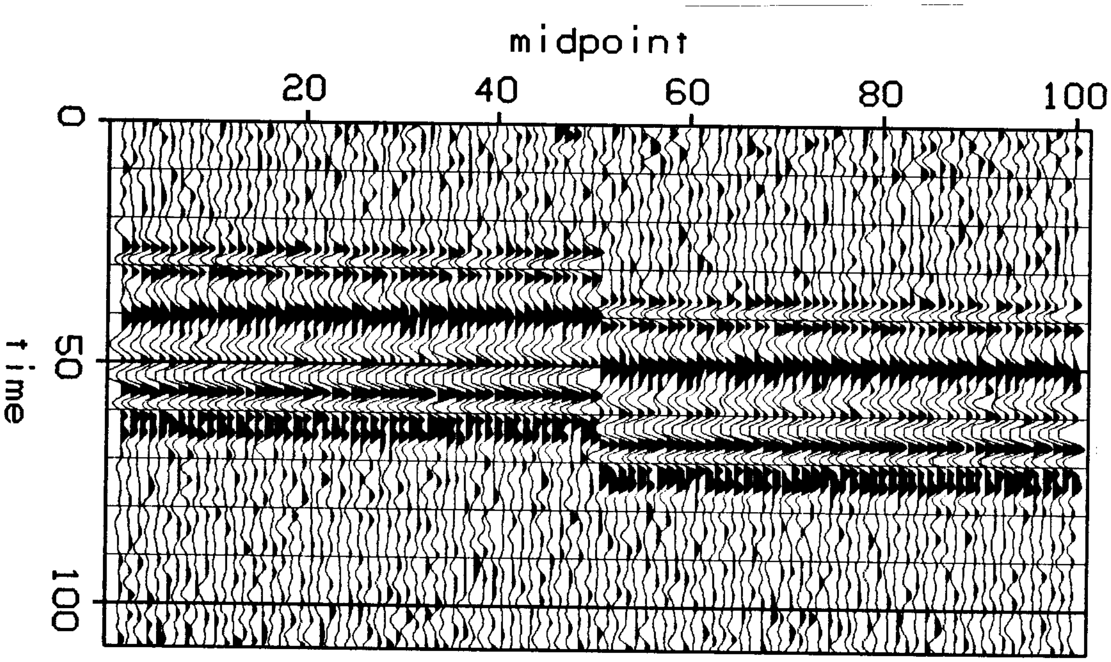


FIG. 2. Stack with the synthetically known static correction. ("The correct solution").

