D019

Re-binning Pre-stack Seismic Data for Fluid Contact Determination - AVO Screening and Visualisation

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SUMMARY

Common Contour Binning (CCB) is an approach, based on the principles of the CMP method, to re-organize and filter post- and pre-stack seismic data. It is a very powerful technique to highlight subtle hydrocarbon-related amplitude effects on both pre- and post-stack data. Pre-requisite is that such effects are structure conformable with available interpretation, and that they are flat in the domain of investigation. Under these conditions, CCB can identify fluid contacts which are not or hardly visible on conventional seismic displays. As CCB can also highlight subtle AVO effects on raw pre-stack data, it is a very effective technology for interpretive use of unconditioned pre-stack data early in the exploration cycle.

Introduction

With the advent of seismic processing, interpretation and visualisation technology, more data products are available to the interpreter than ever before. At the same time, the ongoing exploration effort in mature basins such as the Southern North Sea require that more subtle traps, and play types not previously recognised are investigated, and that even marginal amplitude effects are exploited to de-risk prospects. In addition, the time available to mature leads into drillable prospects is reduced by many factors; of which reduced license time, aging infrastructure and available ullage capacity on platforms and pipelines are a few examples. Technology that enables the interpreter to handle the large volumes of data and to present it in a comprehensible way on displays, is provided by the recent advances in workstation, data management, and visualisation technology.

However, considering all these factors, in order to exploit the wealth of information residing in our seismic data products, new tools and concepts are needed to realise the value of this information within the time-frames available. To this end, Flierman, Van Der Weide, Wever, Brouwer and Huck (2008) presented various filtering techniques that enable the interpreter to accelerate the structural, tectonic, amplitude and hydrocarbon potential interpretation of seismic data. One of these filtering techniques, Common Contour Binning (CCB), is very effective in detecting subtle structure conformable amplitude anomalies, and builds on the ideas of De Haan, Arts and Neele (2001). However, the technology is sensitive to remnant multiple energy and discards any AVO effects which might reside in pre-stack data. This paper presents an extension of the Common Contour Binning technology into the pre-stack domain, which enables the interpreter to screen large amounts of data for very subtle AVO effects.

Common Contour Binning

The Common Mid Point method (Mayne, 1962) is based on the fact that the same area in the subsurface is illuminated by different source-receiver pairs. In 3D acquisition, the spatial delimitation of this area was defined as the 'seismic bin'. Provided that the overburden is locally invariant, and/or is corrected for using normal and dip move-out, all source-receiver pairs within the seismic bin can be added together through stacking. Thereby, the signal-to-noise ratio is greatly improved. Fundamentally this says that for any subsurface area that is illuminated in a stationary sense, i.e. invariant or gentle geology and same area sampled, data can be combined and exchanged. Historically this has been exploited to generate super-gathers through the stacking of gathers in adjacent bins. However, by using geologic knowledge this concept can be further exploited, as bins can be defined in such a way that both the target area that is sampled is invariant, and the geology above is sufficiently stationary.

Common Contour Binning is based on the fact that all seismic traces that penetrate the top of a hydrocarbon accumulation at the same depth will in principle sample the same hydrocarbon column length. In other words, for these traces the imprint of any hydrocarbon related effect on the seismic response will be similar, provided that the medium is sufficiently isotropic. In spatial terms this means that all traces meeting these criteria will be located along the same depth contour line and that in this subsurface area, the sampled volume is identical, despite the lateral extent. This means that this area meets the original criteria Mayne defined for seismic bins, and that this area can be used to re-arrange both the CMP definition and thus the seismic data. Hence the name Common Contour Binning.

With this Common Contour Binning technology, or CCB in short, very subtle hydrocarbon-related seismic anomalies can be highlighted and hydrocarbon - water contacts can be pin-pointed. The key assumption in this is that these features are structure conformable and flat in the domain of observation. Figure 1 presents on the left side a Common Contour Bin generated on post-stack data. On the zero line, the original Top Reservoir interpretation is located. Knowing the reservoir tends to show dim amplitudes when gas bearing, one can easily pin-point the gas-water contact at 2136ms two-way time. The right side of figure 1 presents a 3D view of the structure assessed with the post-stack CCB, with Top Reservoir instantaneous seismic amplitudes in white-yellow-red and discontinuities in green-blue. The thin green line around the mainly whitish top outlines the confirmed gas-water contact. From the seismic amplitudes, this is not obvious as dim amplitude areas are dispersed downwards on the flank of the structure. However, by adding sufficient traces within a contour interval, this dispersion effect is suppressed, and a clear amplitude cut-off can be found.

