Stanford Exploration Project, Report 79, November 16, 1997, pages 53–63

Stanford Exploration Project, Report 79, November 16, 1997, pages 53–63

Statics estimation by optimization of local slant stacks

Steve Cole[1]

keywords: *statics, slant stack, estimation*

ABSTRACT

Estimating statics by maximization of stack power presumes that NMO correction has flattened events. For estimating statics prior to NMO correction, or where a sufficiently accurate NMO correction is not available, an alternative is to optimize the power of local slant stacks. Long wavelength statics present a problem, as with other algorithms, but varying the number, size, and overlap of the local slant stacks can help.

INTRODUCTION

One class of algorithms for statics estimation involves finding those time shifts that maximize stack power. Ronen and Claerbout (1985) developed a method for maximizing the stack power of NMO-corrected CMP gathers. Rothman (1986) added the power of simulated annealing to allow the power maximization scheme to handle large statics and find the global maximum of stack power.

For these methods to be successful, NMO correction must first be applied to flatten the events. There are several situations where a sufficiently accurate NMO correction is not available, or where one might like to estimate statics before this NMO correction is applied. For example, in array studies where a 2-D array records signals incident on the array over time from different sources (Cole, 1988), the possibility of recording events with different dips simultaneously means that no moveout correction will flatten all events. In conventional exploration work, the departure from normal moveout that may require DMO or migration may also mean that NMO correction will not adequately flatten the events.

In both of these cases, an alternative procedure is to estimate statics by maximizing the power of local slant stacks. Rather than attempting to flatten events with a moveout correction, use local slant stacks to estimate the dips present in the data. Then by crosscorrelating each trace with a local stack, estimate the time shifts that

[1]**email:** not available

improve the alignment of events within the local slant stack. This procedure can be applied iteratively until the stack power is maximized.

Local slant stacks have been used in statics estimation by Kirchheimer (1990). Instead of optimizing stack power by crosscorrelations, he obtains time shifts from the local stacks, and then decomposes these time shifts into surface-consistent shot, receiver, and midpoint components.

In this paper, I describe a local slant stack based method for determining statics by stack power optimization, and illustrate it using 2-D and 3-D synthetics, followed by a real 3-D example, quarry blast data from the SEP passive experiment. As implemented here, the method deals only with receiver statics, as appropriate for the types of data I am dealing with. However, an extension to include shot statics should not be difficult.

METHOD

The framework for the statics program is the same that I have used previously for 3-D data interpolation (Cole and Claerbout, 1992) and noise suppression (Cole, 1993). In fact, the computer program included with the CD-ROM version of this report includes the earlier data processing capabilities, along with the addition of the statics method described in this paper.

The resulting algorithm has three main parts – dip estimation, statics solution, and interpolation.

Dip estimation

Local slant stacks are performed at a number of locations to determine the dips present in the data. Semblance is computed as a function of time, in time windows of user-specified size. The semblance coefficient is a ratio of the power of the stacked trace to the mean power of the unstacked traces.

In each time window, the dip giving the maximum semblance value is picked for use in the statics estimation and interpolation.

In 3-D, I typically perform the dip estimation on a grid that is coarse compared to the receiver geometry. The number of dips makes this step relatively expensive. A grid fine enough to insure that each trace contributes to a few local slant stacks is usually sufficient.

It is also possible to use beam stacks (Biondi, 1992) instead of local slant stacks. Beam stacks offer improved resolution as the number of neighboring traces used is increased. However, beam stacks require an extra piece of information, effectively the distance from the source to the stack location. For array studies with unknown source locations and multiple sources present, this information is not available. A procedure that scans over beam stack trajectories would be an interesting alternative, though more expensive that the local slant stack technique because of extra parameters corresponding to the source location.

Statics estimation

Local slant stacks are computed again, using the single dip picked from the semblance scans of step one. Here the conventional stack is used, rather than the semblance measure, so that traces may be subtracted from and added back into the stacks as the statics algorithm proceeds.