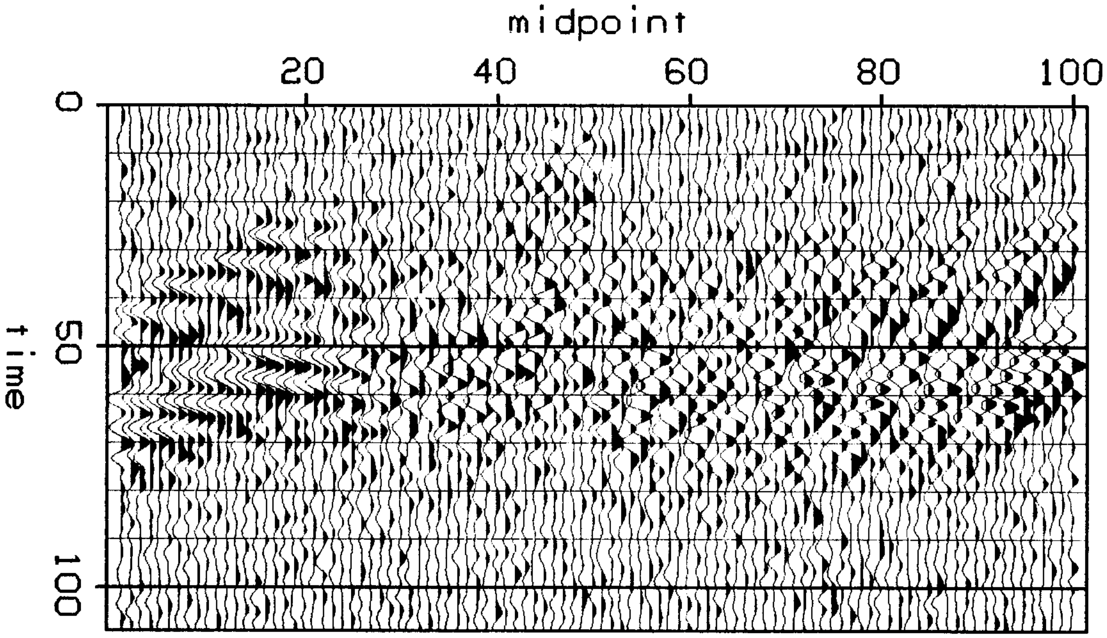


FIG. 3. Stack with static correction produced by straight ascent. (Synthetic).

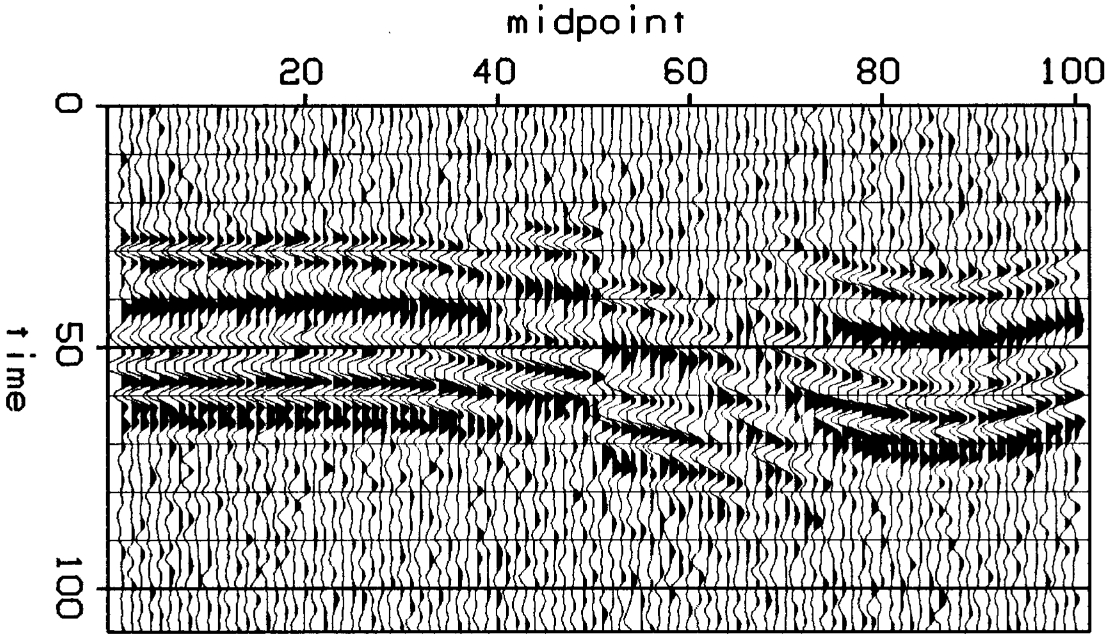


FIG. 4. The best of the 40 stacks with static correction estimated by straight ascents from random starting points.

