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Acquisition Footprint Removal

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ABSTRACT

Economical concerns in general necessitate sparse recording of seismic data. In addition, the necessity of high spatial resolution dictates small field arrays. When combined, these two factors lead to various aliasing artifacts in the processed seismic data. Steeply dipping noise and multiples create artifacts in multichannel processes like tau-p filter, F-K filter, stack, DMO and migration. These spatially periodic artifacts, also called footprint, appear often in early time slices of low fold 3-D surveys. They often have patterns corresponding to periodic source and receiver locations used in many land recording geometries.

When such spatial periodicity exists it manifests itself as peaks, or spikes, in the wavenumber (Kx-Ky) transform of each constant frequency slice. When the dip structure of the data is not complex, i.e., when data are made of a few events each with planar dips, with little or no faulting, it is possible to devise a technique to detect these spectral peaks in the data. Since these patterns vary temporally and spatially it is beneficial to use time space gates. Once detected, spiky locations in the wavenumber domain can be surgically edited with little or no damage to underlying data. It is also possible to apply f-Kx-Ky notch filters if their locations are known beforehand.

INTRODUCTION

Leakage of steeply dipping noise, such as shot noise or multiple energy, into 2-D stack volumes and the control of this leakage by use of a combination of shot/receiver arrays and the recording geometry is well known (Morse and Hildebrandt, 1989). Noise appears on stack volumes as spatially periodic artifacts and this phenomenon is known as hatching or jitter as illustrated in Figure 1 which shows a portion of a CMP line from a deep water 3-D marine survey. Of course, suppression of multiple energy before stack helps reduce such artifacts to a large degree. Figure 2 shows that interpolation alone can suppress such artifacts significantly as long as one uses an algorithm that can handle aliased data (e.g., Gülünay and Chambers, 1998). Such recording artifacts are more common on 3-D land surveys due to large source and receiver line intervals, low fold, periodic offset and azimuth variations and/or less effective source/receiver arrays. 3-D marine surveys may exhibit artifacts in the crossline direction due to the limited number of cables and multiple boat passes (swaths).

In addition to noise a variety of offset-related processing artifacts contribute to footprint (Hill et al., 1999). Algorithmic response of multichannel processes to spatial sampling is best addressed within the processing algorithms. For example, response of DMO to irregular spatial sampling can be addressed within DMO (Schleicher and Black, 1989; Beasley and Klotz, 1992; Ronen,1994).

Even after careful preprocessing, however, some footprint may still be left in the data. To minimize its harmful effects, Meunier and Belissent (1992) proposed using deterministic filters that are derived from the 3-D field geometry. Gülünay et al. (1994) suggested the use of data driven wavenumber domain notch filters on each frequency slice of 3-D stack data. Hampson (1994) suggested the use of deterministic filters for 2-D stack data at the same meeting.

An example of spatially periodic artifacts on land 3-D data is given in Figure 3. This stack volume was recorded with a zig-zag shooting pattern over an area of fairly flat structures. The sum of the wavenumber domain spectra for this 3-D volume is shown in Figure 4. The footprint manifests itself as small and organized local peaks (about 36 dB down with respect to the dominant zero dip event) in the F-Kx-Ky domain

Locations of these peaks can be determined from such a plot or can be picked automatically as suggested by Gülünay et al.(1994). Recently, Gülünay (1999, 2000) suggested a similar data driven method that is capable of handling dipping events as long as the dip structure of the data is not complex. In this paper this improved technique is briefly described, practical aspects of the method are discussed and application to two land data volumes are given. Note that there are t-Kx-Ky domain footprint removal methods as well (Drummond et al., 2000). It is our understanding that this method works time slice by time slice and we expect it to be difficult to apply to dipping data.

THE METHOD

The footprint model used by Gülünay assumes that it is spatially periodic both in amplitude and phase and can be modeled as convolution of the data with a modulated comb function. It is implicitly assumed that the spatial periodicity of the noise is not shared by the underlying data. Since the wavenumber response of a comb function in space is also a comb function, each linear event in the time space domain is a suite of spikes in the frequency slices centered around each event. The amplitude of these spikes is dependent on the dips of the noise, the data themselves, and vary with frequency, yet the relative location of the spikes around each dominant event is the same. By allowing dip correction during spectral summation along frequencies, one can design a frequency independent notch filter from the data, and apply it, around each event in each frequency slice. During the filter design one can make use of thresholds for consistency of the peaks across frequencies, their amplitudes relative to the event and their ratio to their neighbors in each frequency slice so that spurious peaks are not picked. Of course, if the notch filter pattern can be estimated from the geometry, it can be applied as well.

