Successful Vibroseis Acquisition in the Polish Carpathians

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Abstract. The seismic acquisition in mountainous terrain has traditionally been a costly challenge. The dynamite is generally the source of choice. The Polish Carpathians is no exception to this. The problem is of course that the time and safety issues of using dynamite significantly increase the cost of acquisition. This is particularly the case because Polish regulations do not permit pre-loading of dynamite.

To reduce cost and maintain good data quality, Apache Corporation undertook a Vibroseis test program in the last quarter of 1999. The problems that had to be addressed in designing the Vibroseis program were both logistical and technical. The existing dynamite data is generally of low signal to noise ratio (S/N) with the shallow charges showing worse s/n than the deeper charges. Generally the data in the Carpathians is limited by coherent near-surface noise generated by the seismic sources and by ambient sources. Both of these noise sources appear as "secondary sources" which 2D seismic processing has difficulty in suppressing. Additionally, the data also indicates significant static problems. Given that a Vibroseis source is much weaker than dynamite the stated problems would be accentuated. The test program resulted in modified acquisition methods, which allowed Apache to record the information needed to isolate the "secondary source" and reduce the noise.

Fourteen kilometers of Vibroseis data was successfully recorded in poor weather conditions and the processed sections of the data were as good or better than offset dynamite data. This leads to the expectation that if acquisition t[1]hen this method is indeed viable as a standard acquisition tool in the hilly terrain of the Carpathian regions.

Key words: Vibroseis, Acquisition, Carpathians, Noise, Groundroll

Background

The Cross-line field spatial sampling is required to provide the necessary information to allow removal of scattered waves generated by the source. The existing dynamite data shows scattered noise wave events. The data also implies significant static problems. Since both arise from near-surface inhomogeneities, they are often associated. The poorly sampled cross-line noise scattered from a large number of fairly weak inhomogeneities give rise to a random noise look on the 2D data. While this kind of noise can be reduced relative to signal by increased fold that is not always the best solution.

The scattering noise waves can be grouped into two kinds, faster velocity refractions and slower velocity groundroll. When both noise waves are of comparable strength, the large range of wavelengths present a very difficult spatial sampling problem. The dynamite data has also shown that the scattered groundroll noise is proportional to the direct arrival groundroll and is therefore deemed to be more important than the scattered refractions. For the large groundroll generated by Vibroseis, three field arrays (vibrators, move-up and geophone arrays) are used to attenuate the energy at the spatial alias implied by the inline receiver station spacing and the resulting spatially sampled noise can be reduced in processing.

Regone presented in Carbonate Seismology (Edited by Palas and Marfurt, SEG Geophysical Developments No, 6, 1997, pp281-305) a method for achieving dramatic improvement in data quality in the presence of "secondary source" noise in a controlled test. Regone's method for attenuating "secondary source" noise is to deploy a field array perpendicular to the 2D line direction. The geophones in the array spatially sample the undesired noise and the summation in the array attenuates the noise, 12-20 dB, for noise wavelengths shorter than the array length. The field array is broken into 3 parts that are recorded separately and must be reconstructed in processing.

An initial review of the geology and previous work provided a set of ground rules to begin to lay out the test requirements. The desired signal from steep dips of 70Hz requires spatial sampling of 25m. Additionally, groundroll velocities are in the range of 700m/s to about 1800m/s. At the strong temporal low end of the seismic frequency band the wavelengths are 70m to 180m. Since the groundroll is dispersive the temporal high frequency end reduces in amplitude. Assuming the 2D-line direction is in the dip direction, the inline spacing and arrays are