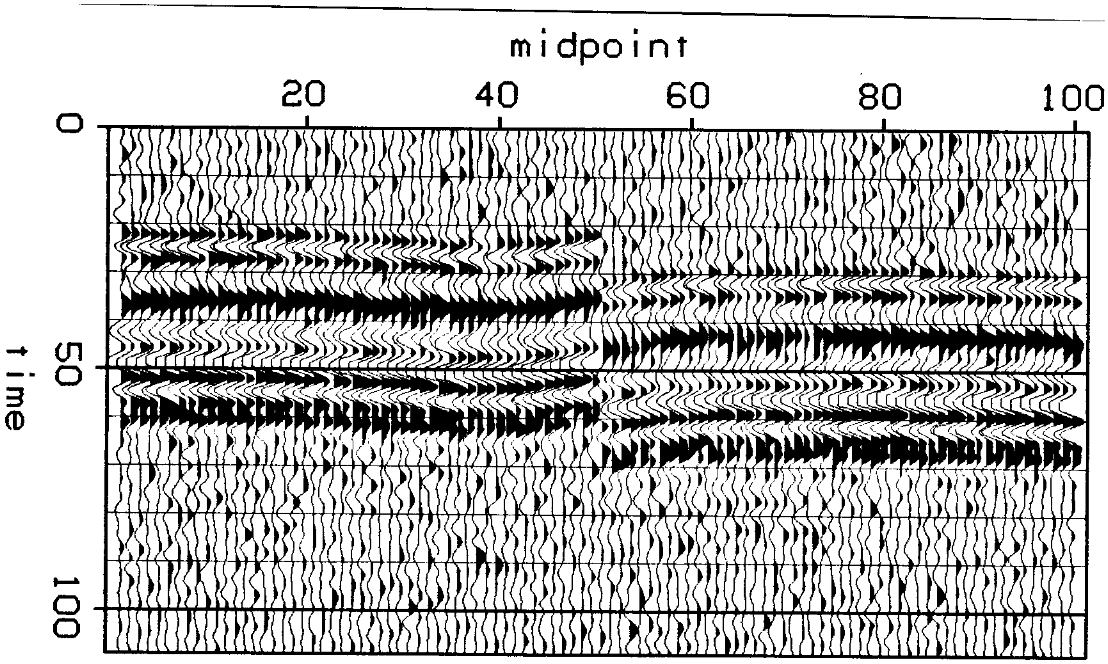


FIG. 5. Stack with static correction estimated by straight ascent from a starting point composed of results of the random tests. (Synthetic).

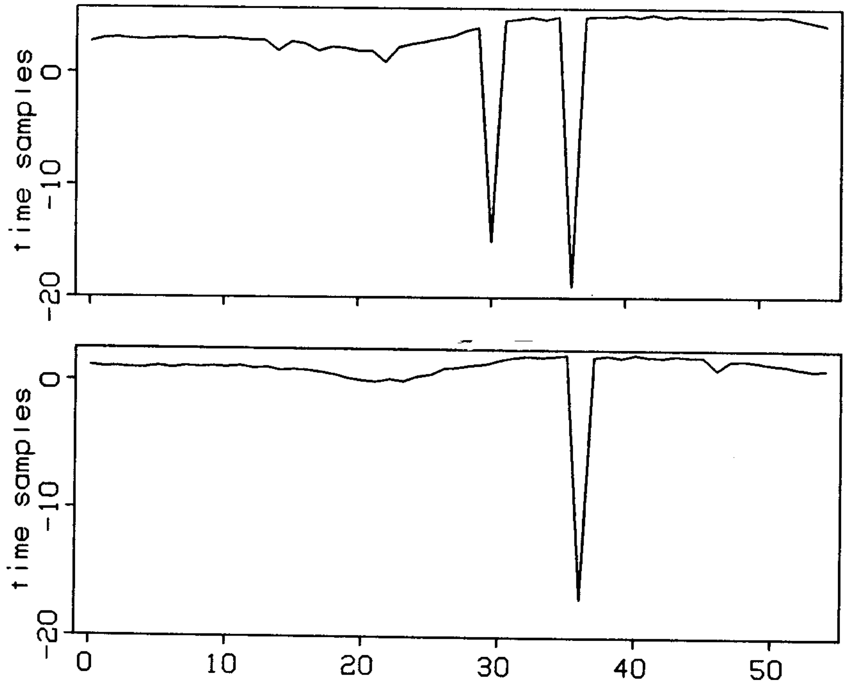


FIG. 6. Errors in shot-statics (above) and geophone-statics (below). (Synthetic).