For a given receiver, the recorded trace is subtracted from all the local slant stacks to which it contributes. The trace is then crosscorrelated against all the stacks to which it contributes, forming a single crosscorrelation function. The lag which gives the largest correlation coefficient is the static value that maximizes the power of the affected stacks. Using this new static value, the trace is stacked back in to all stacks. After a new static value has been estimated for all receivers, the procedure then performs a second iteration, stopping when the stack power has reached a maximum or after a specified number of iterations have taken place.

Interpolation

Using the dips estimated in the first step and the static corrections estimated in the second step, the data are interpolated onto whatever output geometry is desired. Interpolation is performed by a local slant stack, using several neighboring traces. The number of neighbors used need not be the same as in the dip estimation case. In doing the interpolation, it is possible to median filter along the stacking trajectory and/or weight the output by the semblance coefficient obtained in dip estimation (using the semblance measured at the nearest available location). I demonstrated (Cole, 1993) that median filtering can make the interpolation less sensitive to noise bursts on isolated traces. And the nonlinear semblance weighting can enhance coherent events.

2-D SYNTHETIC EXAMPLE

Figure **??** shows a 2-D synthetic example. A dataset containing a single dipping plane wave (apparent velocity 3 km/sec) has had applied to it the statics solution shown in Figure **??**. The trace spacing is 20 meters and the time sampling interval is four milliseconds. A single dip estimation was performed at the middle receiver, using all ten neighboring traces. The statics estimated by the algorithm are shown in Figure **??**. While the relative shifts are correct, there is a time shift that reflects the presence of a DC bias in the random statics values that I chose to apply. This bias has been removed from the solution.

The crosscorrelation functions for each receiver for the first two iterations are displayed in Figure **??**. Figure **??** shows the improvement in the stack over the course of the first two iterations. Actually a single iteration was sufficient in this simple case.

In Figure **??**, random noise has been added to the synthetic. The statics solution in Figure **??** is similar to the previous one, but there is a clear linear trend in the solution that represents poorly estimated long wavelength statics. These become even more problematic on a larger 3-D example in the following section.

Figure **??** shows the result of applying the statics to the noisy data. After statics application, the data have been interpolated onto the original recording geometry by a local slant stack at the correct dip. A median filter has been used in place of the straight stack, and the output has been weighted by the semblance. This nonlinear weighting enhances the coherent signal. Because a single time window was used in this example, some alignment of noise along the same dip can be seen.

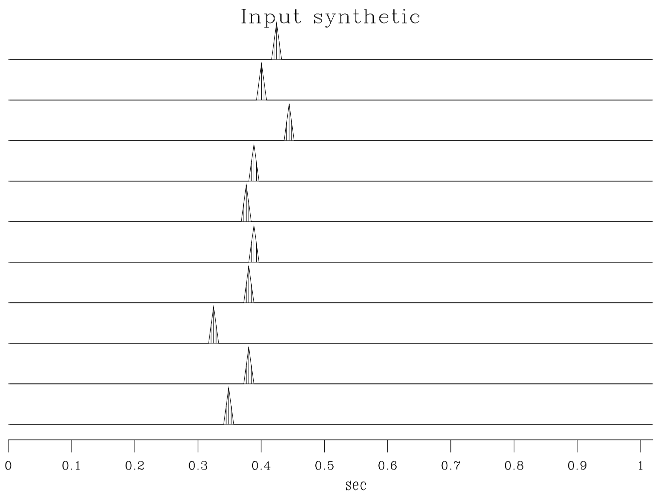


Figure 1: A 2-D synthetic example. The statics shown in Figure **??** have been applied to a dataset containing a single dipping plane wave. steve-syn2d [NR]

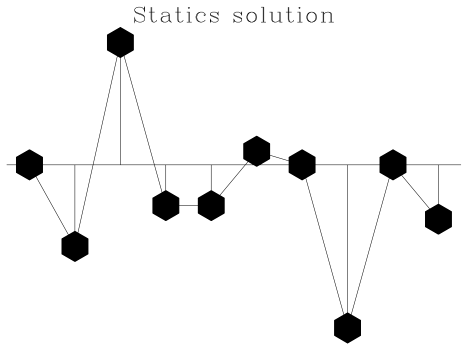


Figure 2: Random statics applied to create the data in Figure **??**. steve-statin2d [NR]

