Detection of Seismic Chimneys by Neural Networks, a New Prospect Evaluation Tool.

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Abstract

This paper describes recent experiences with the seismic chimney detection method developed by Meldahl et al. (1998 and 1999). In this method a supervised neural network and multi-attributes transform a seismic volume into a volume with ‘chimney probabilities’. The mapping of chimneys is used in prospect evaluations as a ranking tool (Heggland et al., 1999 and 2000). The method has given new insights in hydrocarbon migration research and has helped to identify differences between areas with dry wells and areas with discoveries.

Introduction

Seismic chimneys are vertical disturbances of the seismic response. The chimneys may indicate upward migration of fluids and/or gas, and may be used in the interpretation of hydrocarbon migration pathways (Heggland, 1997 and 1998). Seismic chimneys are not clearly visible on timeslices, and it is difficult to make them visible on maps by displaying selected attributes. Manual mapping of seismic chimneys is also difficult, as the extent of chimneys on seismic sections may not be very well defined. To make the mapping of seismic chimneys more consistent and efficient, a new method has been established. This method makes use of a neural network that has learned to classify the seismic response in terms of chimney and non-chimney.

Method

The method applied for detection of chimneys in seismic data is part of a generalized patent pending method for the detection of seismic objects (Meldahl et al., 1998 and 1999). A neural network has been applied to make a classification of the seismic data into two groups, chimneys and non-cimneys. Multi-trace and multi-attribute calculations are performed on the input seismic data, in order to increase the contrast between chimneys and the background. The different attributes that are input to the neural network are weighted according to how much they contribute to the contrasting of chimneys. The attributes that seem to give the highest contributions are the variance of the dip, trace to trace similarity, which is low within chimneys, and energy (or absolute amplitude), which generally is lower within chimneys than in the areas surrounding them. The neural network is trained on attributes extracted at chimney and non-chimney example locations identified by the interpreter. After training, the network is applied to the entire dataset. In the chimney detection process, multiple vertical attribute extraction windows are used. This enables the network to distinguish between objects with a certain vertical extent and objects with similar attribute characteristics but ‘without’ a vertical dimension. The neural network finally makes a classification of the seismic data into chimneys and non-chimneys. The output samples will be given high values for chimneys (high probability) and low values for non-chimneys (low probability). Figure 1 shows a seismic section from the input data and the corresponding section from the output data. The output data should ideally show only seismic chimneys and a background with no objects, however, there are other vertical objects with similar seismic characteristics that are not chimneys, such as data-merges and faults. The interpreter therefore has to be cautious when applying the results. The seismic chimney detection method has been applied to 3D seismic data only, but should work also for 2D data. Maps of chimneys may be generated from the 3D output data by taking timeslices at different levels or by outputting data at interpreted horizons.

Results

The semi-automated detection of seismic chimneys has been applied to several 3D seismic data sets from the Norwegian shelf (Heggland et al., 1999) and the Gulf of Mexico (Heggland et al., 2000) with consistent results. Hydrocarbon migration systems around proven oil and gas fields and possible migration systems around prospects have been visualized by the method. The chimneys may indicate fluid and/or gas migration from a source rock into a prospect, spill through faults surrounding a reservoir, or leakage from the top seal of reservoirs. In this way the tool is used in the ranking of prospects. Seismic chimneys frequently tie in with hydrocarbon escape related features (Hovland and Judd, 1988) like pockmarks, carbonate mounds and mud volcanoes, as well as with amplitude anomalies indicating shallow gas accumulations. Identification of such hydrocarbon associated features supports the chimney interpretation process. The mapping of chimneys also have significance in geohazards interpretation, the other main application of the chimney cube.

The semi-automated detection of chimneys has made it possible to make a consistent comparison between chimneys in areas with dry wells and in areas with discoveries. Preliminary results show a difference in the density of chimneys. The discovery wells and oil and gas fields are located in areas with a high density of chimneys, whereas most dry wells are located in areas with a low density of chimneys, or no chimneys at all. Chimneys are observed to have different appearances. The extent and shapes vary, and they may form clusters with varying extent and shapes. Chimneys also appear at different stratigraphic units, indicating different periods of migration. The most recent period when chimneys reach the seabed, seems to be the most significant period with respect to prospectivity of an area.

Figure 2 shows a 3D visualization of chimneys which indicate hydrocarbon migration from Jurassic faults into an Eocene reservoir, as well as to the seabed. Amplitude anomalies at the top of the chimneys may represent shallow gas accumulations. The Eocene reservoir has been drilled by two wells that showed oil and gas columns. A third well drilled in an area without chimneys was dry.

Conclusions

The detection of chimneys by the use of multi trace and multi attribute calculations, and neural networks has improved the identification of chimneys and made the mapping more consistent as compared to manual mapping. The method has been used in prospect evaluations as a ranking tool. It has led to new insights in hydrocarbon migration research, such as revealing differences between areas with dry wells and areas with discoveries and fields.