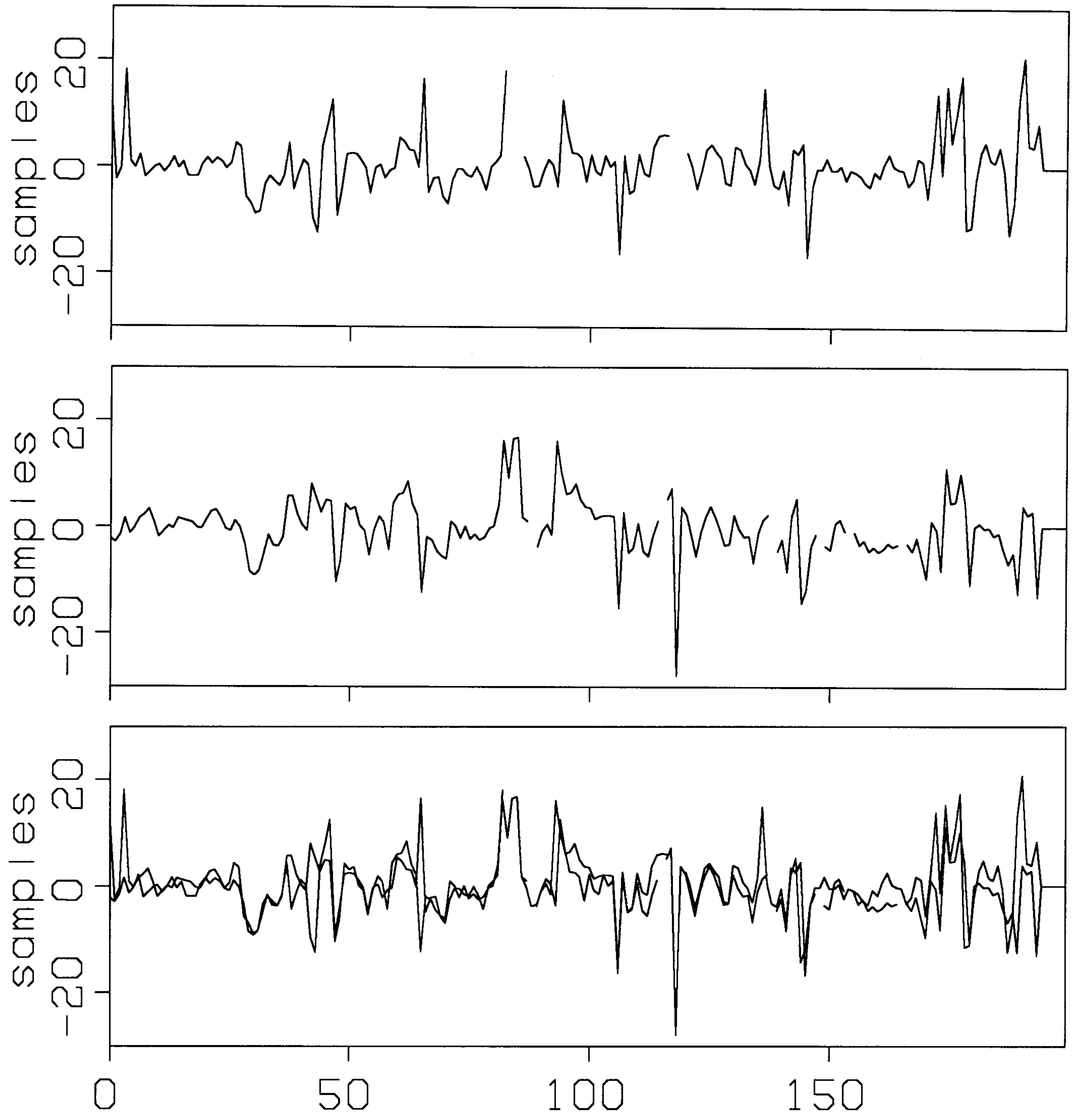


FIG. 7. Shot statics (above), geophone statics (center) and both shots and geophones (below). (Field).

