Amplitude Preserving Kirchhoff Pre-stack Time Migration for Time Lapse Processing on Troll West

David Bannister, Momotchil Roussanov, Charles Jones, GEOTRACE TECHNOLOGIES LTD

Abstract

A method of applying weighted scalars in preserved amplitude pre-stack depth migration (Jousset, 1999) has been adapted for time processing and included in a time lapse (4D) processing scheme incorporating Kirchhoff pre-stack time migration.

The method, known as ADA (Acquisition Dependent Amplitude) compensation removes the requirement for a pre-migration regularization stage, honours the true source and receiver locations of the data and reduces the acquisition footprint.

The method is applicable to 3D acquisition and is particularly well suited to 4D studies, where removal of acquisition effects to improve repeatability is a key requirement. The application of ADA on multiple vintages of 3D data acquired over the same area provides a testing ground to demonstrate the effectiveness of this technique.

Presented in this case study is an example of the application of the ADA method to time lapse processing of data from the Troll West gas province.

Introduction

Numerous vintages of 3D seismic data have been acquired over the Troll West area during its production lifetime. Five surveys, acquired between 1989 and 2003, were used in a time lapse study over a 650sqkm area, covering the key production zones.

The base survey for the time lapse study was formed using a merge of the NH8901 and NH9101 datasets. The first monitor was formed from a merge of the NH0002 and NH0102 datasets and a second monitor was derived from the NH0301 dataset, with infill around the platforms being extracted from the base survey.

The base survey, in particular, comprising the vintages of data from 1989 and 1991, exhibits strong acquisition footprint anomalies associated with irregular acquisition coverage. .

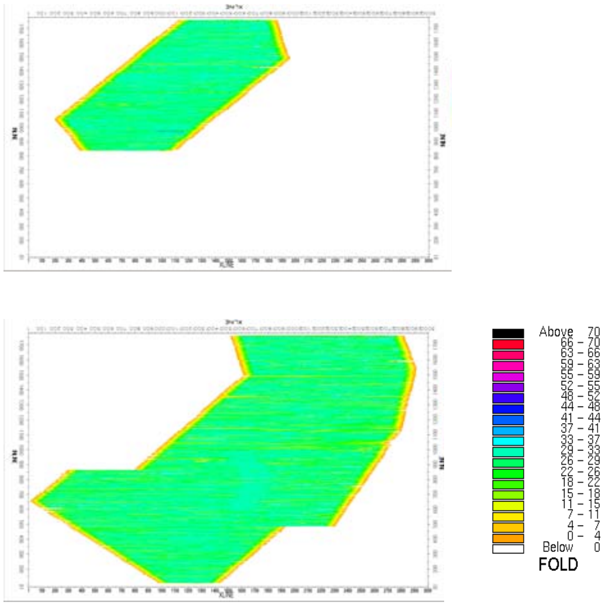

Figure 1. Full fold bin populations for NH8901 and NH 9101 surveys

Figure 1 shows the irregularity in the acquired fold for all offsets for the two datasets forming the base survey, the origin of these anomalies being the cumulative effects of strong feathering, dropped shots and missing, or edited, receiver channels. Whilst binning can alleviate a portion of these effects by creating a more uniform fold of cover for each binned offset plane, local variations in trace density that have dimensions smaller than the bin size are not accounted for.

The inclusion of a Kirchhoff pre-stack migration has become standard in conventional time processing flows and also in time lapse (4D) processing. Usually the application of a Kirchhoff pre-stack time migration is preceded by regularisation stages, such as bin centring, fold normalisation and azimuthal moveout correction, in order to compensate for the acquisition footprint and improve the amplitude treatment and signal to noise response of the imaging step.

Without these stages, Kirchhoff artefacts in the form of steeply dipping energy are common place in areas where the fold of cover fluctuates and the summation of the smears has not produced a cancellation of the energy for non geological dips.

Frequently, however, the various assumptions made during the different regularisation stages can be detrimental to amplitude preservation, particularly in areas of geological dip.

The effect of the irregular sampling in these datasets is illustrated on both unmigrated and migrated offset volumes. Figures 2 and 3 show a representative crossline extracted from a common offset volume before and after migration. The variable amplitudes and vertical striping are typical of 3D marine surveys suffering from variations in source positioning and cable feathering. In many instances a two dimensional median filter is applied post migration in order to remove this effect in standard 3D processing, but there is a noticeable effect on amplitudes using this approach, which is not recommended for true amplitude processing or time lapse studies.

