We LHR3 11

The Application of Data Conditioning, Frequency Decomposition and RGB Colour Blending in the Gohta Discovery (Norway)

S. F Gilani* (DEA E&P Norge AS) & L. Gómez-Martínez (GeoTeric)

SUMMARY

Geological Expression workflows, involving data conditioning and frequency decomposition can be used to detect subtle changes within the seismic signal, increase the confidence on the seismic interpretation and de-risk exploration and appraisal wells. This article explains how the application of these workflows to the Permian carbonates in the Gohta discovery (Barents Sea, Norway) and how the results can help to increase the confidence on the proposed appraisal programme.

The data was conditioned using post imaging techniques. The first step involved noise cancellation of the seismic data using structurally oriented and edge-preserving algorithms. An area of poor quality data due to shallow gas clouds was identified to the south of the Gohta structure. Both noise cancellations were then combined and this noise cancelled dataset was used as an input for the spectral enhancement. Two different spectral enhancements were tested using different methods; one involved the enhancement of the low frequencies and the other one involved an enhancement of both the low and the high frequencies, aiming for a white spectrum. Frequency decomposition and RGB blending were applied on both enhanced datasets. The bright colours observed in the blends were interpreted as an indicator of the presence of oil and gas.

Introduction

The workflow of data conditioning, frequency decomposition, Low-frequency enhancement and RGB colour blending helped de-risking Gohta appraisal well. The Gohta discovery is located in Barents Sea (Norway) on the south western edge of the Loppa High, on the Polhem Sub-platform, bordering the Hammerfest and Tromsø basins.

The Gohta discovery well (7120/1-3), drilled by the operator Lundin in 2013, discovered oil and gas in the Røye Formation of Permian age, with possible hydrocarbon migration from the basin immediately to the northwest. A drill stem test was performed, showing very good production rates and confirming the presence of an open reservoir system. The trap is defined as a four-way dip closure, with a reservoir consisting of Permian porous karstified carbonates of the Tempelfjorden Group. The pay zone consists of a 25 m gas column and 75 m of oil.

In 2014, the Gohta appraisal well 7120/1-4 S was drilled to the Upper Røye Formation in the northern part of the Gohta structure, where a bright colour blend response had been identified in the area using the workflow proposed in this paper. The workflow involved several steps of data conditioning to improve both the signal-to-noise ratio and the frequency content of the dataset; then different methods of frequency decomposition were applied. Frequency decomposition and RGB blending were tested on both conventional spectral enhanced and low-frequency enhanced datasets. The bright colours observed in the blends were interpreted as an indicator of the presence of oil and gas. The results of this work supported the presence hydrocarbons on the proposed location of the Gohta appraisal well (7120/1-4 S) and encountered gas but the testing in the oil zone was inconclusive because of the technical problem of isolating gas flow from the oil zone, proving the validity of this technique as a DHI.

Geological Expression workflow

In order to identify the extents of the reservoir and its internal variations, a Geological Expression workflow (Henderson, 2012) was applied to the data. As shown in the chart (Figure 1), the workflow involved several steps of data conditioning to improve both the signal-to-noise ratio and the frequency content of the dataset; then different methods of frequency decomposition were applied to identify the subtle changes within the seismic signal which can be related to changes in reservoir thickness, fluid content or lithological changes.