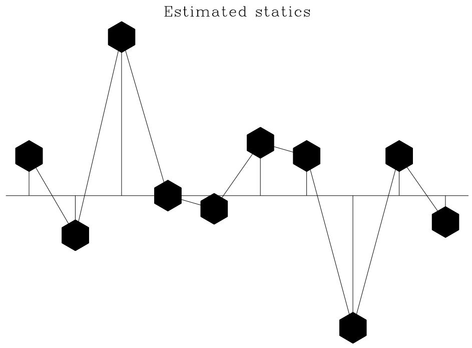


Figure 3: Statics solution estimated by the algorithm. steve-statout2d [NR]

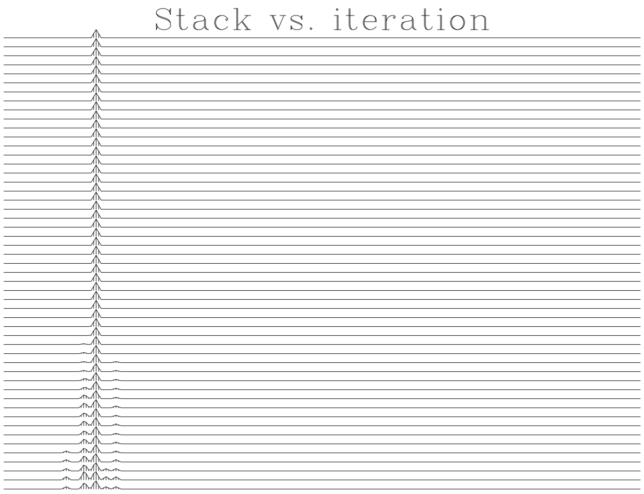


Figure 4: Iterative improvement of the local slant stack. The bottom trace is the initial stack. Each additional trace represents the result of updating the static solution for a single receiver. The first ten traces correspond to the first iteration of the algorithm, the second ten to the second iteration. steve-stak2d [ER]

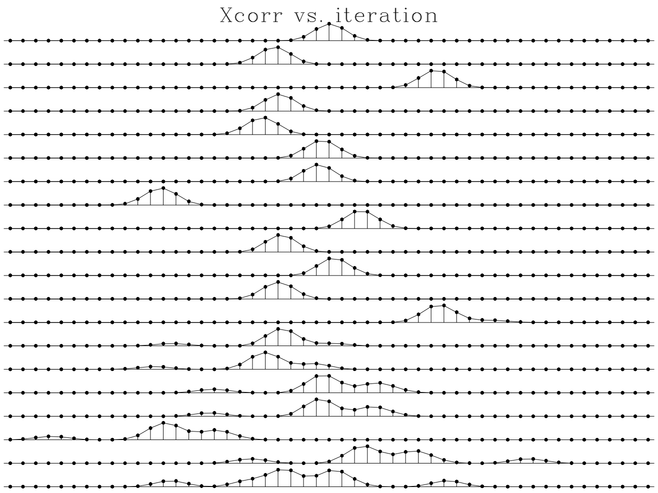


Figure 5: Display of crosscorrelations for the first two iterations. From bottom to top, the first ten traces are the crosscorrelations for the ten different receivers for iteration one, the next ten for iteration two. steve-xcor2d [NR]

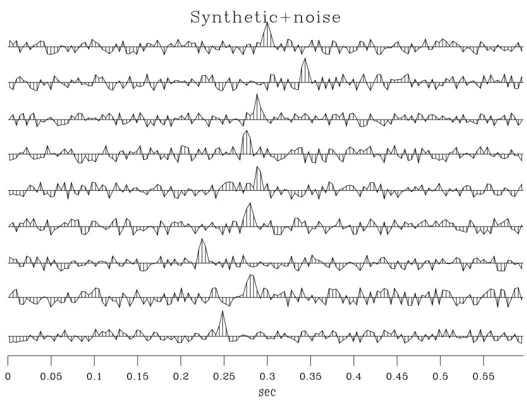


Figure 6: Synthetic with random noise added. steve-noise2d [NR]