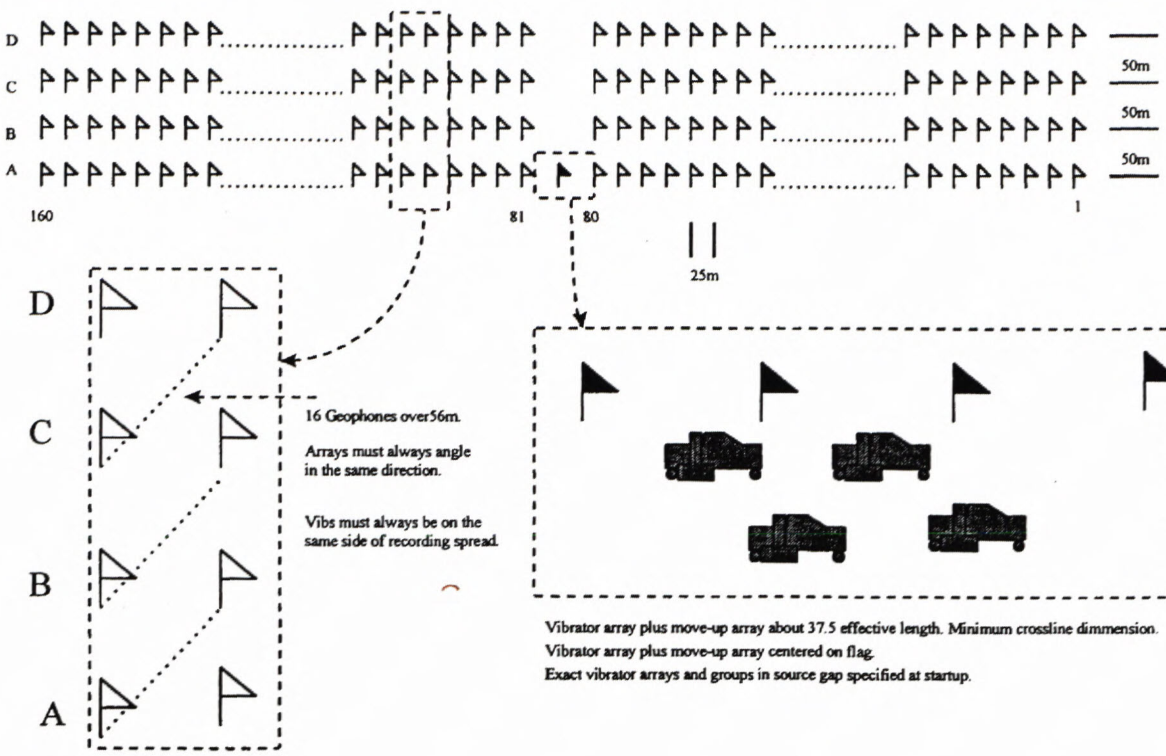

Fig. 1 Multifold Acquisition. After Regone, 1997

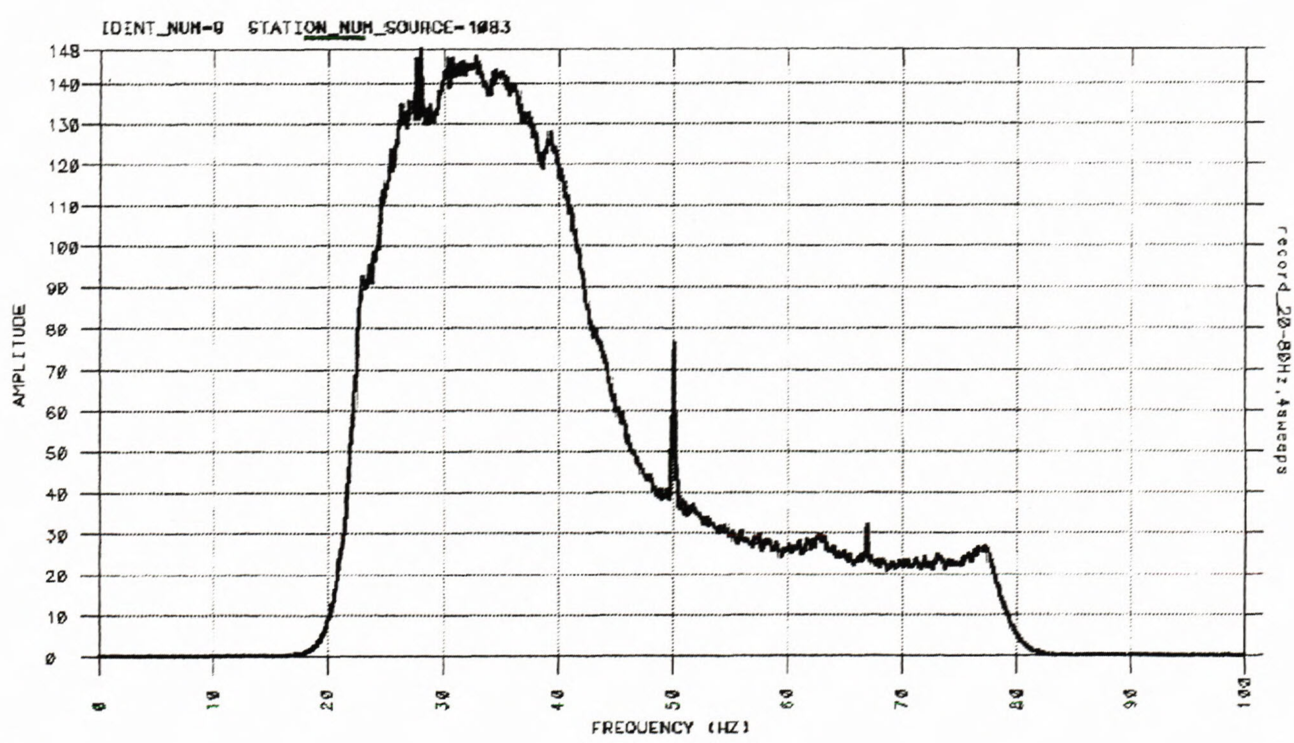

Fig. 2

fixed. Longer arrays are automatically constructed in the inline direction by stacking with the Anstey criterion. The crossline spacing must be satisfied without rollalong. It was estimated that a 150m effective array would provide 12+ dB attenuation of the crossline-scattered groundroll. Optimally, geophones should be spaced at no more than 5m intervals. However, a box of geophones over a 150m by 25m intervals is impractical and would make static

