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Detailed Imaging of Seabed and Sub-seabed Geology from 3D Seismic Data Using Frequency Decomposition

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SUMMARY

The study focuses on detailed imaging of the seabed and the shallow sub-seabed sequences of a deep water area particularly affected by seabed features such as pockmarks, faults, carbonate hardgrounds and hydrate mounds. Three workflows that were applied to achieve this objective are discussed: noise cancellation, spectral enhancement and standard frequency decomposition with RGB blending. Noise cancellation was successful in attenuating much of the coherent and random noise present in the original data set. Vertical resolution, reflector continuity and event separation was improved by spectral enhancement. Frequency decomposition and RGB blending revealed a wide range of geological features on and under the seabed. With the help of these techniques one can distinguish the seabed features and identify and map different elements, such as faults, channels and pockmarks, as well as submarine landslides, mass transport complexes, outrunner blocks of varying sizes and corresponding glide tracks below the seabed. The results confirm that volumetric frequency decomposition and RGB blending lead to an improved and more reliable assessment of shallow geohazards by assisting interpreters to identify a wide range of geological features in unparalleled detail, in a reasonable amount of time.

Introduction

Frequency (or spectral) decomposition and RGB blending are powerful tools used to highlight local changes in the amplitude and frequency content of seismic data, revealing gross geological trends and subtle geological variations. The frequency content of the seismic signal is affected by changes in bed thickness, lithology and fluid content. These changes, and the interplay between the different frequency responses, can aid both stratigraphic and structural interpretation, revealing geology that was previously hidden within the seismic data.

The main objective of the study was to provide detailed imaging of the seabed and the shallow sub-seabed sequences of a deep water area particularly affected by seabed features such as pockmarks, faults, carbonate hardgrounds and hydrate mounds. Three workflows were run to achieve this objective: noise cancellation, spectral enhancement and standard frequency decomposition with RGB (Red-Green-Blue) blending.

Data Conditioning

The noise cancellation process improves the signal to noise ratio of the data and therefore improves the reflector continuity. An edge preserving, structurally orientated finite impulse response median hybrid filter (SO FMH) was used to remove coherent noise in the data, improving reflector continuity whilst preserving subtle details like edges, corners and sharp dips in the structure. It uses pre-computed dip and azimuth steering volumes to align itself along the geology. The remaining random noise was attenuated using an edge preserving, structurally orientated, adaptive anisotropic diffusion filter (TDiffusion). It is very sensitive to small scale discontinuities and is ideal for removing random noise whilst preserving subtle structural details.

The vertical resolution and localisation accuracy of seismic data are dependent on the frequency content of the seismic signal. High resolution and accurate localisation are associated with a high mean frequency and a large frequency bandwidth. The aim of the Spectral Enhancement workflow is to maximise the mean frequency and bandwidth of the seismic data by producing a “white” spectrum, i.e. one in which all frequencies contribute equally to the power in the signal. Balancing the spectrum in this way can enable differentiation of previously irresolvable events. The spectral enhancement applied to the data on both low and high frequency contents resulted in a 23% increase in bandwidth but kept the dominant frequency nearly constant.

Figure 1 shows a comparison between the original data and the same section after noise cancellation and spectral enhancement. Data conditioning resulted in enhanced reflector continuity and event separation but preserved, and occasionally sharpened the edges which represent faults and fractures.

Frequency decomposition and RGB blending

Frequency decomposition extracts band limited versions of the data and offers a much more sensitive method of analysing seismic data than the full frequency amplitude response. It can provide information about stratigraphic facies boundaries, structural and stratigraphic geometries, stratigraphic heterogeneities and bed thickness variations. The decomposition is achieved through application of a set of bandpass filters to the seismic traces. Specifically, a set of Gabor wavelets are used flexibly to provide a choice of decomposition options. This allows either decompositions with properties similar to an FFT (Fast Fourier Transform) or similar to a Wavelet Transform to be produced. For this project, two types of frequency decomposition were tested: Constant Bandwidth and Uniform Constant Q.

> ***Constant Bandwidth**:* The bandwidth of the filters is constant and independent of the central frequency. Constant Bandwidth mode is usually used when the aim of the spectral decomposition is to differentiate between large scale geological elements on the basis of their bulk properties, for example delineation of large salt bodies or gas chimneys. Due to the narrow

bandwidth and large filter length, the Constant Bandwidth method provides the highest resolution in frequencies; however, it is the most inferior in vertical resolution.

Uniform Constant Q: In Uniform Constant Q, the ratio between the frequency bandwidth and central frequency is constant, and central frequencies increase by a constant amount. The higher the central frequency the shorter the filter length, which leads to a significant increase in vertical resolution. On the other hand, increasing bandwidths of the filters result in a slight decrease in resolution of frequencies.

