P061

Prestack Seismic Signal Enhancement by Dip Detection and Dip Selection

N. Gulunay* (CGGVeritas), G. Ajlani (ADNOC), A. Leveque (CGGVeritas) &
J. Holden (CGGVeritas)

SUMMARY

Historically, 3D land data has been noisy when compared to 3D marine data. Recently we have witnessed the advent of high density 3D land recordings with folds in excess of 400 that help to reduce noise on the final images.

There are many surveys where gathers for such high fold data are so noisy to allow any prestack work. Furthermore noisy, low fold, mostly old vintage 3D data is still a common occurrence on interpreter's desk. To enhance signal on such noisy gathers as well as on their stacks is the task that this paper aims to address.

Introduction

Despite the advances in imaging techniques the main idea, “the power of stack”, that Mayne (1962) introduced in relation to common reflection point stacking almost half a century ago, still seems to be the main workhorse for enhancing/detecting signal in low signal-to-noise ratio (SNR) data. It is well known that a fold of N brings about a signal enhancement by a factor $N^{1/2}$. Even then stack volumes are often noisy and one may wish to resort to post stack, or even prestack, cleaning, by stacking along dip directions to enhance low amplitude signal buried under high amplitude noise assuming that a cube of data can be formed.

More specifically, if a small space window (of size N_x traces along x-direction and N_y traces along y-direction) around a location of interest (x, y) is considered then stacking this small cube along a dipping plane (dip p_x and dip p_y) of the signal acts as if fold has increased by a factor N_x*N_y. This corresponds to a signal enhancement by $(N_x*N_y)^{1/2}$. If all coherency values of dips on the data are available through mechanisms like semblance analysis then all significant events can be detected and enhanced along their planar dips (producing signal) and then this signal can be added back to original data by a user controlled amount to bring about the desired signal enhancement. Alternatively, if there are undesired but strongly coherent events on the data, then the signal model obtained in a specified dip range can be subtracted (not shown here) from the input volume to attenuate undesired dips.

While forming signal from the slant stack traces we propose using only one p-sample per event from the forward tau-p transform. That is, for each significant semblance local maxima in tau-p domain we use the p-trace that passes from that maxima only ignoring the “wings” of the tau-p transform. What we mean by “wings” and the reasons for forming signal in this manner are explained in Gulunay et al (2007) along with a brief review of Tau-p transforms. Although such an approach can not model signal variations within the space window (N_x N_y) it provides a powerful noise suppression mechanism. Here we illustrate the method with two field data sets.

Field data examples

We illustrate this process on two data sets. The first one is a multi-vintage merged transition zone 3D survey. The data were acquired with many different source types and configurations over an area that included some environmentally sensitive zones towards the coastal margins. This resulted in severe access problems, with the consequence of a highly irregular shooting and recording geometry which was compounded by a lack of far-offset data, due in part to the multi-vintage acquisition, which could otherwise be used to undershoot this poor access area. Additionally, the individual source effort in this area had to be reduced to respect the environmental considerations. Explosive sources, where they were permissible, were only a fraction of the nominal charge elsewhere on the survey, and similarly the vibrator sources had to be used on reduced drive levels. The net result of these local limitations to the acquisition was very low fold data of exceptionally poor SNR.

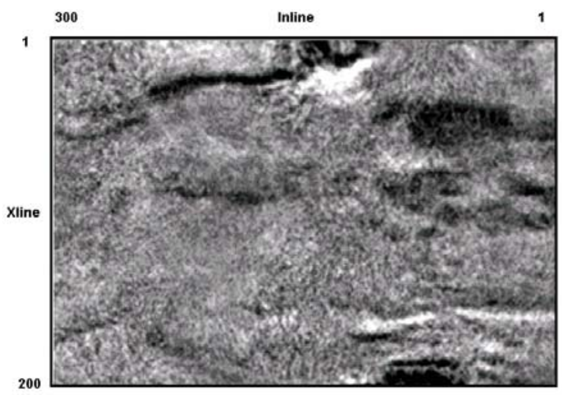

Figure 1. A time slice (at 972 ms) of the one offset class (900m-999m) of the merged survey.

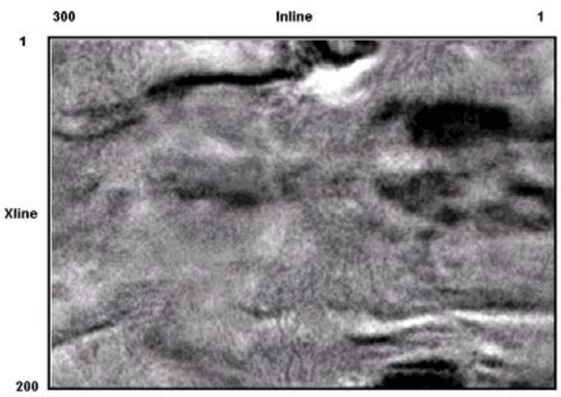

Figure 2. Same time slice after 3D coherency enhancement .