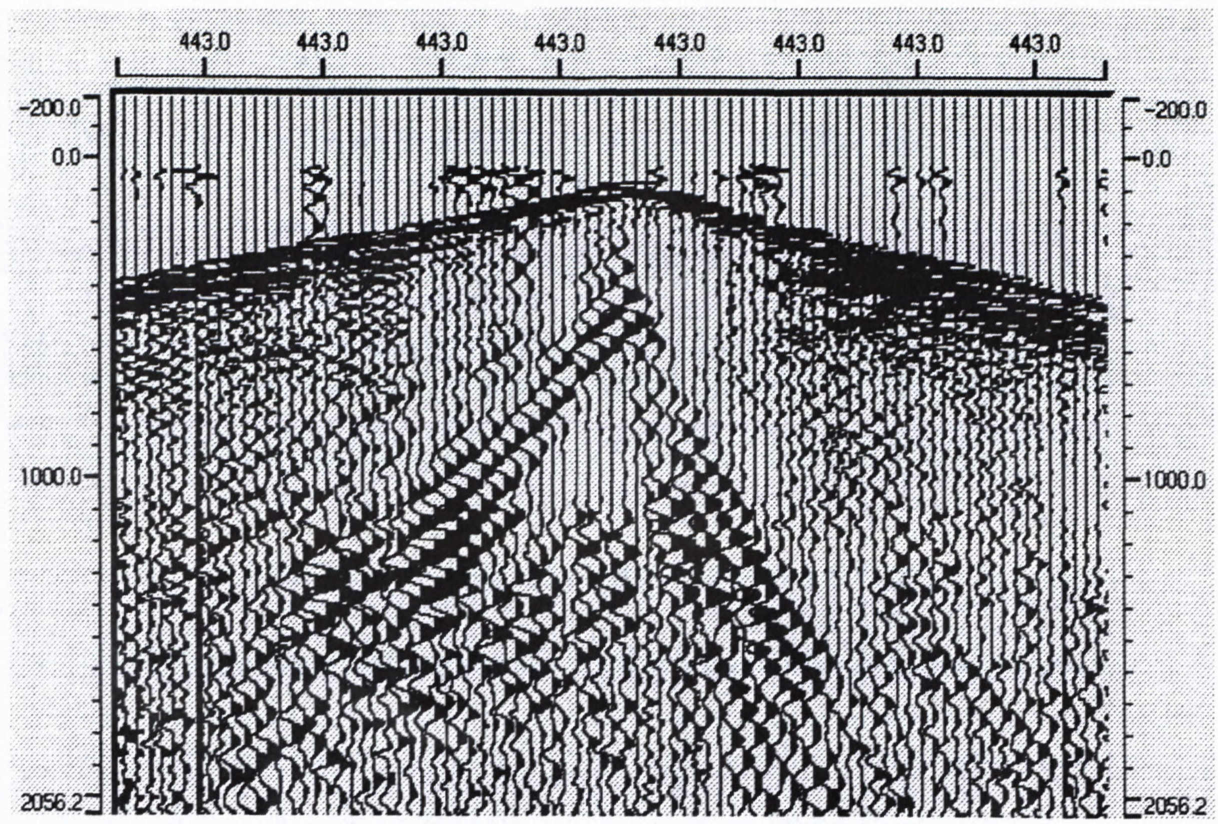

Fig. 3

control impossible. As a compromise, a diagonal line array is used with each of the 3 sub-boxes. The sub-boxes are 25m inline and 50m crossline. The sub-boxes can be combined in processing to form the crossline array. The idealized layout is shown in figure one.

Results

The standard Vibroseis tests were performed to optimize recording parameters. Figure 2 shows a frequency plot of a 20-80 Hz sweep. The plateau above about 60 Hz was viewed as the noise floor. A low frequency of 10-60 Hz was selected to maximize the signal bandwidth from the sweep tests, however as will be later seen, this envelope should be pushed to 70 Hz.

The sweep tests showed that adding more sweeps increased the amplitude of the record relative to ambient random noise. The improvements are not dramatic and the cost would increase substantially for a large number of sweeps. However, some coherent groundroll was observed on these tests that was not seismic source related.

When the "secondary source" is inline to the 2D seismic line its effect can be seen. In figure 3, a back-scattered refraction is noted. Because this event is in the line direction, it is seen at its true velocity. It can be removed in processing by velocity filtering but it is not removed by the CMP multifold process. As shown in figure 3 the "secondary source" event does not seem to be a major issue. However, when the "secondary source" is not inline to the recording spread, the problem is more vexing. The "secondary source" energy is hyperbolic, and it looks like a desired signal. Again, the CMP method does little to attenuate it. Evaluating a field record in the presence of side-scattered noise can be extremely misleading. The hyperbolic events, which one thinks of as characteristic of signal, can be side-scattered noise.

Figure 4 shows a single vibration point from the test line with the 3 elements of the cross-line array. Each of the three elements is too short to attenuate the side-scattered noise. When the three elements of the array are summed the result is shown in figure 5. Figures 4 and 5 are displayed at the same scale and gain correction. The lower amplitude in the area above the airwave is an indication of the reduced noise due to the 150m cross-line field array. About 6 dB of noise attenuation has been demonstrated prior to processing. It should be noted that the 150m array will only attenuate those velocities up to 1500m/s at 10Hz.

Proposed Method of planning a 2-D Survey in the Carpathian Mountains.

A constant source of frustration to seismic field personnel is the philosophy of data acquisition project planning which results in explorationist planning line locations with reference only to subsurface data and with minimal regard for surface obstacles and topography. The end result has often been in the past that the explorationist is subsequently very disappointed with the poor quality of expensive data. Additionally the explorationist is frequently faced with large skips over crutial areas. Preplanning and direct continuous communication are necessary to record data that is both of good quality and in the right spatial location to be of use.