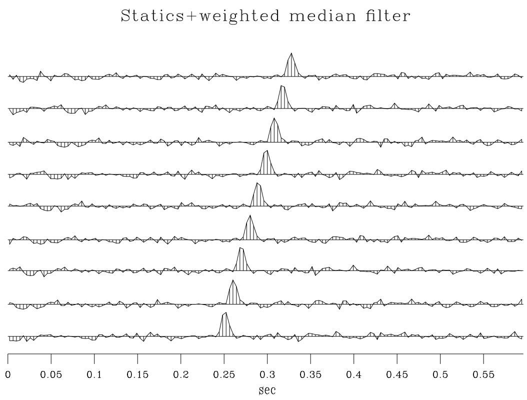
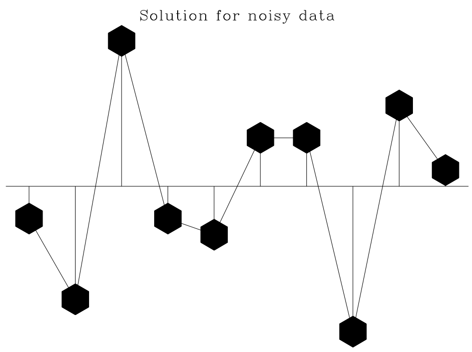


Figure 7: Noisy synthetic after application of statics, followed by interpolation onto the original grid, using a median filter and semblance weighting. A single semblance computation window was used for the entire trace, and some alignment of the noise can be seen. steve-noiseout2d [NR]

Figure 8: Statics solution for noisy data. Compared with Figure **??**, here there is a trend from lower left to upper right, indicating that the long wavelength statics have not been determined well. steve-noisestat2d [NR]



3-D SYNTHETIC EXAMPLE

Figure **??** shows a 3-D version of this synthetic. There are 169 receivers in a 13 by 13 grid, the same recording geometry as the SEP passive experiment. The 13 lines are shown in a single plot for convenience. The statics that have been applied are shown in Figure **??**.

The difficulty in handling long-wavelength statics varies dramatically depending on how the local slant stacks are parameterized. In Figure **??**, relatively few local slant stacks were used (a five by five grid spread evenly over the array), with 15 neighboring traces stacked into each. This makes for little overlap between stacks. The statics solution has a large long-wavelength component. In contrast, in Figure **??**, a local slant stack was performed at each receiver, using 5 traces. This results in a greater degree of overlap; most traces contribute to five or six stacks instead of two in the previous case. The solution is less affected by the long wavelength problem, perhaps because of the greater amount of overlap between stacks. The data are shown in Figure **??** with the better of the two statics solutions applied.

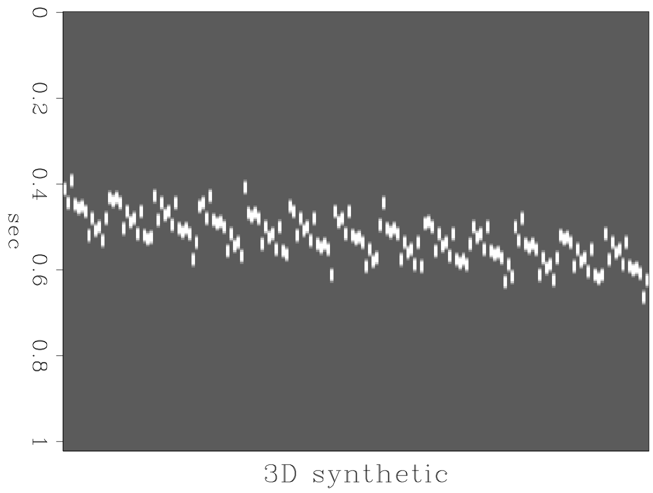


Figure 9: A 3-D synthetic containing a single dipping event, before (left) and after (right) removal of statics. steve-syn3d [NR]

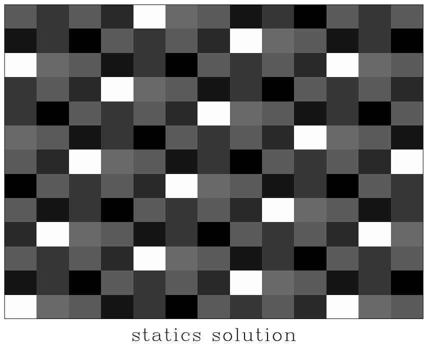


Figure 10: Plan view of the 13 by 13 receiver array showing the known statics applied to the synthetic. steve-stat3d [NR]

