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**Seismic Evidence of Vertical Fluid Migration Through Faults,  
Applications of Chimney and Fault Detection.**

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**Summary**

Columnar disturbances in seismic data are frequently interpreted as free gas in the sediments, either as small accumulations captured in the shales, or as upward migrating free gas. These features, usually termed seismic chimneys, or gas chimneys, have been observed to tie in to features associated with gas seepage, like pockmarks and carbonate build-ups, and to shallow gas accumulations and faults. Recent studies have revealed that chimneys can represent a link to deeper hydrocarbon accumulations.

To improve the consistency in the mapping of chimneys, a method for semi-automated detection of chimneys was developed. This method has also been adapted for fault detection.

Gas seepage features and chimneys have been observed at different stratigraphic levels, which indicates that gas seepage is not a continuous process, but takes place during limited periods on the geological time scale.

Due to capillary resistance, vertical migration of hydrocarbons in shales has to happen through faults or fractures. Examples from 3D seismic data show that most chimneys are located at faults or fractures.

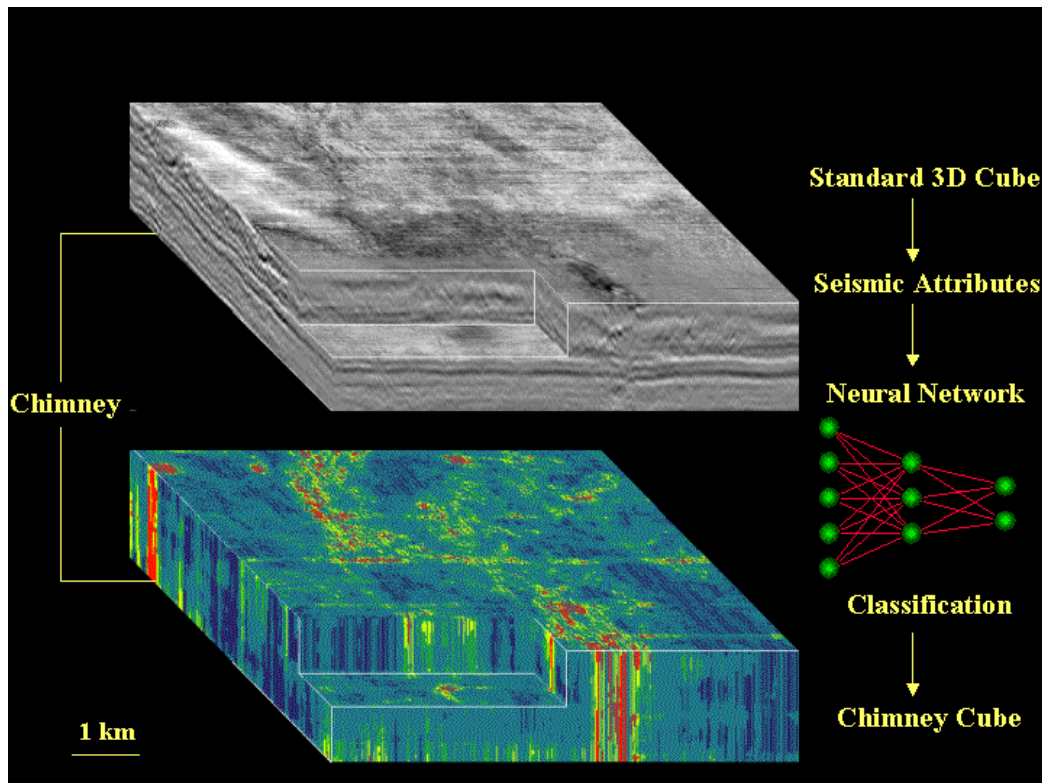


Figure 1. Standard exploration 3D seismic data before and after chimney detection.

## Introduction

Since the late 1980's, exploration 3D seismic data have proved to be very useful for shallow gas and geohazards evaluations for E&P drilling sites (Heggland et al., 1996).

As part of this work, indicators of fluid flow, like gas chimneys, pockmarks, possible carbonate build-ups, as well as mud volcanoes and diapirs are mapped. Studies of these shallow features have also been focused on whether they can give information about deeper hydrocarbon accumulations.

## Method

The mapping of gas chimneys from seismic data can be time consuming and difficult, because of their diffuse character and often weak appearance. To improve the identification and mapping of gas chimneys, a method was developed to detect gas chimneys in seismic data (Meldahl et al., 1998, 1999, Heggland et al., 1999). The method with examples and interpretation is also described in Heggland et al., 2000, and Meldahl et al., 2001.