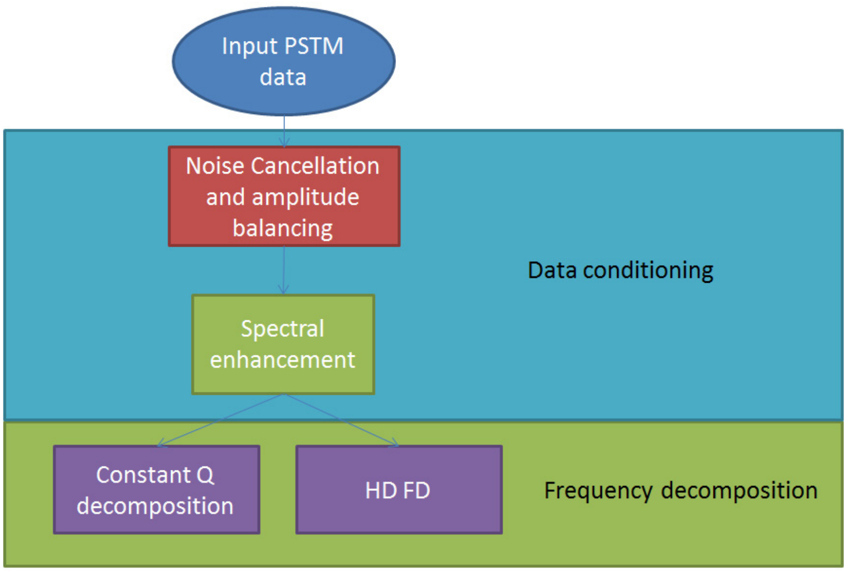

Figure 1 *Geological Expression workflow chart.*

Noise cancellation

Noise cancellation was applied as a first step to condition the data and ensure the data quality is optimised as much as it can be in the post-imaging domain. Two different noise cancellation workflows were applied for two different areas within the region of interest. For the areas with good seismic imaging (i.e. not affected by the gas cloud), a gentle noise cancellation workflow was applied. This consisted of a structurally oriented and edge-preserving finite impulse response median hybrid filter (SOFMH) targeting coherent noise, followed by a tensor diffusion algorithm targeting random noise. This combination of filters resulted in an increase in the signal-to-noise ratio, improving the continuity of the seismic reflectors while preserving the fault breaks.

For the areas where the seismic signal is degraded due to the presence of the shallow gas cloud, a stronger noise cancellation using a mean filter was applied. Both noise cancellations were combined using a chaos-based mask volume, and then the amplitudes were normalised by estimating the amount of amplitude reduction produced by the gas cloud, and applying an amplitude scaling factor using the chaos-based mask. The two noise cancellations were combined using this mask volume, so that the aggressive noise cancellation was used for areas with high mask values and the gentle noise cancellation for areas with low mask values, with a smooth transition between them. Finally, the amplitude of the noise cancelled merged volume was balanced, matching the dominant amplitudes of the low-amplitude areas below the gas cloud to those of the stable well imaged areas. As a result, the low amplitude areas are better imaged and the stable areas still preserve the high amplitudes.

Conventional spectral enhancement

This technique aims to balance the contribution of frequencies within the data, producing a 'white spectrum', where all the frequencies contribute equally to the signal power. This leads to a better vertical resolution as a result of the increased bandwidth and higher mean frequency of the output volume. To achieve the optimum results in the Gohta dataset, both the low and the high end of the spectrum were boosted. The spectral enhancement was carried out by decomposing the signal in a number of band-pass filters using a modified Fast Fourier Transform (FFT), and then the band-pass volumes were recombined using weighting factors to generate the target spectrum.

Low-frequency enhancement

Several authors (Goloshubin *et al*., 2002; Burnett and Castagna, 2003; Castagna *et al*., 2003; Tambunan *et al*., 2007; Yu *et al*., 2011) have used low-frequency effects as a predictive method for identifying and mapping hydrocarbon reservoirs by applying frequency dependent processing. The method involved the analysis of an amplitude spectrum for the time window of interest for several seismic lines. After analysing the spectrum, a low-pass and high-frequency cut filter was designed on the frequency domain and applied over the entire seismic volume. The amplitude envelope of the filtered seismic volume was then calculated and used to multiply the input data, producing the final enhanced data. By doing this multiplication, the low-frequency reflectors were enhanced and the high frequency reflectors were still preserved.