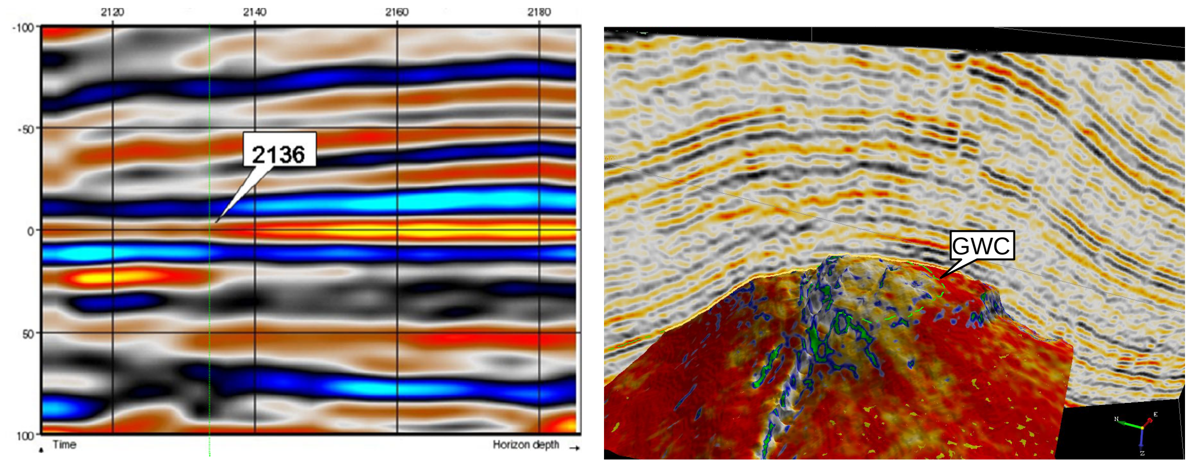

Figure 1 *Conventional CCB display over a thin reservoir (visualized on the right side) with a dim-spot AVO behaviour in stack domain (left) (red/yellow = negative & hard, (bright) blue = positive). 3D view of the structure and overburden, with Top Reservoir instantaneous amplitudes (white = dim, red = negative = hard reflector, background seismic same scaling).*

Common Contour Binning for Pre-Stack data analysis

Based on exactly the same logic in which post-stack data is re-sorted and stacked within Common Contour Bins, also partial angle stacks, and pre-stack data can be analysed. For the pre-stack case, the re-binning is performed on offset-planes resulting in a single super-gather per contour interval (Chandler, 2008). For a 3D structure, this yields a 3D CCB volume sorted along the original z-domain (depth or time), the offset, and the position with respect to horizon depth defining the bin. For visualisation purposes, a stratal slice is cut through this volume along the original Top Reservoir interpretation. This resulting slice has offset on the one axis, horizon depth on the other axis, and amplitudes are colour coded. See Figure 2 as example, which will be explained later.

Case Study: Southern North Sea thin Sandstone reservoir

As a case study, a gentle four-way dip closure in the Southern North Sea is used, see right side of Figure 1. The structure lies below 2 km depth under a relatively simple anticlinal overburden. In the overburden, minor faulting is visible but this does not affect the imaging of the target. The structure itself shows clear signs of faulting, indicated by the green and blue lineaments on the Top Reservoir surface. On this surface, instantaneous amplitudes are visualized from white (dim) to red (negative) with same scaling as background seismic.

Forward seismic modelling for stack and pre-stack response was performed on well-logs of the gas-discovery well drilled on the structure. Figure 3 presents synthetic gathers for gas (original logs), water after fluid substitution (middle gather), and a PreSTM gather at the well location (right). Visual comparison of the synthetic gathers with the measured gather immediately suggests that the structure should be gas-bearing, as indicated by the class-2 AVO anomaly. The modelling confirmed that in stack view, a gas-bearing reservoir is characterised by a clear dimming of amplitudes. The clear class-2 AVO would not always be observable. Note that a raw PreSTM migrated RMO archive was used without cable statics, hence the timing difference between well and pre-stack seismic. In addition, the very far offsets in the gather are not flat, suggesting remnant high-order move-out and/or anisotropy.