DATA EXAMPLES

Two land 3-D data examples are presented in this paper. The first one is a 3-D migrated data set. In this survey, receiver lines are 5-stations apart (10 CMPs) and shots are on lines perpendicular to the receiver lines, except that after every 5 shots they move to the right by two stations, leading to a slanted shot line pattern. The shot lines repeat laterally at 7-station intervals (14 CMPs) as shown in Figure 5. A time slice (at 600 ms) from that volume is shown in Figure 6. Diagonal striations are apparent on this time slice, especially on the left side of the figure. These are due to the recording geometry shown in Figure 5. Figure 7 is the output of our acquisition geometry footprint suppression method.

The second data set is a DMOStack volume of a land 3-D vibroseis survey. It was recorded with an orthogonal recording geometry where N-S shot lines and E-W receiver lines were each 16 CMP cells apart and CMP cell size was 82.5'x82.5'. A shallow time slice from the DMO stack volume is shown in Figure 8. In this figure one can spot the sparse shooting patterns causing rectangular acquisition artifacts in the figure. Figure 9 is the same time slice after application of the footprint removal algorithm. Figure 10 and 11 illustrate the acquisition footprint removal of similar artifacts on a deeper time slice of the same DMOStack volume.

CONCLUSIONS

In this presentation, a brief review of Gülünay's (1999, 2000) acquisition footprint algorithm is provided. Recent experience with two new field data examples is discussed. Results obtained on these data sets suggest that the data driven Kx-Ky notch filtering method applied on each frequency slice, can be effective in reducing acquisition footprints. Because notch filtering suppresses noise as well as some small proportion of the underlying signal, the method requires close QC to make sure that coherent events are not attenuated by the algorithm.

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REFERENCES

Beasley, C. and, Klotz, R., 1992, *Equalization of DMO for irregular spatial sampling*, 54th Annual Meeting of the European Association of Exploration Geophysicists, Expanded abstracts p.232-233.

Drummond, J. (Jock) M., Budd, A. J. L, and Ryan, J., W., 2000, Adapting to noisy 3D data- attenuating the acquisition footprint, submitted to the SEG 2000.

Gülünay, N. and Chambers, R., 1998, Trace interpolation with data adaptive filtering in the frequency wavenumber domain, 60th Annual Meeting of the European Association of Geoscientists and Engineers, Extended Abstracts, Paper 2-52.

Gülünay, N., Martin, F., and Martinez, R. D., 1994., 3-D data acquisition artifacts removal: spot editing in the spatial-temporal frequency domain, 56th Annual

Meeting of the European Association of Geoscientists and Engineers, Abstracts Book, Paper H049.
Gülünay, N., 1999, Acquisition geometry footprints removal, 69th Annual Meeting of the Society of Exploration Geophysicists, Expanded Abstracts, p. 637-640.
Gülünay, N., 2000, 3-D Acquisition footprint removal, 62nd Annual Meeting of the European Association of Geoscientists and Engineers, Abstracts Book, Paper L-17.
Hampson, G., 1994, Relationship between wavefield sampling and coherent noise attenuation, 56th Annual Meeting of the European Association of Geoscientists and Engineers, Abstracts Book, Paper H054.
Hill, S., Shultz, M. and, Brewer, J., 1999, Acquisition footprint and fold-of-stack plots, The Leading Edge, Vol. 18, No. 6, p. 686-695.
Meunier J. and Belissent, M. ,1992, Reduction of 3D geometry generated artifacts, VIth Venezuelan Congress.
Morse, P. F., and , Hildebrandt, G. F., 1989, Ground-roll suppression by the stackarray, Geophysics, 54, 3, p. 290-301.
Ronen, S., 1994, Handling irregular geometry: Equalized DMO and beyond, 64th Ann. and Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, p. 1545-1547.
Schleicher, K. L., and Black, J. L., 1989, Effect of irregular sampling on prestack data, 59th Ann. and Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, p. 1144-1147.