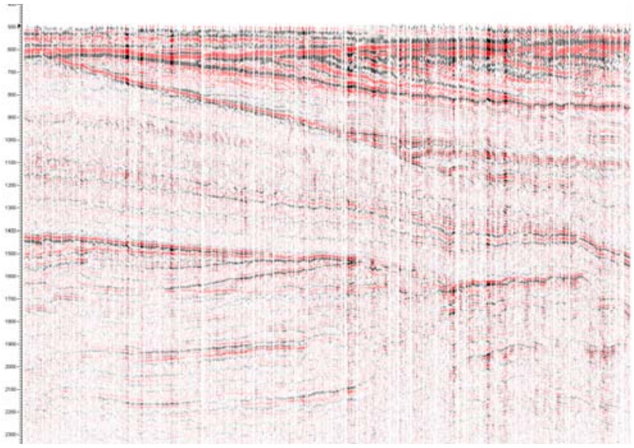

Figure 2. Example crossline for a single offset plane, pre-migration

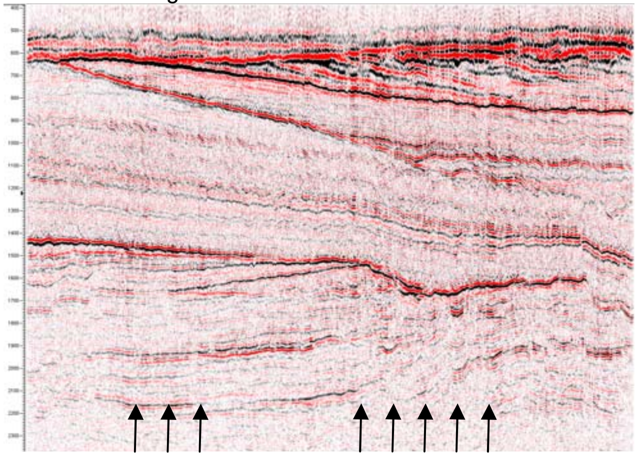

Figure 3. Example crossline for a single offset plane, post migration

Method

Thierry et al. (1998) described the mathematical function that maps the strength of the subsurface illumination for a pre-stack depth migration of data having ideal acquisition geometry. For each point in the subsurface, the illumination is determined by the degree to which rays either converge on, or diverge away from that point. Jousset et al (1999) extended this function to account for variations in subsurface illumination for the case where the acquisition geometry is no longer regular by introducing an additional term composed of a matrix of weights derived from the source and receiver positions for an acquired survey.

ADA is an implementation of the method proposed by Jousset for preserved amplitude depth migration that can equally be applied in time domain processing when a Kirchhoff pre-stack algorithm is used. The technique compensates for the fluctuations in fold by the application of the scalars to the traces input to the migration.

In this work, the base and monitor surveys were sorted into common offset volumes and binned using zero expansion to remove over fold data. ADA uses the true source and receiver location for each remaining trace in a common offset volume to form a network of triangles. The mid points of sides of each triangle are used to define the nodes of a polygon surrounding each mid-point for all source and receiver pairs. The area of each polygon is then used as a measure of trace density and used to calculate the weights to be applied by the migration to each trace.

Results

Figure 4 shows the scalars generated by ADA for a single offset plane extracted from the base survey. Within the display there is a clear division where the two individual surveys are merged, which reflects the different acquisition geometries. There is also a further area of uniform cover, which is an area of infill from the 2003 vintage, where the acquisition had a different configuration and was less irregular. These scalars were applied to the data and the offset plane shown in figures 2 and 3 was remigrated. (Figure 5).