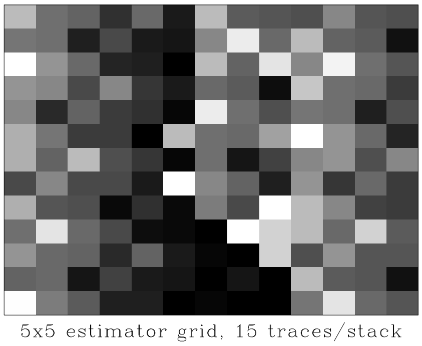


Figure 11: Statics estimated from relatively few, wide-aperture local slant stacks. This solution has a large long-wavelength component. steve-long3d [NR]

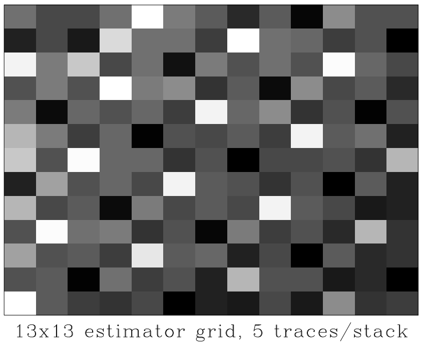


Figure 12: Using more, smaller stacks with a greater degree of overlap gives a solution closer to the applied statics. steve-short3d [NR]

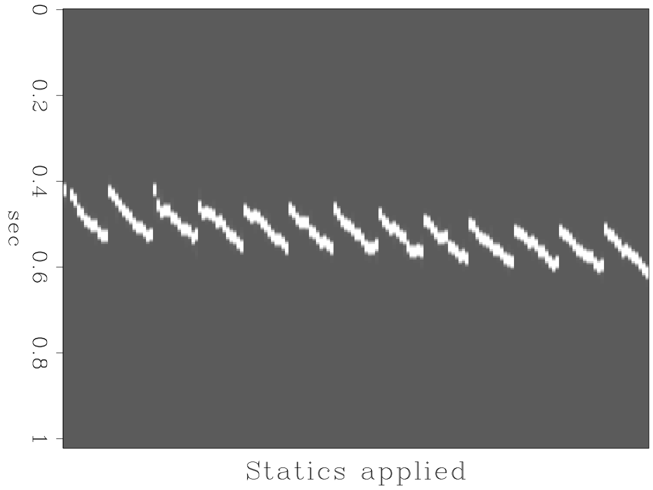


Figure 13: 3-D synthetic after application of statics from Figure **??**. steve-app3d [NR]

REAL DATA EXAMPLE

Finally, using the same slant stack configuration as in the more successful synthetic of Figure **??**, I estimate statics from a quarry blast recorded by the SEP passive array. Note the event on the right hand side of the section at around 10.2 seconds; it seems to be much improved with the application of statics. Further tests with the other blasts and passive data will hopefully validate this statics solution.

CONCLUSIONS

Optimizing local slant stacks offers a way to estimate statics without having to moveout-correct the data. Like other statics techniques, it has difficulty handling long-wavelength statics. Careful selection of the number, size, and amount of overlap between local slant stacks appears to improve the ability of the method to deal with long-wavelength terms, but more experience is needed. Beam stacks may be a useful addition to the method.

REFERENCES

Biondi, B., 1992, Velocity estimation by beam stack: Geophysics, **57**, no. 8, 1034–1047.

Cole, S. P., and Claerbout, J. F., 1992, A 3-D local plane-wave interpolation scheme: SEP–**73**, 147–160.

Cole, S., 1988, Examination of a passive seismic dataset using beam steering: SEP–**57**, 417–426.

Cole, S., 1993, Interpolation, noise suppression, and velocity filtering in 3-D: SEP–**77**, 37–42.

Kirchheimer, F., 1990, Residual statics by cdp-localized stack optimization: Geophys. Prosp., **38**, no. 6, 577–606.

Ronen, J., and Claerbout, J. F., 1985, Surface-consistent residual statics estimation by stack-power maximization: Geophysics, **50**, no. 12, 2759–2767.