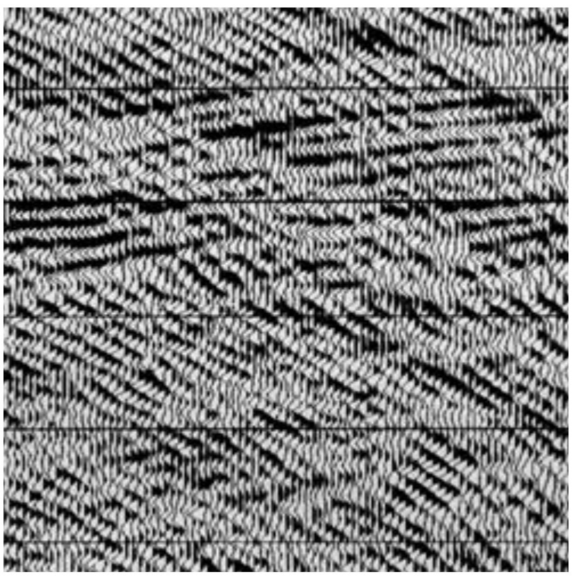

Figure 1. Stack of a CMP line. Multiples leak into the stack.

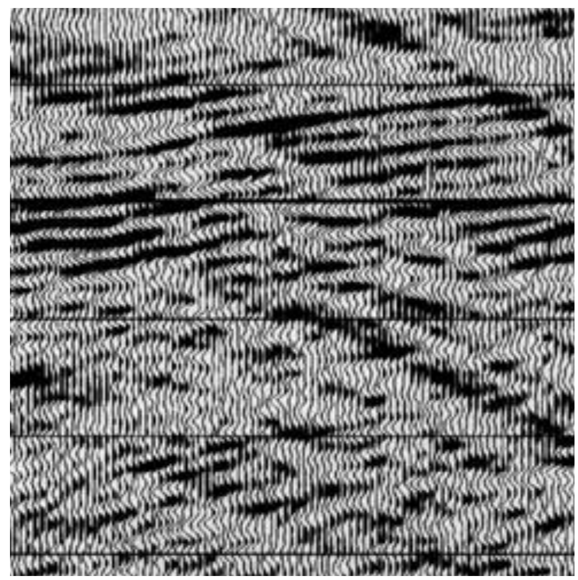

Figure 2. Same stack after application of prestack data interpolation that can handle aliased data.

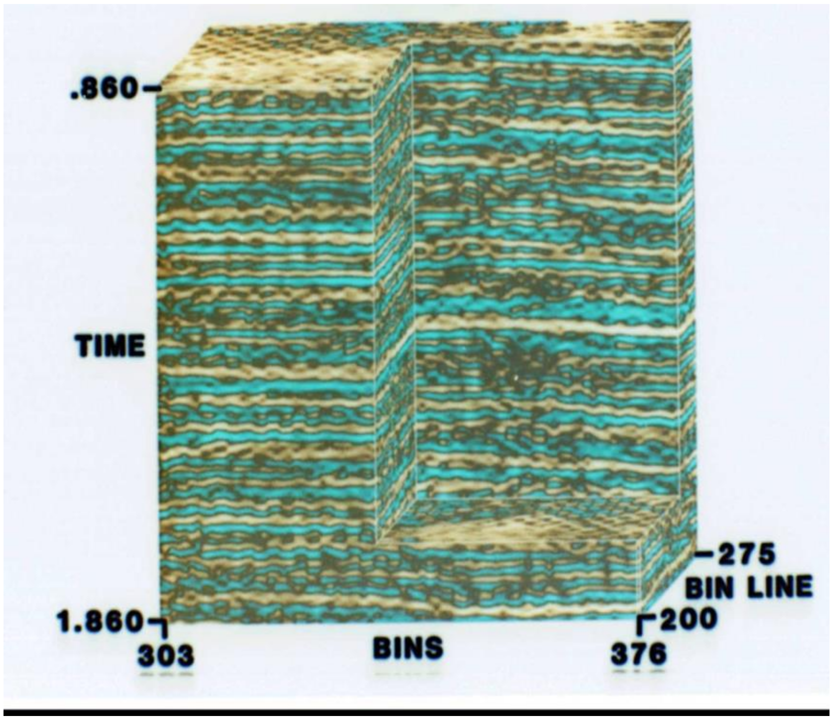

Figure 3. Stack volume of a 3-D land survey where a zig-zag shooting pattern was used.