After careful initial processing, which paid particular attention to phase-matching the many different sources and receivers, the resolution of surface-consistent statics through a cascaded refraction and reflection solution, and a variety of pre-stack de-noise strategies, the data were processed through a Kirchhoff pre-stack time migration. The resultant post-migration offset cubes could then be used for 3D de-noising which, due to the acquisition, was not possible earlier in the processing sequence. The 3D coherency enhancement algorithm described here was used to good effect in this area Elementary blocks of 12 x 12 traces in windows of 500ms were selected, with 50% overlap in time and space. 50% of the model was added back to produce the final image.

A time slice (at 972 ms) for the offset class 700-799m is shown in Figure 1. Noisy character of data is evident in the time slice. Figure 2 shows the same time slice after the data went through coherency enhancement method described in this paper. Suppression of noise took place leading to a clearer picture of the time slice. Vertical sections (crossline 30) before and after the process are shown in Figures 3 and 4 respectively. Random as well as coherent noise suppression (of dips exceeding what is allowed during the forward tau-p_x-p_y transform) is evident in Figure 4.

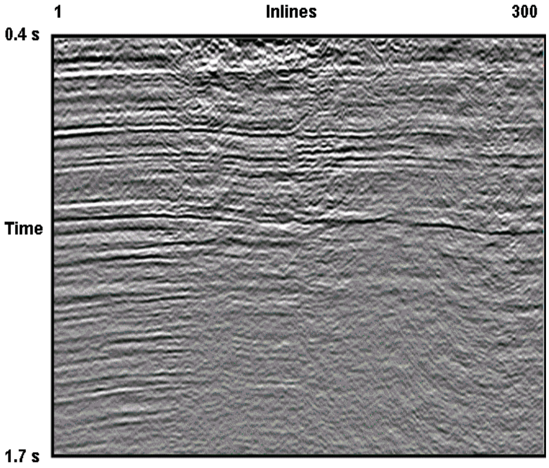

Figure 3. A crossline before 3D coherency enhancement.

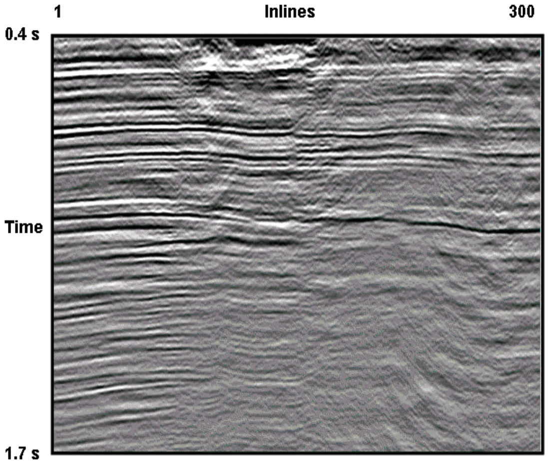

Figure 4. Same crossline after 3D Coherency enhancement.

The second data set is a high fold land 3D data set from the Middle East. Data was recorded with cross spread type orthogonal shooting but is very noisy due to small field arrays and nearby exploration activity. Figure 5 shows a typical 3D CMP gather (with NMO) from the survey. Note strong source generated noise as well as lack of signal in the shallow portions of near offset traces. As events within each gather are time aligned while doing velocity analysis which also aligns events on the stack for lateral coherency one may consider to forming 3D cubes along offset (trace number of offset sorted data to be more accurate) and CMP directions. Searching for best alignment directions in such cubes are similar to (but not same with) forming super gathers in multi-focus or CRS techniques. That is, events on the consecutive CMPs are mixed across most coherent dip directions, so are traces within each gather across offset direction.