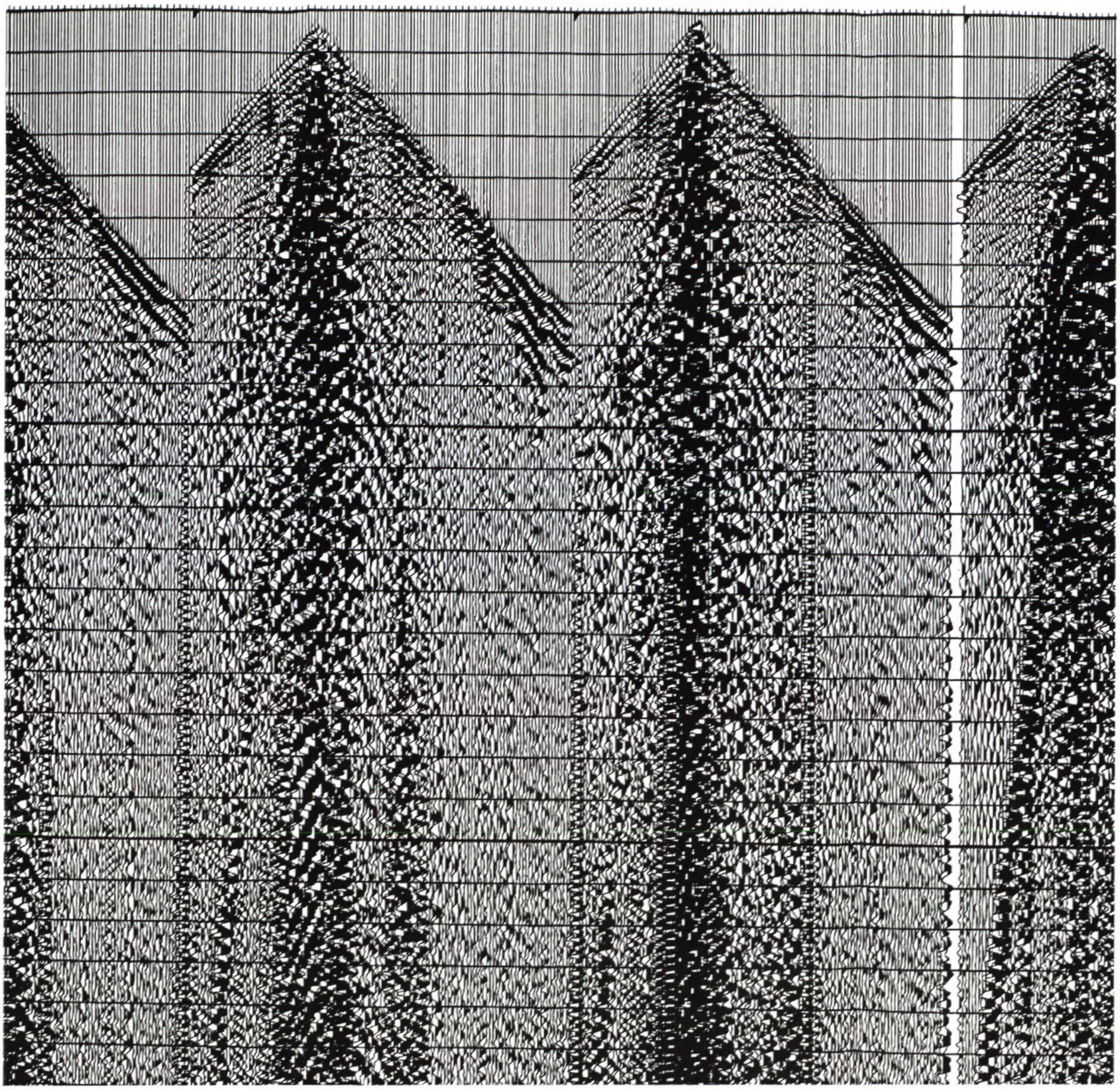

Fig. 4

During the period of the above test program the Field Data Acquisition Supervisor was able to assess the area of operations both visually and by scrutinizing detailed maps. It appeared that in most areas good seismic lines could be shot provided they would be planned from the point of view of field personnel accustomed to recording in these conditions. It is recommended that any potential explorationist supply the Contractor chosen to acquire lines in the Carpathian Mountains with maps from which the co-ordinates of the extremities of areas of interest may be obtained. The areas of interest should then be transposed by the Contractor onto 1:25,000 topographical maps. It would then be the Contractor's task to seek out all possible line routes to cover the area in as much detail as possible. This would not be simply a mapping exercise – the Contractor would be required to research the lines in the field in order to guarantee feasibility of data acquisition. The Client should advise the approximate line grid spacing required. The Contractor should be required to submit line proposals. Contractor should seek out only line routes on which 75% of nominal full fold vibroseis data can be guaranteed. The line bend tolerance and frequency and vibrator offset limits should be discussed to create a balance between data quality and feasibility. If insufficient lines to satisfy the Client's needs have been identified the contractor should return with suggestions for lines of a more crooked nature – receiver lines in long, straight sections following the trend of a crooked VP line. If this again fails to make sufficient data available a mixed source line may be considered. If more lines were to be proposed than actually required, as is most likely to be the case, the Client would be at liberty to choose the lines most suitable to he needs, safe in the knowledge that resultant data would be of the best possible quality in the Carpathian Mountains.