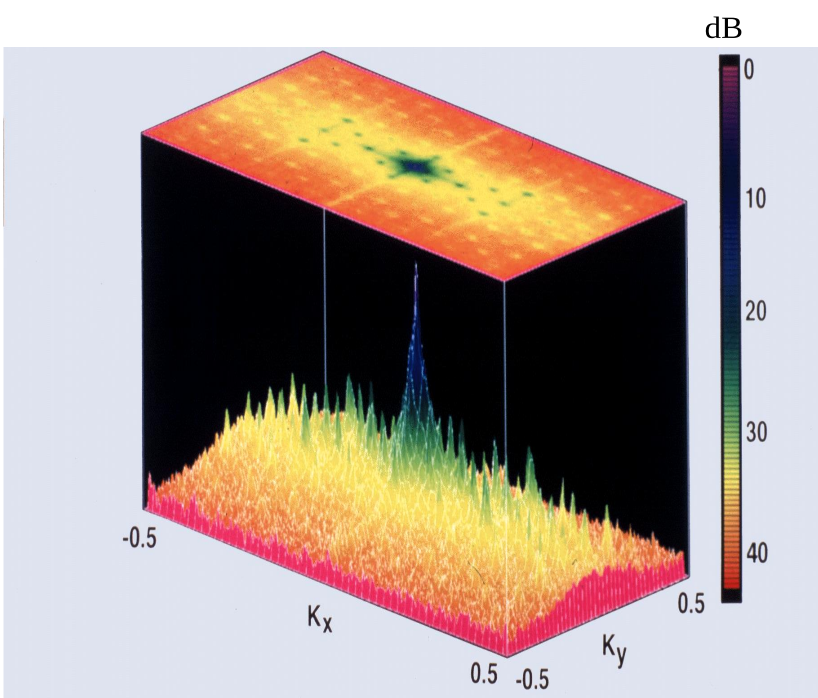

Figure 4. Sum of Kx-Ky spectra for the data in Figure 3.

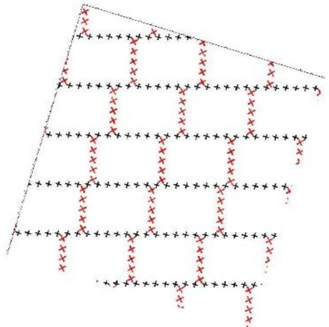

Figure 5. Geometry of a 3-D land survey.

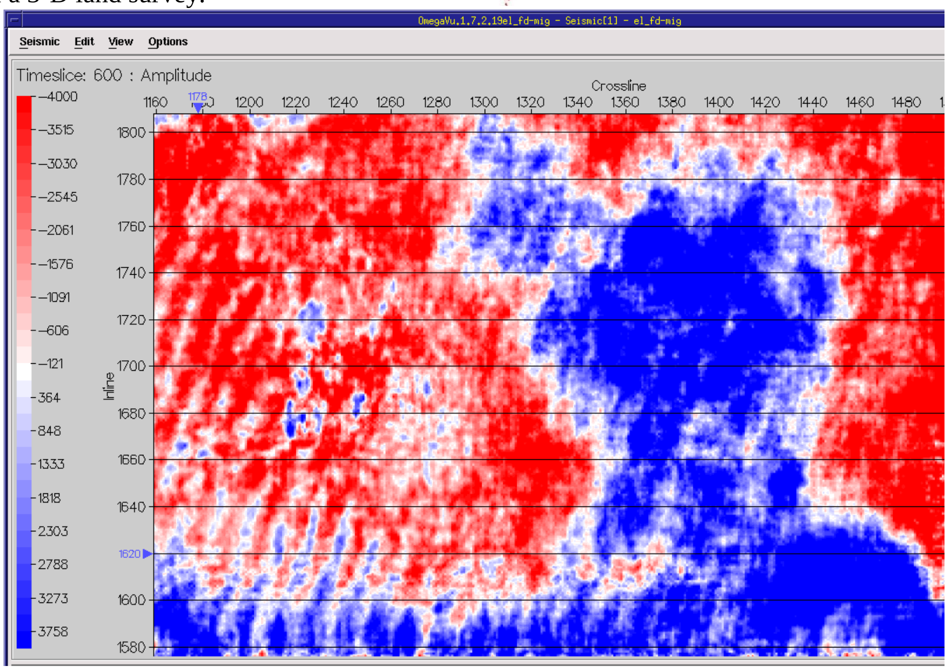

Figure 6. Time-slice at 600ms.