The result of applying such a process to the traces of Figure 5 is shown Figure 6b. Here we used a space window of 10 traces by 10 CMPs and time window of 400 ms, with 50 percent overlap in all directions, to generate forward tau-p transforms and searched for dips up to 6 ms per trace. We kept a low semblance threshold to allow all significant semblance maxima, and added 70 percent of the signal to the 30 percent of the “input” to obtain the output. Comparing with input 6a and the difference 6c it is clear that this is a powerful process for noise suppression and the signal damage is minor. Elimination of strong noisy trace from what we call "input" was achieved by internal RMS amplitude calculation, thresholding, and, scaling before traces were put into the forward tau-p transform as, otherwise, strong smearing artefacts would have resulted from the large amplitude noise trace as well as leakage from mixing 30 percent of it with the signal.. Stack of 20 consecutive CMPs before and after 3D coherency enhancement (Figure 6 d and e) as well as the difference between stacks (Figure 6 f) shows that the process preserves signal reasonable well. Similar comparisons are given in Figures 7a, 7b and, 7c, for 200 consecutive CMPs. Some signal damage is apparent in the difference plot (Figure 7c) at deeper times. In the first one second, however, it is clear that benefits of process outweighs any harm, if any, it may have caused.

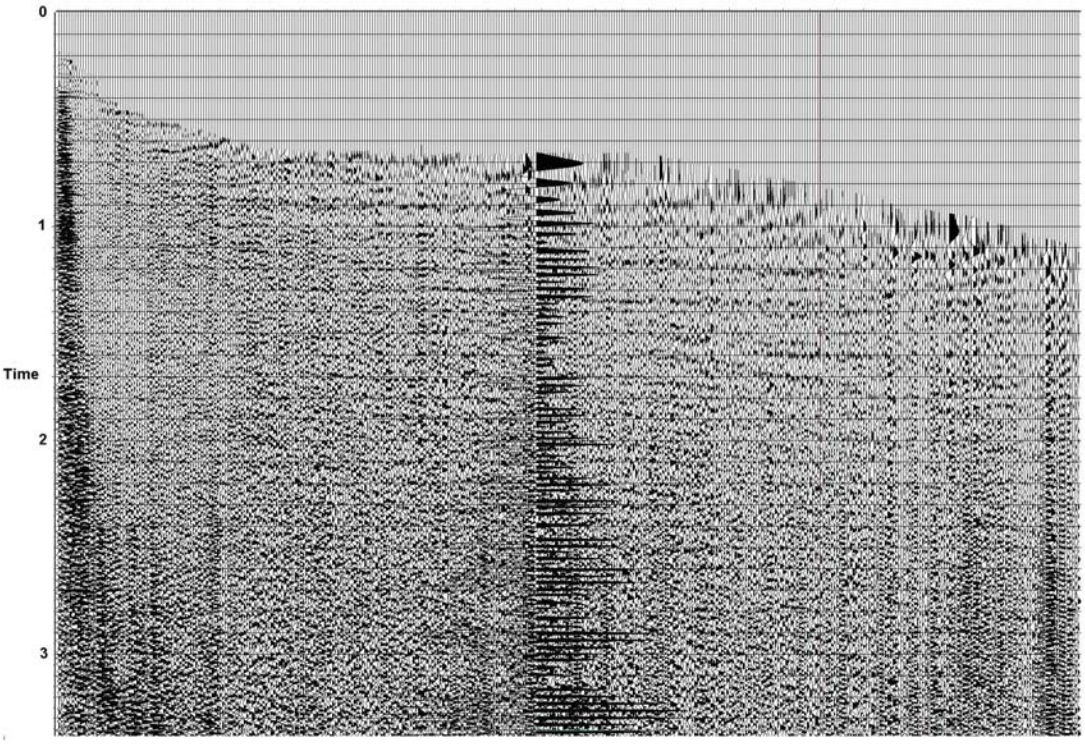

Figure 5. An NMO corrected CMP gather of a 400 fold 3D land data from the Middle East.

Conclusions

Low fold 3D seismic data, especially, offset class cubes, that are encountered in land or transition zone surveys can benefit from the signal enhancement method described here. The method can also be used with high fold but noisy 3D land data sets to enhance signal by implicitly merging CMPs together along dip directions. The method is based on transforming the data in small time space cubes into forward tau-p domain and then selecting the most coherent events in that domain. Once such events are identified (automatically) then they are inverse transformed by only keeping one p (or p_x-p_y) sample point per event. That is, the inverse tau-p transform is nothing but the propagation of distinctly separated p traces back to input offsets (back projection) and blending with the input.