However, most of the offset-interval is sufficiently flat to give reliable relative AVO results without any further gather conditioning, offset balancing, or (post-) processing.

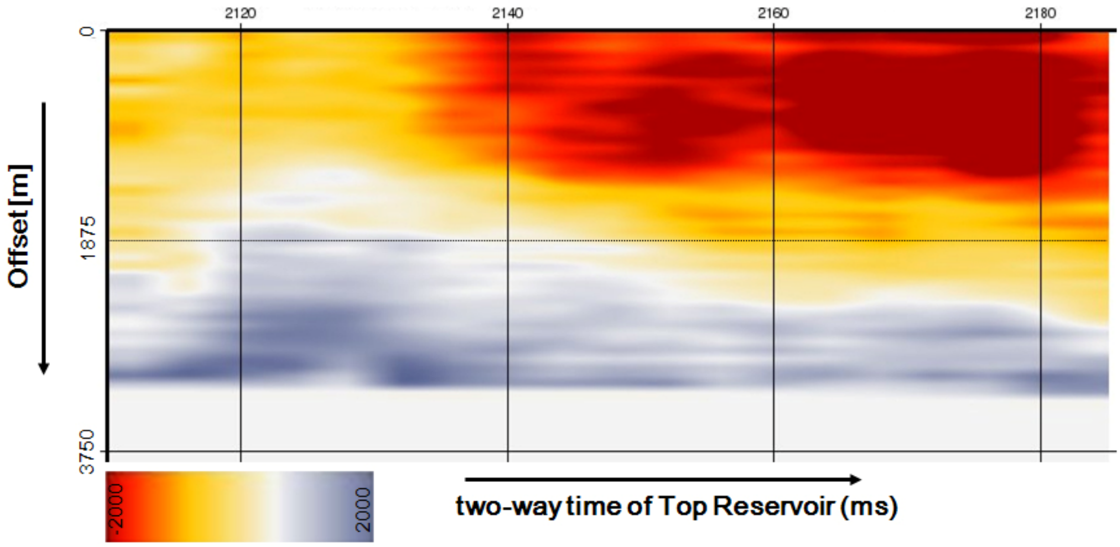

Figure 2 *Pre-stack CCB over the structure visualised in Figure 1 right.*

The post-stack CCB over the structure was already presented in the left side of Figure 1. Using this image, and the knowledge of the dim behavior of gas-bearing reservoir, one could easily pin-point the probable gas-water contact. The pre-stack CCB over the structure is presented in Figure 2. In this graph, the dark red amplitudes in the upper right area represent the strong negative amplitudes associated with the water leg. They decrease with offset; the positive amplitudes at high offsets are attributed to high-order move-out or artifacts. When moving up the structure, i.e. moving left on the image, amplitudes slightly decrease, until a sudden drop occurs. This is the gas-water contact, again at 2136 ms two-way time. In the left part of the image, the polarity change occurs at significantly smaller offsets than in the water leg. Here it is believed to represent the class-2 AVO anomaly.