The method makes use of multi trace and multi attribute calculations and a neural network (de Groot, P., 1999). The neural network is trained at example locations on different attributes to recognize a chimney. In addition, the neural network is trained at example locations not representing a chimney. The network is finally applied on the total 3D volume to make a classification of the data into "chimney" and "non chimney". The output is a 3D probability cube, giving high values for chimneys and low values in the surrounding volume, see the example in **Fig. 1**. In a similar way, the method has been applied to fault detection (Meldahl et al., 2001, Tingdahl et al., 2001).

To highlight features associated with gas seepage, various attribute maps have been applied, like "edge detection" and rms amplitude. The "edge detection" maps highlight the geometry of the horizons, where features like pockmarks, carbonate build-ups, mud volcanoes and diapirs can be visualized. Azimuth and dip maps are good alternatives for the study of the shape of a surface. The rms amplitude maps can highlight hydrocarbon accumulations and sand deposits (high amplitudes), as well as faults (low amplitudes).

## Results

The semi-automated detection of seismic chimneys has been applied to several 3D seismic data sets from the Norwegian shelf and the Gulf of Mexico (Heggland et al., 2000), see **Fig. 2**.

Seismic chimneys frequently tie in with pockmarks, carbonate mounds and mud volcanoes, as well as with amplitude anomalies indicating shallow gas accumulations. As such, the mapping of chimneys has significance in geohazards interpretation.

Features associated with gas seepage, and chimneys, appear at different stratigraphic levels, indicating that vertical fluid migration occurs within limited periods of time (Heggland, 1997, 1998).

Possible hydrocarbon migration systems have been visualized by the seismic detection method in areas of proven oil and gas fields. The chimneys indicate fluid and/or gas migration from a source rock into a reservoir, and between a reservoir and the seabed. In the same manner, interpretation of detected chimneys are used in the ranking of prospects.

The semi-automated detection of chimneys has made it possible to make consistent comparisons between chimneys in areas with discoveries and in areas with dry wells. Preliminary results have showed a difference in the density of chimneys. Discovery wells and oil and gas fields are located in areas with a high density of chimneys, whereas dry wells are located in areas with a low density of chimneys, or no chimneys at all.

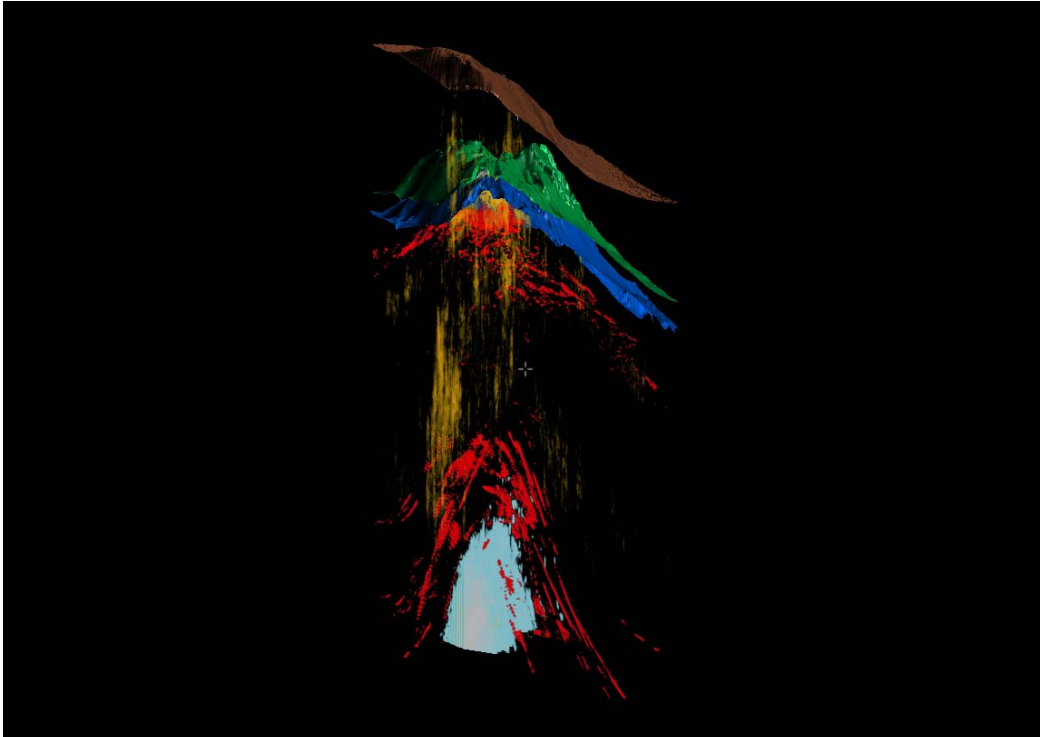


Figure 2. Visualization of 3D seismic data, Gulf of Mexico. Mapped horizons (brown, green, blue), high amplitude clusters (red), detected salt diapir (light blue) and detected chimneys (yellow).