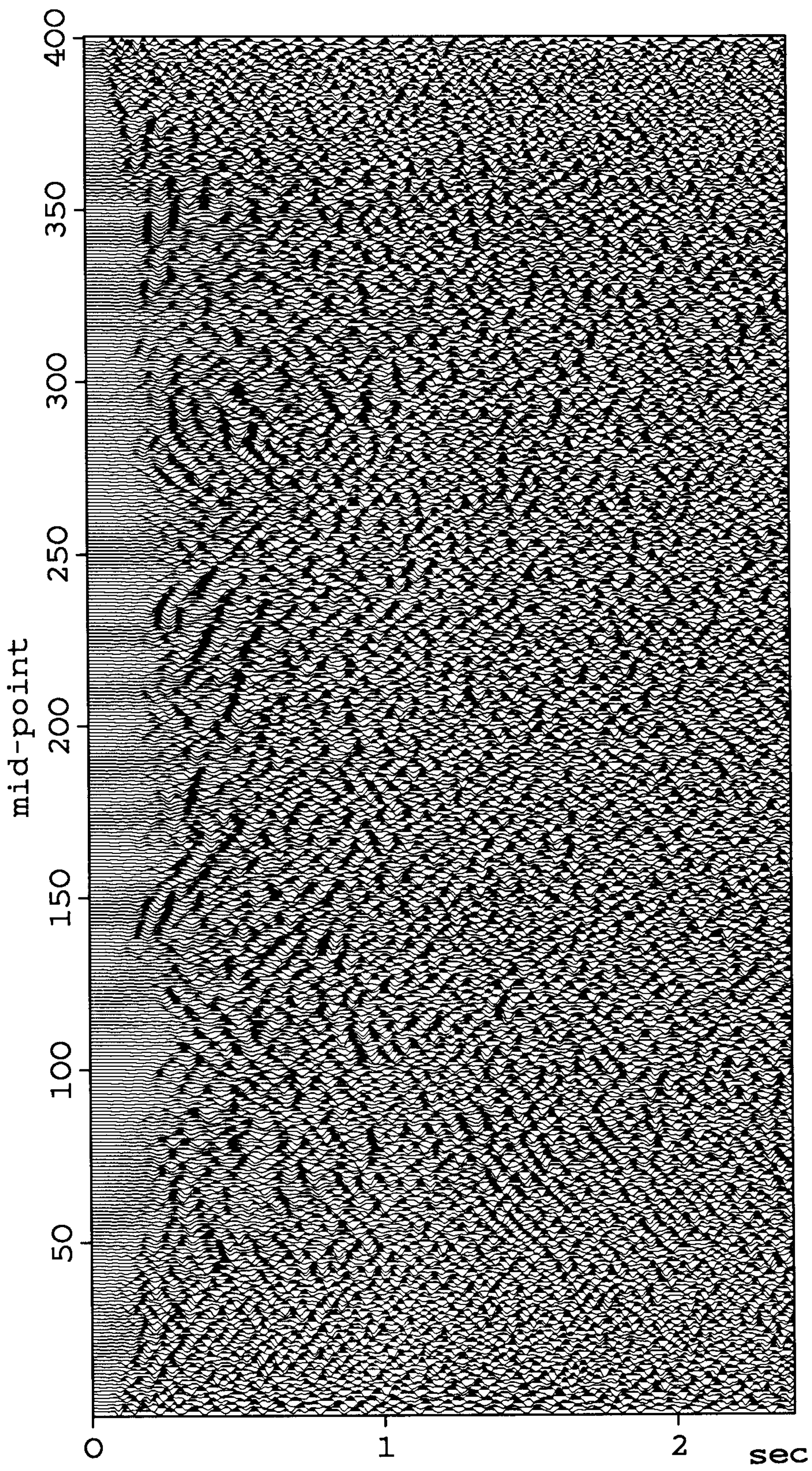


FIG. 8. CDP-stack without static correction. (Field).