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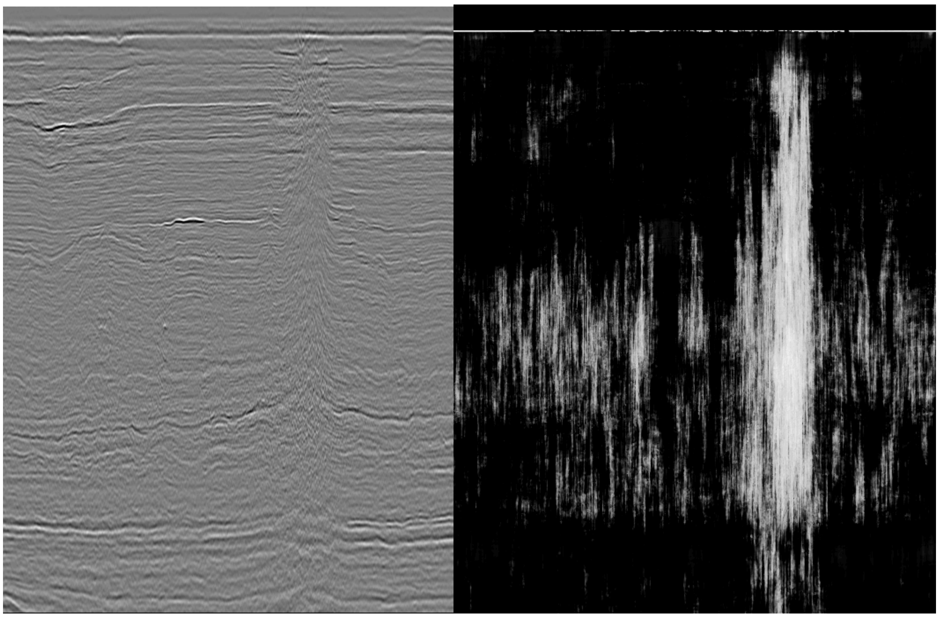

Figure 1. Comparison of standard seismic (left) and detected chimneys (right).

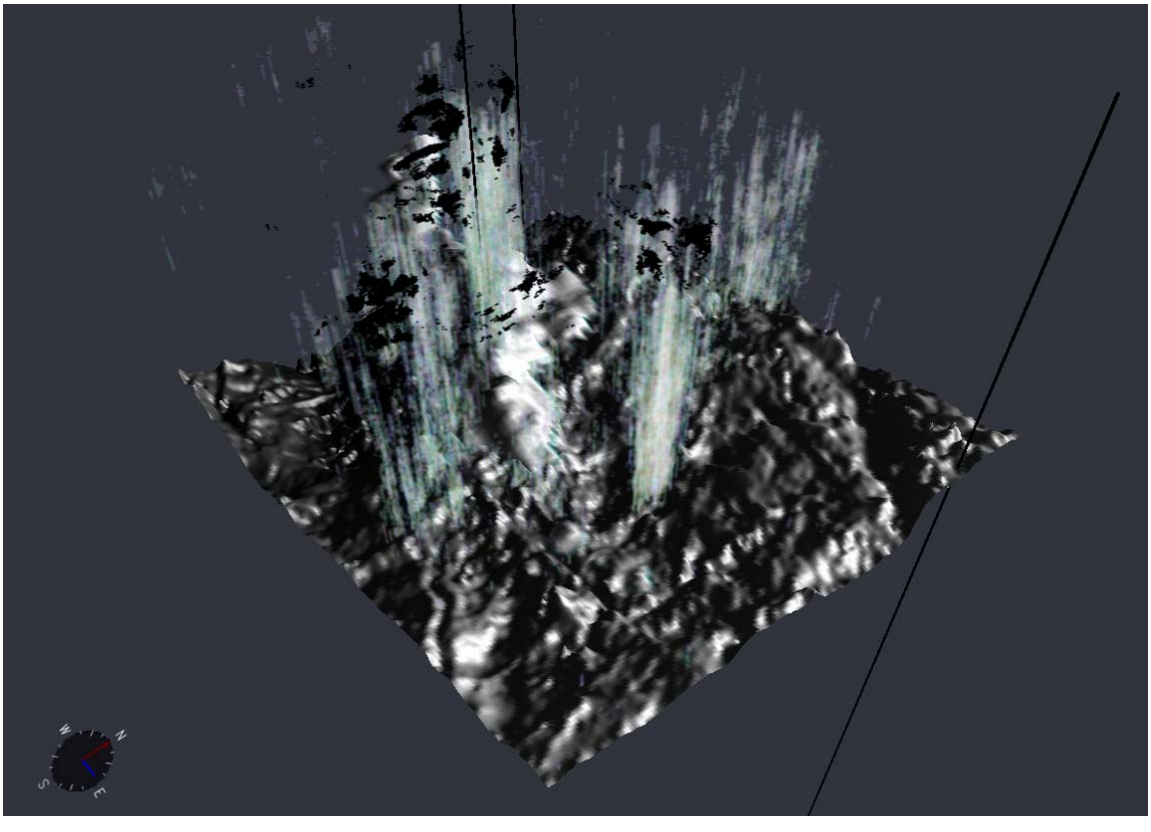

Figure 2. 3D visualization of seismic chimneys between top of Jurassic faults (at the dark surface) and the seabed. The smaller white surface represents the top of an Eocene reservoir. The two wells penetrating this surface showed oil and gas columns. The third well (at the right) was dry. Amplitude anomalies (black) on top of chimneys indicate shallow gas accumulations.