Acknowledgments

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References

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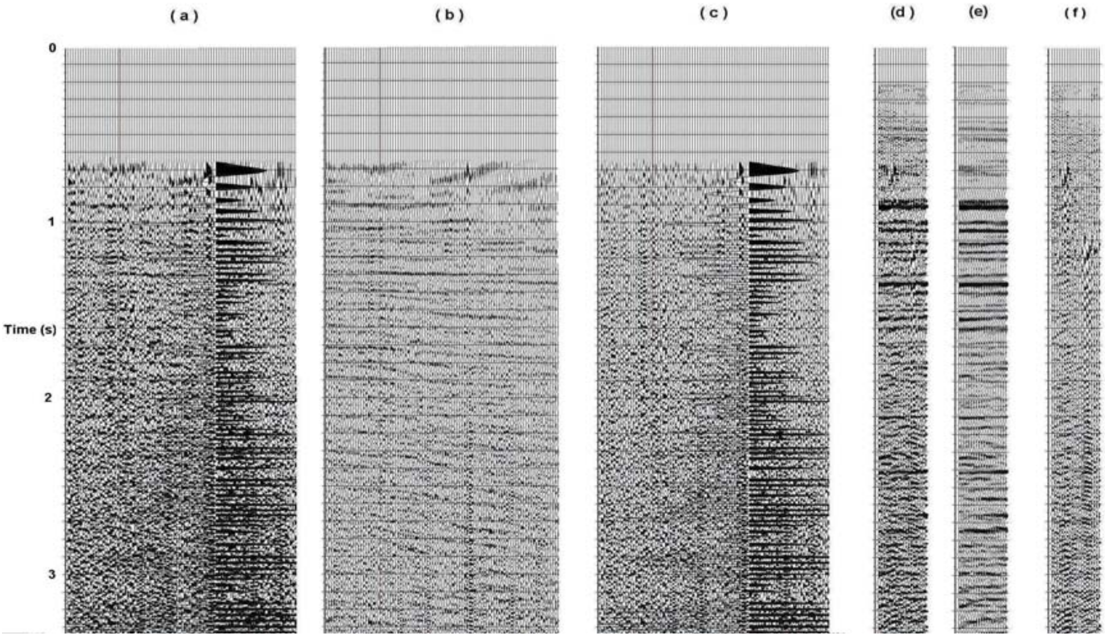

Figure 6. (a) Input traces (some of the far offsets shown in Figure 5) (b)-output of 3D coherency enhancement method (c)-difference between input and output, (d) stack of input gathers for 20 consecutive CMPs, (e) stack of gathers in (b) , (f)-difference of stacks in (d) and (e).

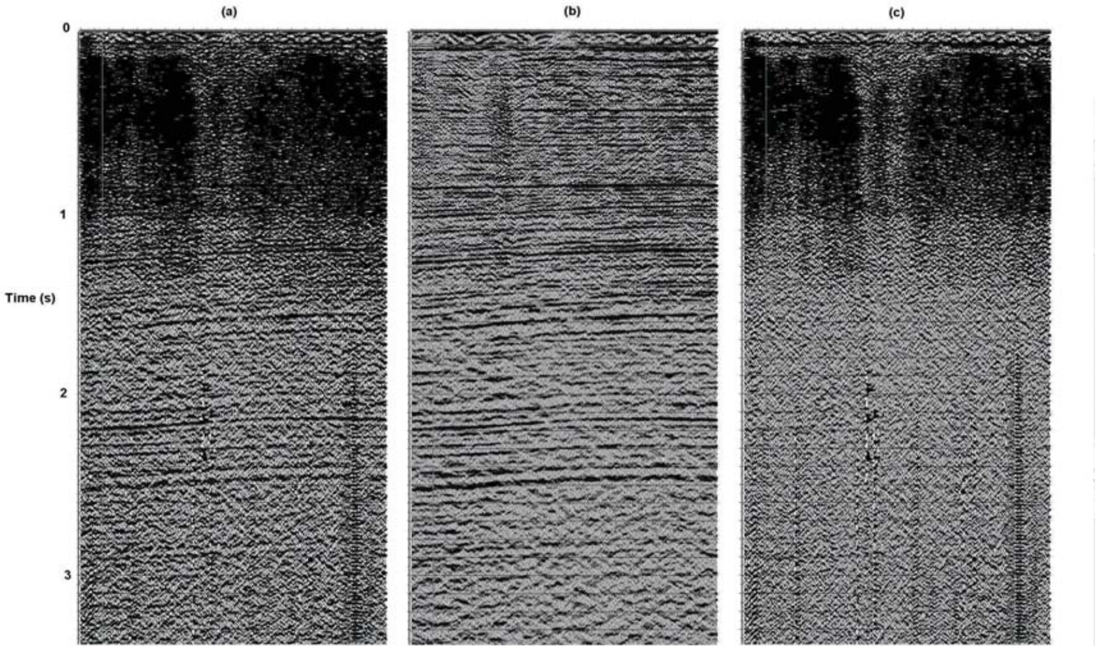

Figure 7. (a)-Stack of 200 consecutive CMPs (b) Stack of same CMPs after 3D coherence enhancement (c) Difference between stacks.