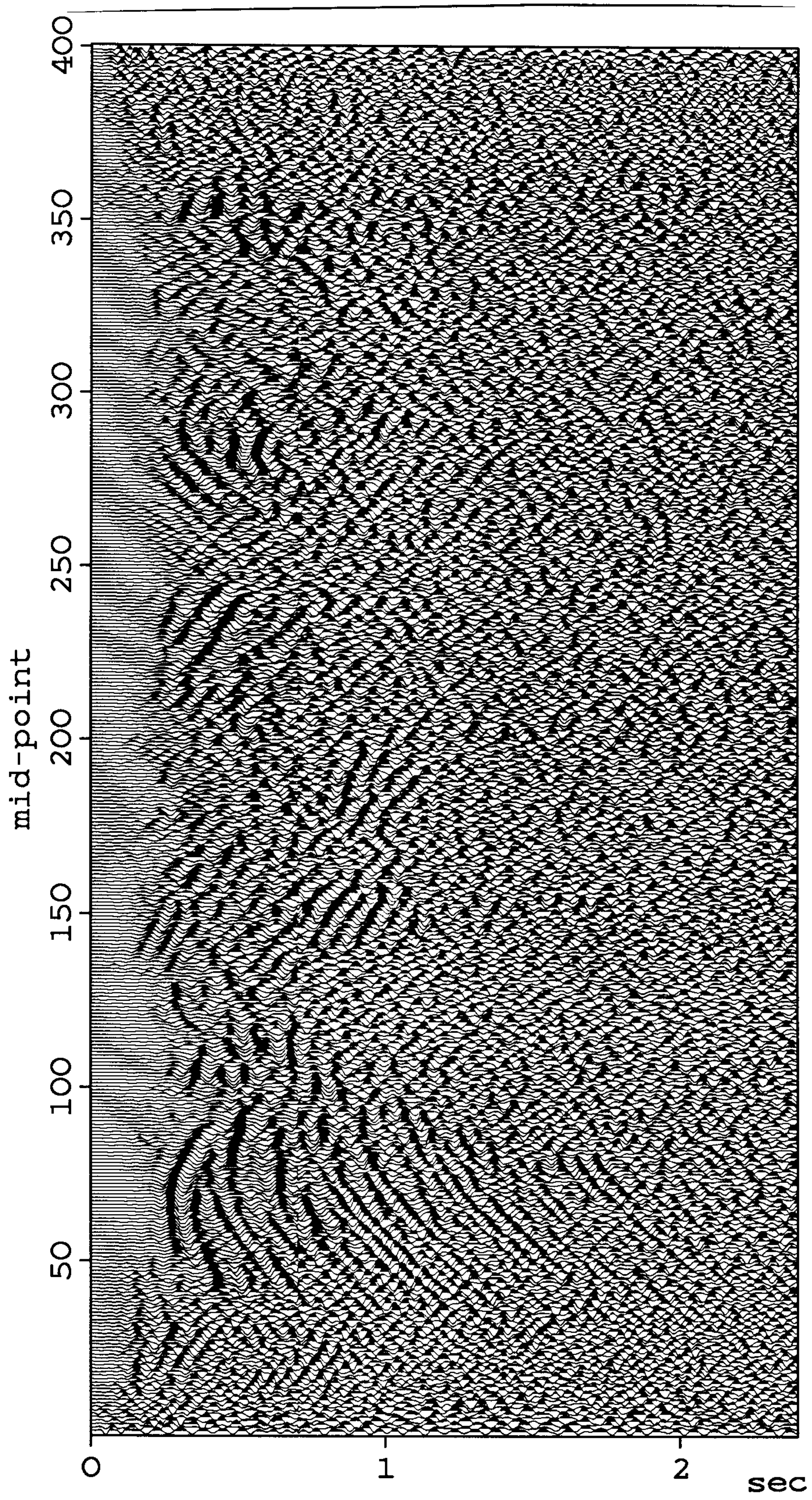
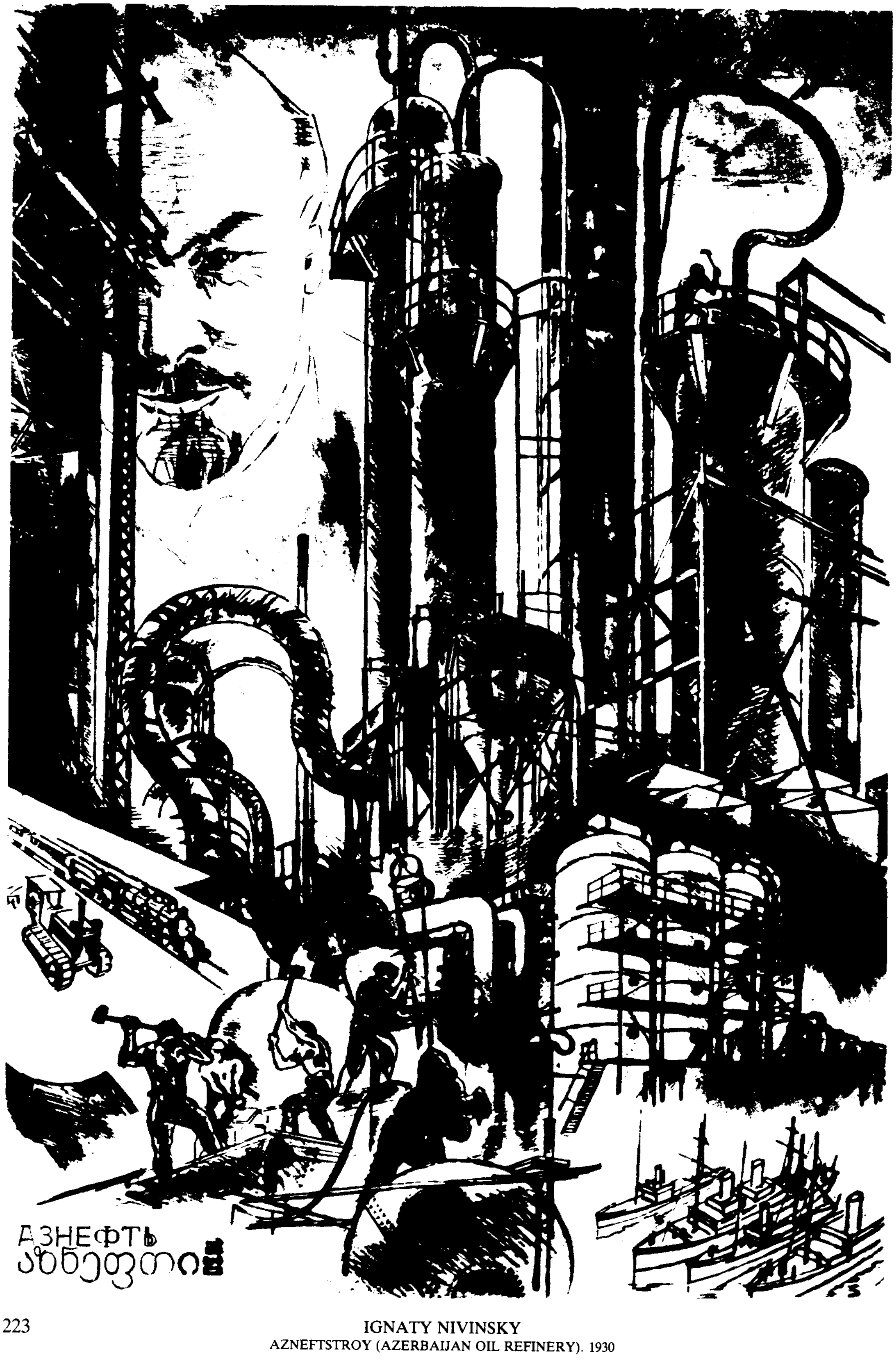


FIG. 9. CDP-stack with static correction. (Field).



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