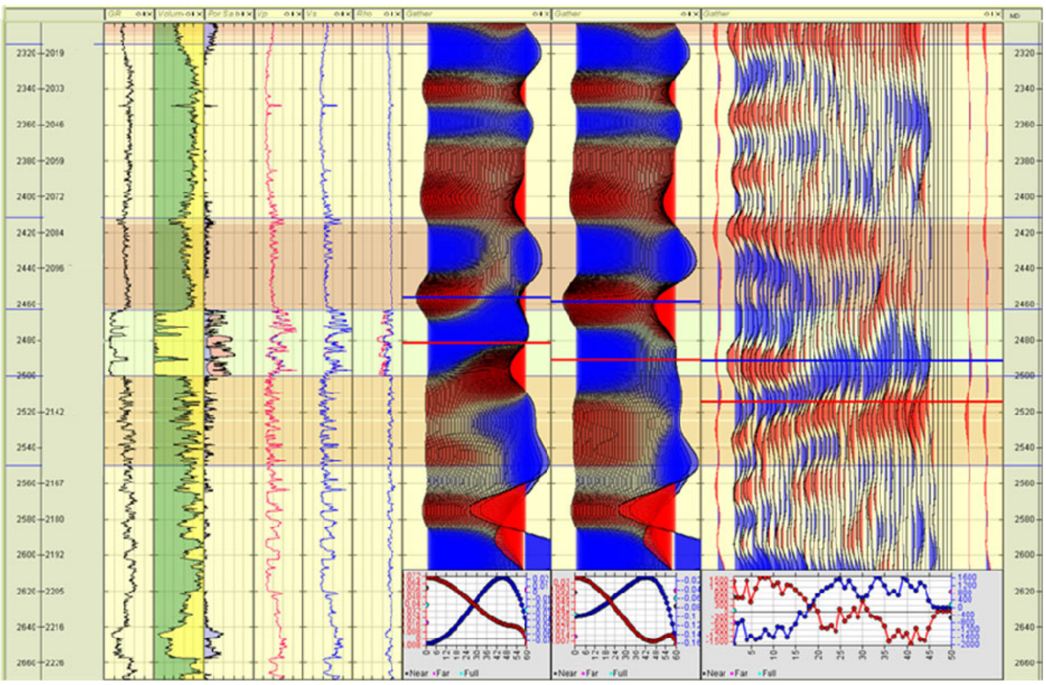

Figure 3 *Forward seismic modelling results for the structure under investigation. On the left side, well logs and evaluations are presented. In the centre and right part of the image, seismic gathers are presented for the gas case, water case, and PreSTM data (from left to right). (Note the time shift between modelled and actual seismic as raw pre-stack data was used.)*

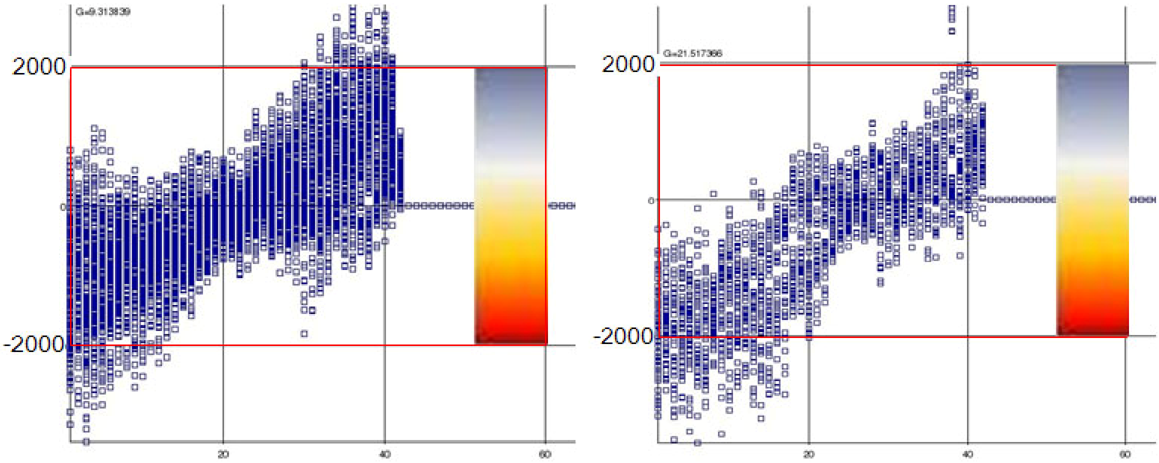

Figure 4 *AVO crossplots from the pre-stack CCB volume from figure 2, at 2120 ms top reservoir two-way time (left) which is gas-bearing, and at 2140 ms top reservoir twt (right) which is water-bearing.*

As the colour coding of the pre-stack CCB display (figure 2) is not always intuitive, AVO graphs per depth bin can be visualised; these are presented in figure 4. In these graphs, all raw amplitude-offset pairs for all CMP's that went into a single bin of the pre-stack CCB image are plotted. On the left side, an AVO graph at 2120 ms twt is displayed, which is in the gas zone. Although the mean value of the data cloud is not obvious, it is clear that most amplitudes are less negative than in the graph on the right side, which presents the AVO behaviour of the water-leg. Also apparent is the relatively large scatter of the raw AVO data compared to the average trend. Because CCB removes this scatter by offset-preserving spatial averaging, it enables the interpretation of the amplitude behaviour as function of hydrocarbon content, whereas this is not possible using the raw data.

Conclusions

Common Contour Binning is a very powerful technique to highlight subtle hydrocarbon-related amplitude effects on both pre- and post-stack data. Provided that such effects are flat in the domain of investigation, and that they are structure conformable with available interpretation, CCB can highlight even subtle AVO effects on raw pre-stack data. This way, it is a very effective way to use unconditioned pre-stack data for interpretive purpose and AVO analysis early in the exploration cycle.

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