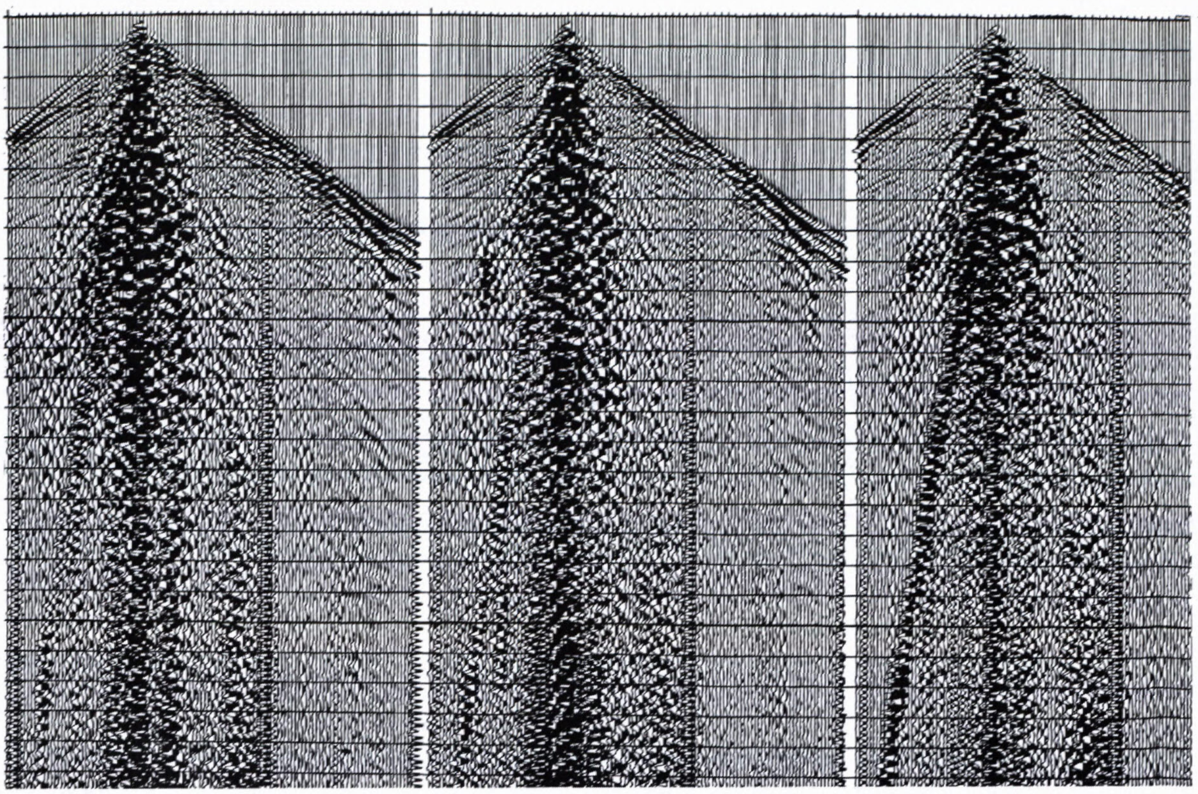

Fig. 5

Summary

It is concluded that some of the coherent noise arriving from the side of the 2D line can indeed be attenuated.

In post processing it was noted that there is improvement in the stack section from the use of the crossline arrays. There was however no noticeable improvement from the long inline arrays even for low relief or flat events.

To get the most economic use of Vibroseis the following was concluded:

1. Use linear arrays (inline) of 25 meters (not longer).
2. Deploy 2 parallel strings with the biggest separation possible.
3. Make sure that sweep tests are thorough and that allowance is made on the high end of the frequency range for steep dips.
4. Ensure that the vibroseis array has a good crossline component (as the test) to attenuate the ground roll in the crossline sense.
5. Use longest possible offsets. These tests showed that the first 600m was mostly noise.
6. Use medium weight Vibs to help navigate the terrain.
7. Allow extra time for pre-permitting and line layout.
8. The key to using vibrators is thorough reiterative line planning with line layout flexibility.
9. Where necessary in fill with dynamite.

References

Regone C., 1997: Carbonate Seismology. Ed. Palaz, I., Marfurt K., USA, Soc. Exp. Geo., 281-299p.