Rothman, D. H., 1986, Automatic estimation of large residual statics corrections: Geophysics, **51**, no. 2, 332–346.

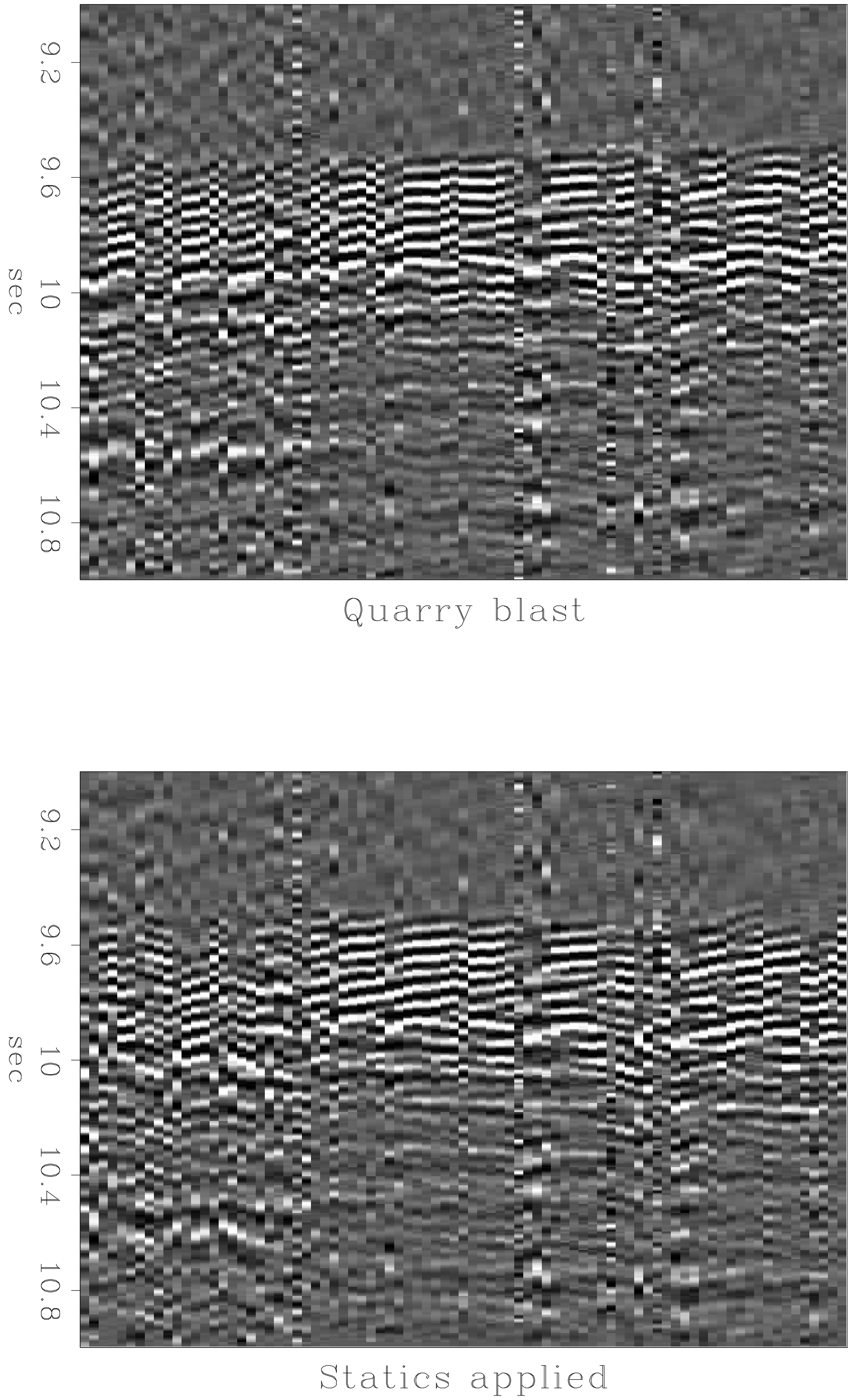


Figure 14: Quarry blast data before (top) and after statics removal. steve-blastcomp [NR]