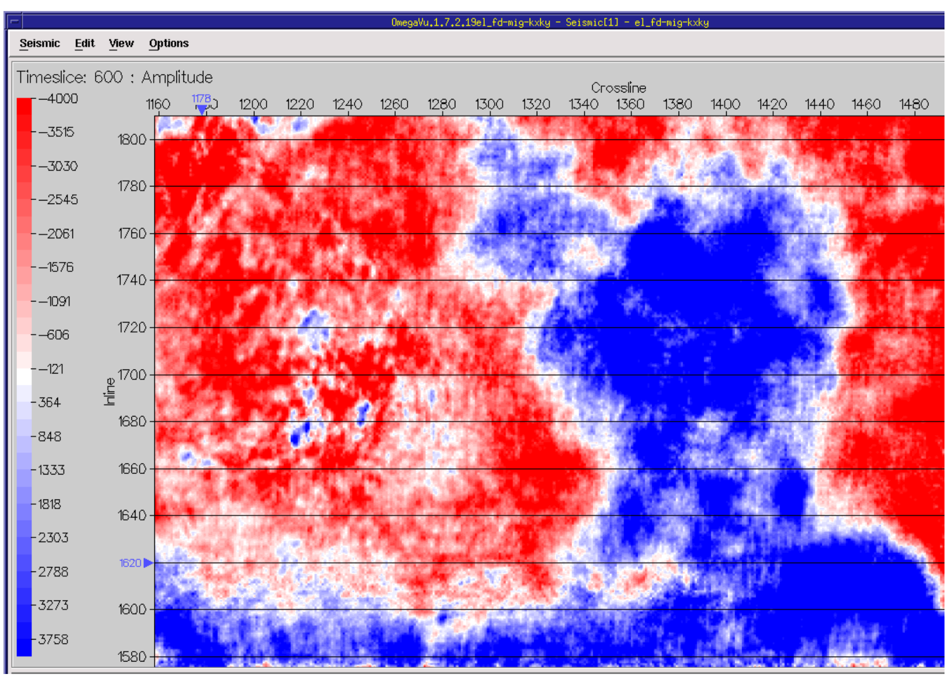

Figure 7. Same time slice after acquisition footprint removal.

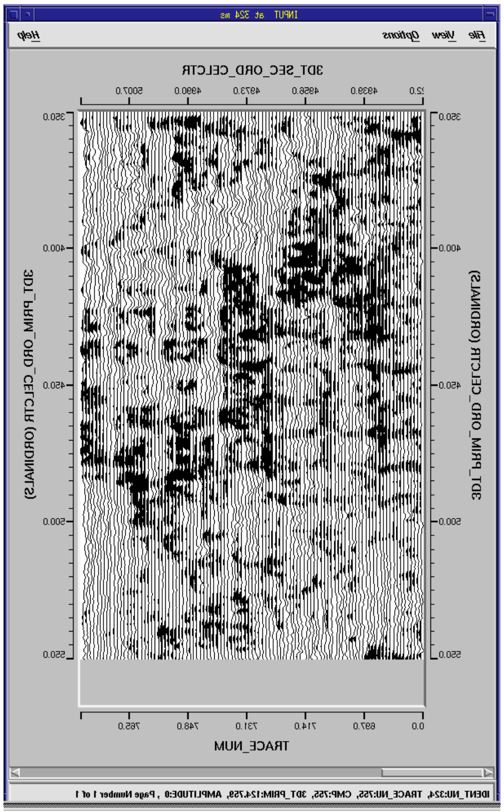

Figure 8. Time slice at 324ms.