Frequency decomposition and RGB blending

The workflow was tested using both the conventionally spectral enhanced data and the low-frequency enhanced data as input volumes. Different frequency decomposition algorithms were tried on the datasets, including the Constant Q method (analogous to a Continuous Wavelet Transform or CWT) and the High Definition Frequency Decomposition (HDFD) method (based on a modified matching pursuit algorithm). Using the conventionally enhanced dataset as an input, the Constant Q method was applied to generate three magnitude volumes for dominant frequencies of 10 Hz, 14 Hz and 22 Hz. These volumes were blended in an RGB colour scheme, so that the 10 Hz volume was assigned to the red colour, the 14 Hz volume to the green colour and the 22 Hz volume to the blue colour. These frequencies were selected based on an assessment of which combination was giving a better looking output blend. The colour blend tends to show bright responses (i.e. high amplitudes) in the areas within the reservoir, while the response is significantly darker outside of the Gohta structure. Changes in colour within the reservoir can be a result of changes in thickness, fluid content or reservoir proprieties. The southern area of the reservoir, which was initially obscured by the gas cloud, shows a chaotic response on the blend, but still has a brighter response than the surrounding areas outside the reservoir, supporting the current gas-oil contact interpretation.

A similar workflow was applied using the low-frequency enhanced dataset as the input. The three magnitude volumes were generated for dominant frequencies of 7 Hz, 13 Hz and 20 Hz. Again, these frequencies were selected based on a qualitative assessment of which combination was producing a better looking blend. In this case, the amplitude contrast (i.e. brightness contrast) between the reservoir and the surroundings was even more evident as shown in Figure 2.

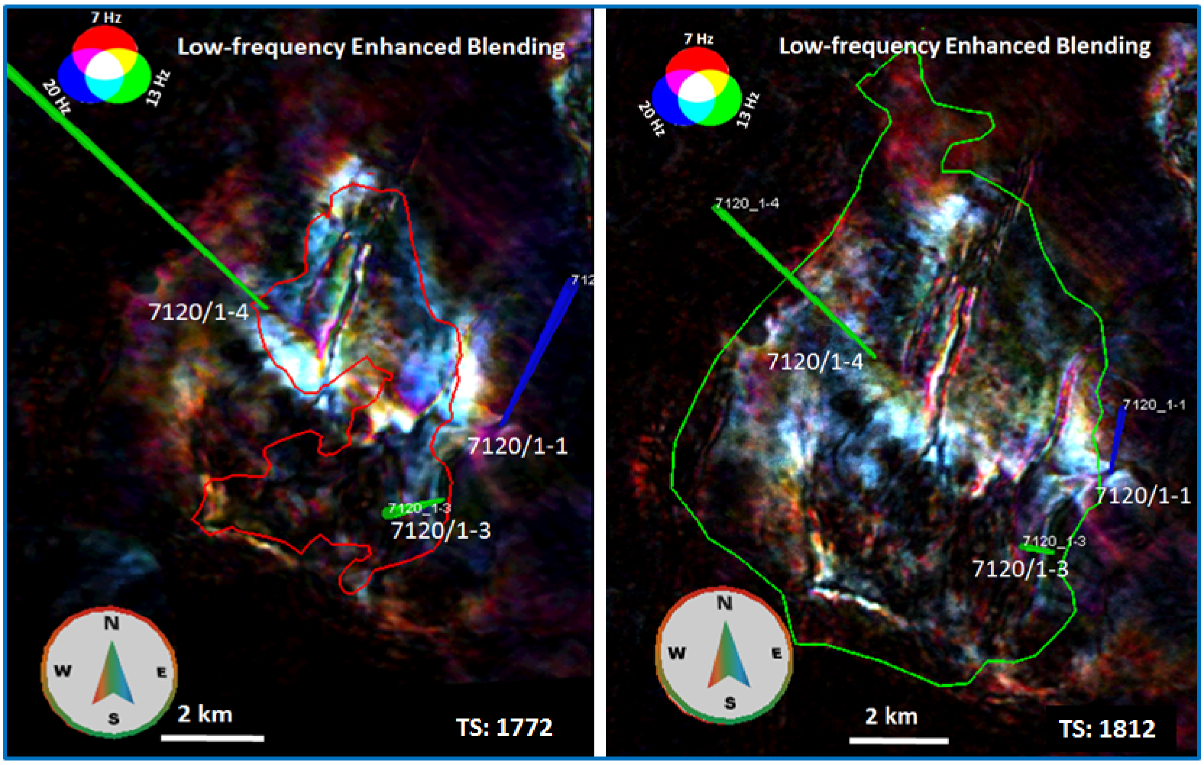

Figure 2 *Time-slices through the gas cap (left) and oil leg (right), showing Constant Q RGB blends generated on the low-frequency enhanced dataset.*