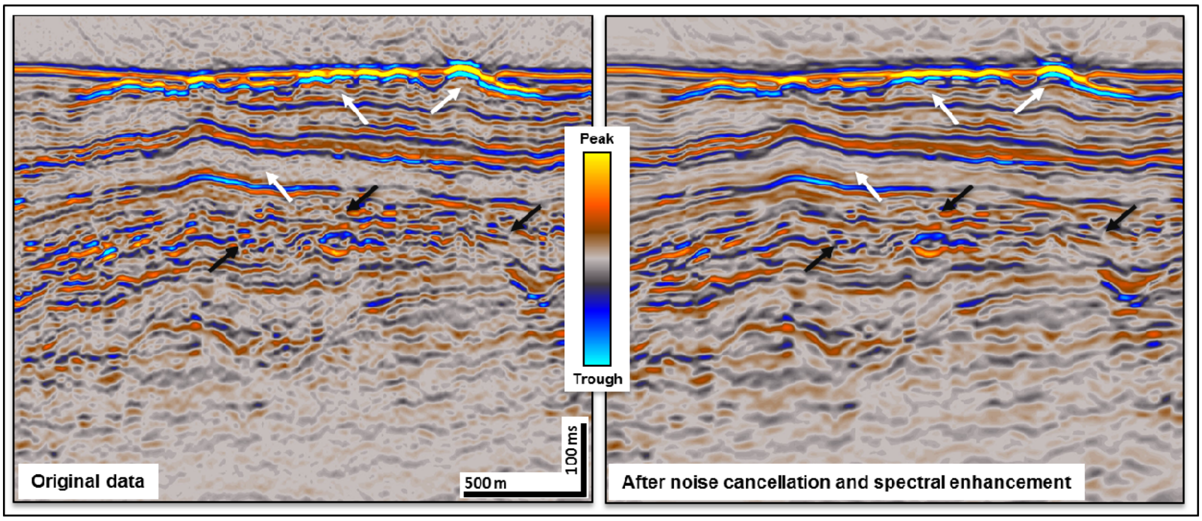

Figure 1 *Comparison of the original and conditioned seismic data. Data conditioning enhanced reflector continuity and event separation (white arrows) while preserving and sharpening faults (black arrows).*

When three frequency magnitude response volumes are combined in an RGB (Red-Green-Blue) colour blend, the relationships and interplay between the frequency responses can be investigated. The colour and intensity apparent in the RGB blend depend on a number of variables related to the frequency and amplitude of the signal, which in turn are determined by the geometry (e.g. thickness) and rock properties (e.g. impedance) of the subsurface. Further analysis of colour blends, especially when compared with existing ground truth data, can assist in quantifying variations in these factors.

Conclusions

Noise cancellation was successful in attenuating much of the coherent and random noise present in the original data set. In order to preserve all geological information, only a gentle level of noise cancellation was applied. Vertical resolution, reflector continuity and event separation was improved by spectral enhancement.

Frequency decomposition and RGB blending revealed a wide range of geological features on and under the seabed. With the help of this technique one can distinguish the different seabed features (e.g. pockmarks and carbonate hardgrounds, see Figure 2), and identify and map different elements, such as faults, channels and pockmarks, as well as submarine landslides, mass transport complexes, outrunner blocks of varying sizes and corresponding glide tracks below the seabed (Figure 3).

Detailed study of the RGB blend allows conclusions to be drawn on the connections between the different features: how carbonate hardgrounds and pockmarks align with faults or the extent and evolution of channels through time.

This study proved that volumetric frequency decomposition and RGB blending resulted in an improved and more reliable assessment of shallow geohazards by assisting interpreters to identify a wide range of geological features in unparalleled detail, in a reasonable amount of time.