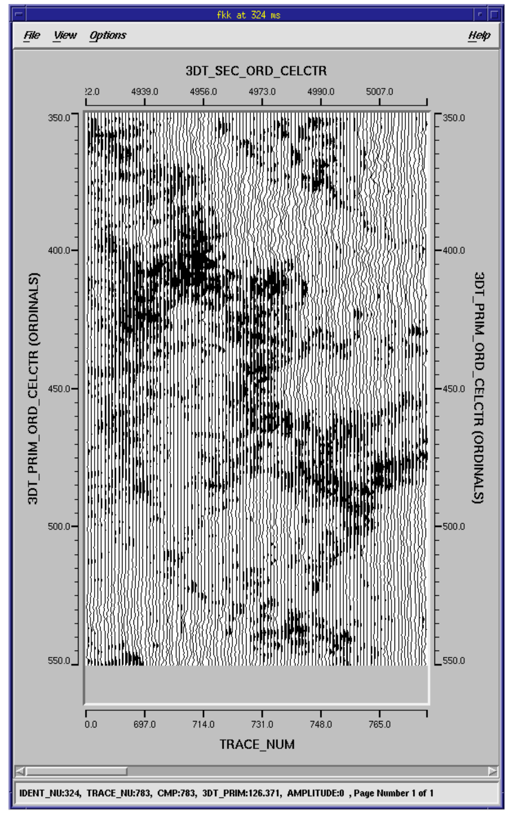

Figure 9. Same time slice after acquisition footprint removal.

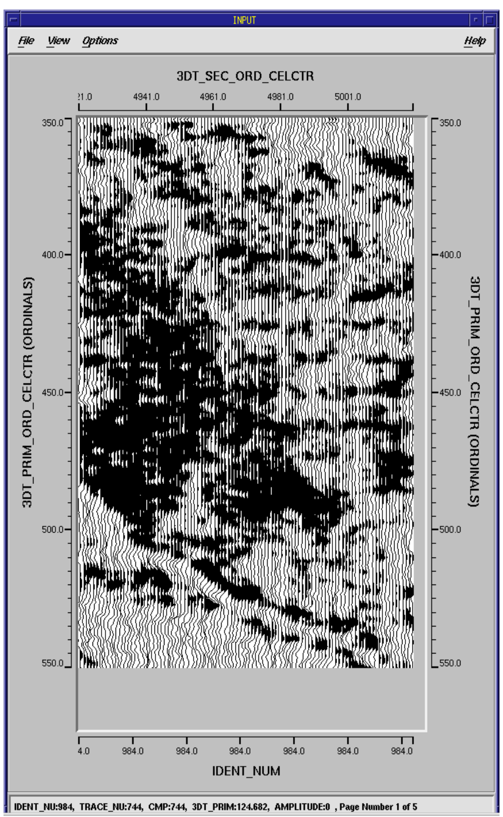

Figure 10 . Time slice at 984 ms.

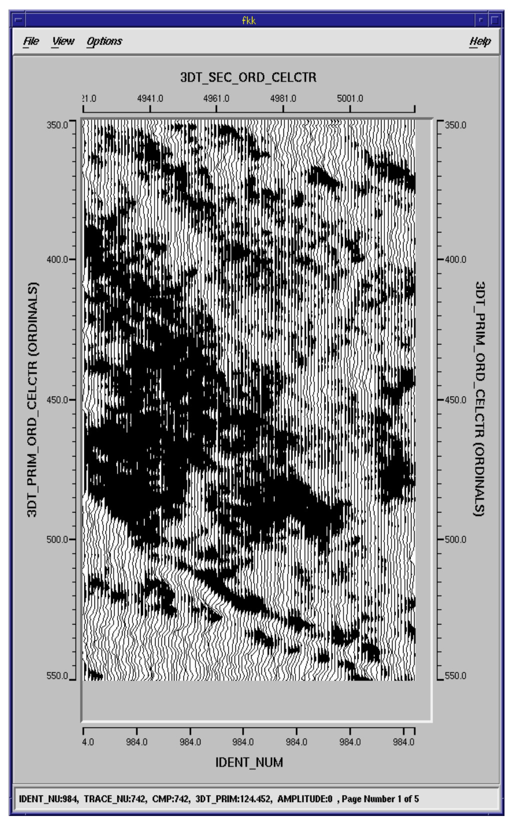

Figure 11. Same time slice after the acquisition footprint removal.process.