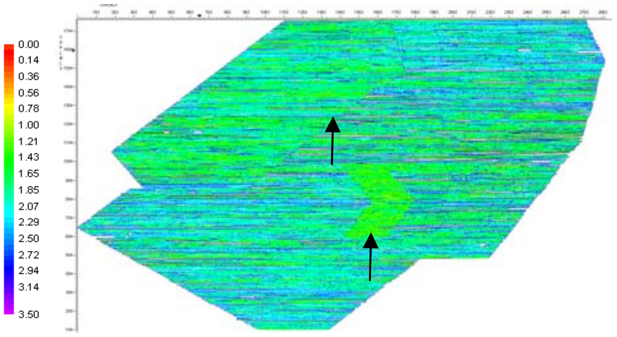

Figure 4. Scalars for a single offset plane from the base surveys

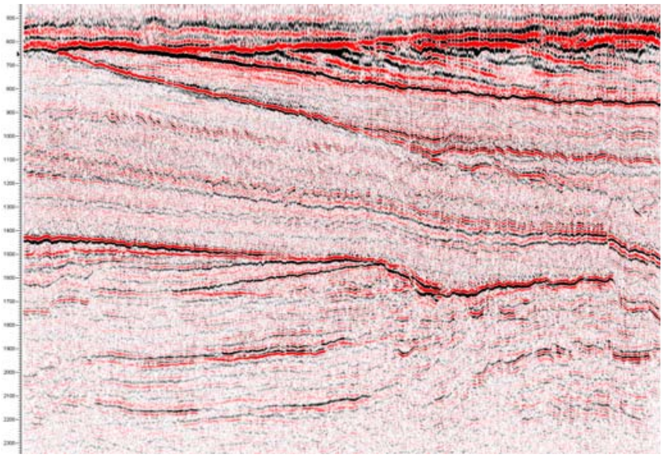

Figure 5. The same crossline as in figures 2 and 3 for a single offset plane, migrated with ADA amplitude compensation.

Figures 6 and 7 show an inline from a full offset stack from the base survey following a Kirchhoff pre-stack migration before and after ADA. The area highlighted shows a particularly strong amplitude anomaly that is directly attributable to the acquisition footprint. In fact, although difficult to appreciate in these displays, there are subtle differences in amplitudes throughout the section.

It is worth while to note that in a standard 3D sequence little is done to verify that the amplitudes of traces output from the migration have been preserved. With 4D processing, we have two datasets where we can directly compare the local amplitudes and this provides us with a verification capability.

The base and monitor surveys were both processed twice through a Kirchhoff pre-stack time migration sequence. In the first pass, no ADA was applied. In the second pass, ADA was applied independently to each vintage. Difference sections were then produced by subtracting the base from the monitor survey. At this point the 4D registration and match of the two datasets has not been performed and much remains be done to improve the 4D repeatability. (Figures 8 and 9).

Even without post-migration 4D registration and match, the displays show a significant improvement in repeatability using ADA. In particular, the high amplitude zone to the right of the section exhibits considerable signal leakage in the non ADA difference section. By contrast, including ADA in the sequence has accounted for the acquisition footprint and the anomalous high amplitudes have been removed. The migration now exhibits a preserved amplitude response and the 4D repeatability is greatly improved.

To demonstrate the dip handling capabilities, an alternative to using ADA for the acquisition footprint removal has been applied using 3D FX trace interpolation followed by mapping of traces to bin centre locations. A comparison of these two approaches is shown in figures 10 and 11.

The effect of applying interpolation and trace mapping is to introduce data dependence to the processing flow, which reduces the repeatability and degrades the 4D image, particularly in areas populated with dipping events.

Conclusions

ADA compensation provides an effective and efficient means of removing the acquisition footprint in 3D seismic surveys in an amplitude preserving manner. The integrity of the technique has been demonstrated on the time lapse processing of multiple vintages of data over Troll West, in which the demands for preserved amplitude processing are exacting. The method reduces artefacts of migration caused by irregular fold of cover whilst permitting the use of true shot and receiver locations for each trace in the migration, reducing the requirement for trace regularisation.

Acknowledgments

The authors wish to thank Norsk Hydro and Troll West licence partners for kind permission to use the examples in this paper.

References

Thierry, P., Lambare, G., Podvin, P., and Noble, M., '3D preserved amplitude pre-stack depth migration on a workstation': Geophysics, 64, no.1, 222-229, January-February 1999.

Jousset, P., Thierry, P. and Lambare, G.,' Reduction of 3-D acquisition footprints in3-D migration/inversion.': SEG Expanded Abstracts 1999.

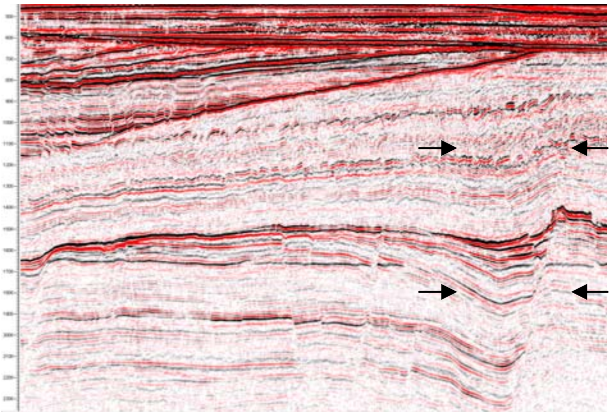

Figure 6. Full offset stack after PSTM without ADA showing a strong amplitude anomaly in the region between the arrows.