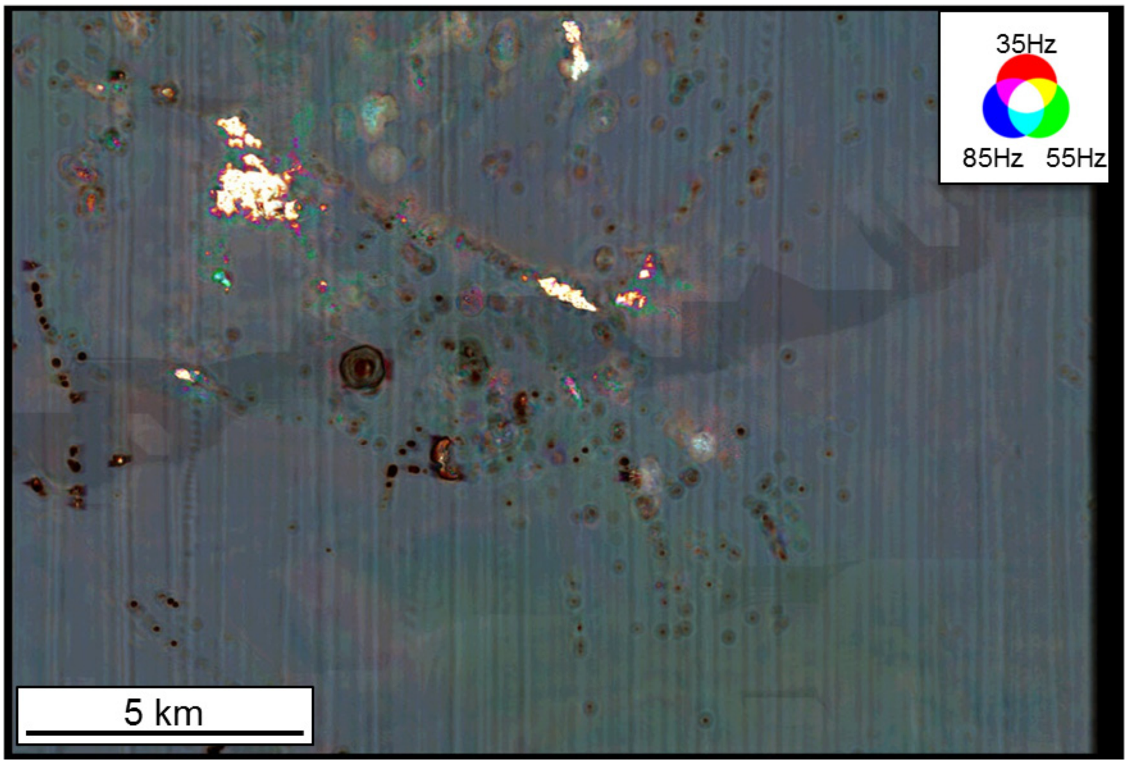

Figure 2 *An RGB colour blend of three frequency response magnitude volumes (35 Hz, 55 Hz and 85 Hz), draped on the seabed. Pockmarks (darker circular features) and carbonate hardgrounds (bright white areas) are revealed.*

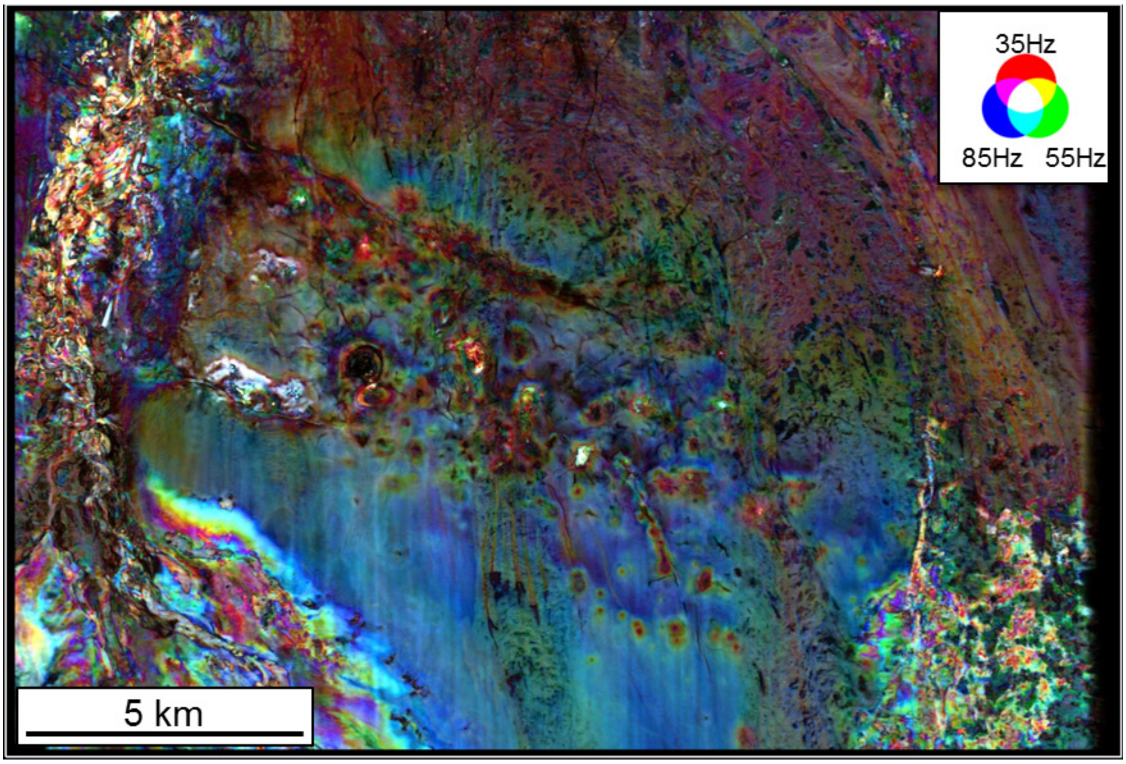

Figure 3 *An RGB colour blend of three frequency response magnitude volumes (35 Hz, 55 Hz and 85 Hz), draped on a horizon approximately 100 ms below the seabed. Pockmarks, faults, channels, mass transport complexes, outrunner blocks and glide tracks can be identified.*

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