One of the drawbacks of the filter-based frequency decomposition techniques, such as FFT or CWT, is that the vertical resolution of the original seismic data is not preserved due to vertical smearing. High Definition Frequency Decomposition (HDFD) is a technique based on a modified matching pursuit algorithm which preserves seismic resolution. With the HDFD method, each seismic trace is decomposed into a number of individual wavelets whose sum equates to the original trace. After decomposition into wavelet responses, a trace can be reconstructed at any given frequency (McArdle and Ackers, 2012). The HDFD was tested both using the conventionally enhanced volume and the low-frequency enhanced volume as input volumes. In both cases, the three magnitude volumes were generated for dominant frequencies of 20 Hz, 30 Hz and 40 Hz. The results of the HDFD colour blends show a clear brightness difference between the areas within the reservoir and outside the reservoir, which could be linked to the presence of hydrocarbons.

Conclusions

Data conditioning, including both noise cancellation and spectral enhancement, optimised the input data to be used for further interpretation and frequency studies. The noise cancellation increased the signal-to-noise ratio while preserving the subtle edges and fault breaks, and the spectral enhancement brought a white spectrum to the data improving the vertical resolution. The amplitude in these areas was corrected using an adaptive amplitude normalisation workflow, which adjusted the amplitudes that were attenuated because of the gas cloud, recovering a similar amplitude range to the surrounding un-affected areas. The frequency decomposition workflow analysed the subtle frequency variations in the seismic signal which were interpreted as changes in reservoir thickness, lithology or fluid content. This technique has been used mainly as a qualitative approach for identifying those reservoir variations. The brighter RGB blend colours observed within the reservoir were interpreted as an indicator of the presence of hydrocarbons. Different approaches of frequency decomposition and colour blending techniques were tested in the dataset, and all of them showed a brighter colour response within the reservoir, which could be an effect of the presence of hydrocarbons.

References

Burnett, M.D. and Castagna, J.P. [2003] ISA method spotted gas anomalies. *AAPG Explorer,* **24**(1), 74-84.

Castagna, J.P., Sun, S. and Siegfried, R.W. [2003] Instantaneous spectral analysis: Detection of low-frequency shadows associated with hydrocarbons. *The Leading Edge,* **22**, 120-127.

Cooke, N., Szafian, P., Gruenwald, P. and Schuler, L. [2014] Forward modelling to understand colour responses in an HDFD RGB blend around a gas discovery. *First Break*, **32**, 87-93.

Goloshubin, G.M., Korneev, V.A. and Vingalov, V.M. [2002] Seismic low-frequency effects from oil-saturated reservoir zones. *72nd SEG Annual International Meeting,* Expanded Abstracts, 1813-1816.

Henderson, J., Purves, S. and Leppard, C. [2007] Automated delineation of geological elements from 3D seismic data through analysis of multichannel, volumetric spectral decomposition data. *First Break,* **25**, 87-93.

Henderson, J. [2012] Geological Expression: data driven-interpreter guided approach to seismic interpretation. *First Break,* **30**, 73-78.

McArdle, N., and Ackers, M. [2012] Understanding seismic thin-bed responses using frequency decomposition and RGB blending. *First Break,* **30**, 57-65.

Norsk Petroleum [2015] http://www.norskpetroleum.no/en.

Partyka, G., Gridley, J. and Lopez, J. [1999] Interpretational applications of spectral decomposition in reservoir characterization. *The Leading Edge,* 18, 353–360.

Tambunan, B.R., Moscato, G. and Schiavone, A. [2007] Analysis of Seismic Amplitude Anomalies in Deep Water Kutei Basin ("Tailored Method"). *77th SEG Annual Meeting,* Expanded Abstracts, 831-835.

Yu, B., Zhou, L. and Wang, X. [2011] Application of the oil-bearing prediction methods based on spectral decomposition. *SPG/SEG International Geophysical Conference,* Expanded Abstracts, 1663-1668.