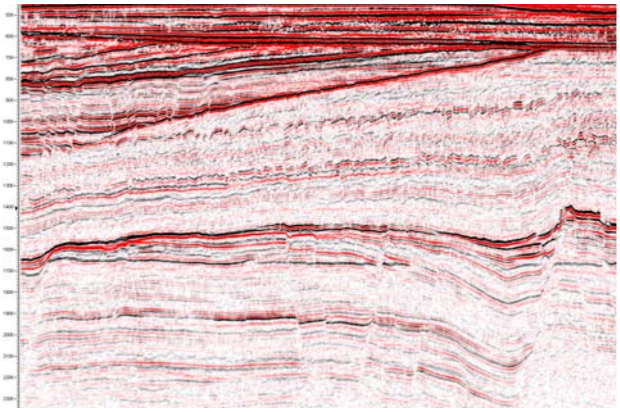

Figure 7. Full offset stack after PSTM with ADA. The strong amplitude anomaly has been removed and the amplitudes throughout the section improved.

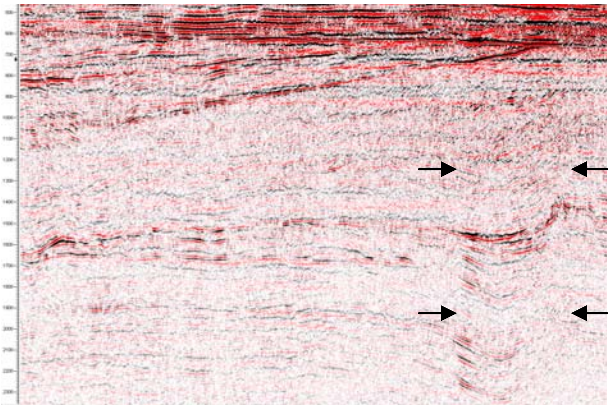

Figure 8. Difference on output of PSTM between base and monitor surveys without ADA. The anomalies highlighted in figure 6 are leaking through.

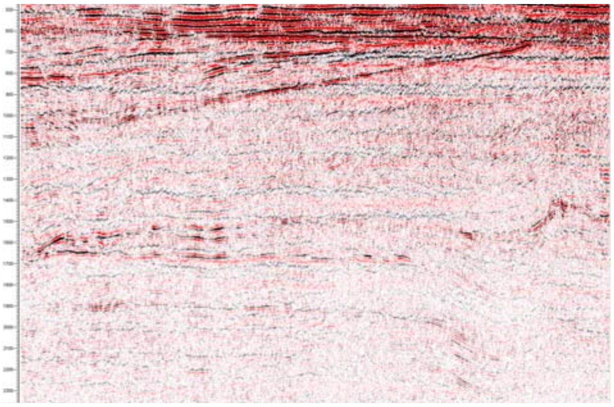

Figure 9. Difference on output of PSTM between base and monitor surveys with ADA. The amplitudes of both surveys have now been preserved.

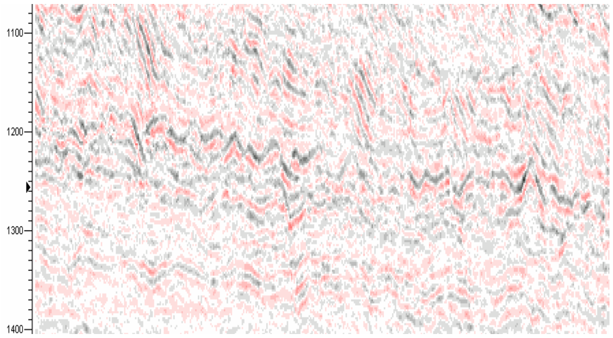

Figure 10. Difference section from globally matched PSTM data after 3D trace interpolation. There is a data dependent element to the dipping energy creating signal leakage.

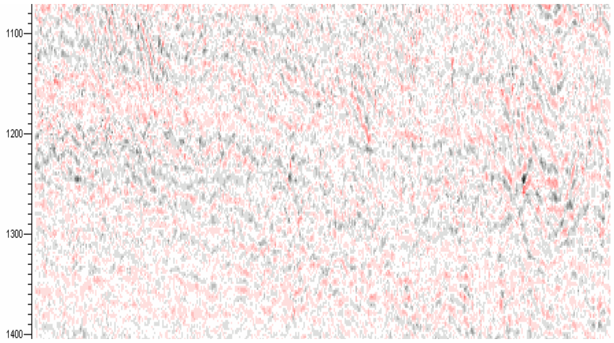

Figure 11. Difference from globally matched PSTM data after ADA. The amplitudes of the dipping events have been handled correctly by ADA.