Vertical migration of hydrocarbons in shales has to happen through faults or fractures, due to capillary resistance in the shales. Detection of chimneys in 3D seismic data shows that, in most cases, chimneys are located at faults or fractures, see **Fig. 3**.

In near surface sediments, and where no faults or fractures are visible, chimneys are still present and they seem to occupy a much larger space than at deeper levels, where the chimneys are located at faults. Above a certain level, where the sediments are less consolidated, the capillary resistance may be small enough to allow for vertical hydrocarbon migration. Another explanation could be that by an upward movement of gas saturated water, gas can be released when the pressure drops.

For other papers on application of chimney detection, see Aminzadeh et al., 2001.

### Conclusions

Results of detection of chimneys in 3D seismic data, show that chimneys tie in to features associated with gas seepage, shallow gas accumulations and deeper hydrocarbon reservoirs.

The appearance of seepage related features and chimneys at different stratigraphic levels, indicate that vertical fluid migration takes place within limited periods of time.

High concentrations of chimneys are observed in areas where discovery wells and oil and gas fields are present. Low concentrations of chimneys are observed in areas with dry wells.

The appearance of chimneys at locations of faults and fractures, strongly indicates that vertical fluid migration through shales takes place through faults and fractures.

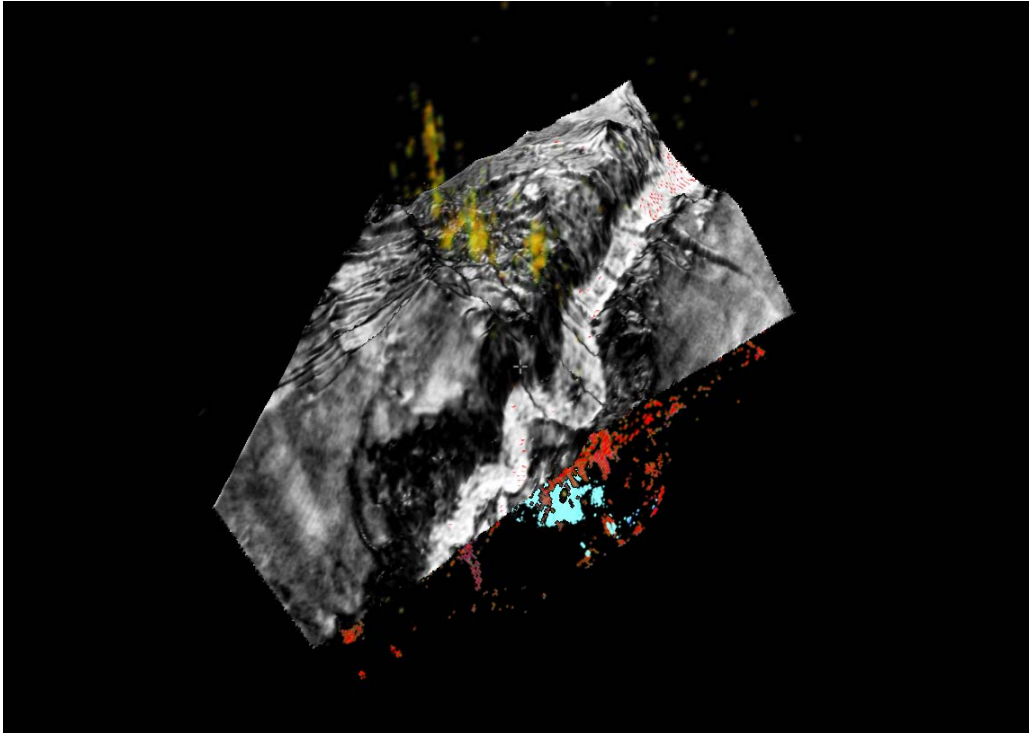


Figure 3. Visualization of 3D seismic data, Gulf of Mexico. Chimneys (yellow) are located at faults visible as low amplitude features (dark) on the amplitude map in display.

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