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Gas chimneys – indicating fractured cap rocks

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Seismic interpreters often observe anomalies that cannot be explained by primary depositional processes or processing artefacts. Gas chimneys are among such anomalies. Several years of research has led to a refined understanding of seismic anomalies related to hydrocarbon leakage processes. The aim of this paper is to present well and seismic data related to gas chimneys and to argue that a fractured cap rock model can explain the observations.

The term "gas chimney" is an interpretive term claiming that gas is causing the noise observed on seismic data. The link between gas chimneys and noise zones is clearly shown on un-scaled seismic data (Figure 1). Here, the primary reflections are very weak or absent. When the seismic signals are gained (Figure 2), the zone with weak primary reflections appears as a noise zone. Wells drilled inside noise zones have:

- higher pore fluid pressure,
- higher mud gas readings,
- higher mud gas wetness,
- more hydrocarbon shows,
- lower velocities, and
- higher temperatures

than wells drilled outside (Figure 3). Similar observations have been made in several well pairs inside and outside noise zones. Based on these observations we believe that gas is one important cause of the noise and that it is appropriate to interpret such noise zones as gas chimneys.

Gas chimneys are observed in low-permeable cap rock shales. We believe that fractures must exist in the low-permeable cap rocks in order to explain the observed oil shows within the gas chimneys. Such fractures can also explain the other observations related to gas chimneys.

Tectonic induced processes can create swarms of fractures, e.g., above salt or clay diapirs. Several gas chimneys exist in tectonic fractured cap rocks above salt structures in the Central Graben. In the northern North Sea, gas chimneys are located in cap rocks that show no or few signs of tectonic activity. These gas chimneys are located above high-pressure Jurassic fault blocks. High-pressure fluids in the Jurassic sandstone reservoirs are interpreted to have hydro-fractured the cap rock. Well observations from gas chimneys inside tectonic fractured cap rocks above salt domes in the Central Graben are similar to those above high-pressure fields in the northern North Sea (Figure 3).

In order to improve our understanding of gas chimneys we tried to mimic the observed seismic noise by seismic modelling. Several scenarios were modelled. The best match was obtained when gas was distributed as wavelength sized patches. The low-velocity gas patches must be irregularly distributed in the low permeable shales. We suggest that fractures, both hydro-fractures and tectonic fractures, distribute the gas into irregular patches within the cap rock.

Based on the observations, interpretations, and modelling we propose that gas chimneys indicate zone of fractured cap rock. If this model is correct it has several implications to the oil industry. E.g., gas chimneys should be interpreted as hydrocarbon migration pathways and the extent and location of the migration route can be mapped directly from seismic data.

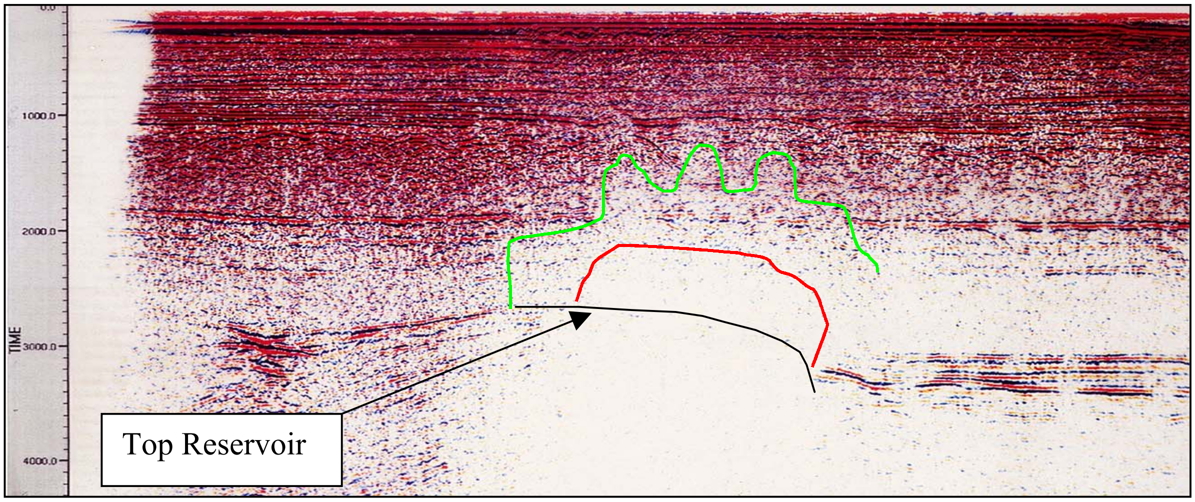

Figure 1. Un-scaled seismic section illustrating that the primary seismic signals are very weak or absent above the Gullfaks South Field.

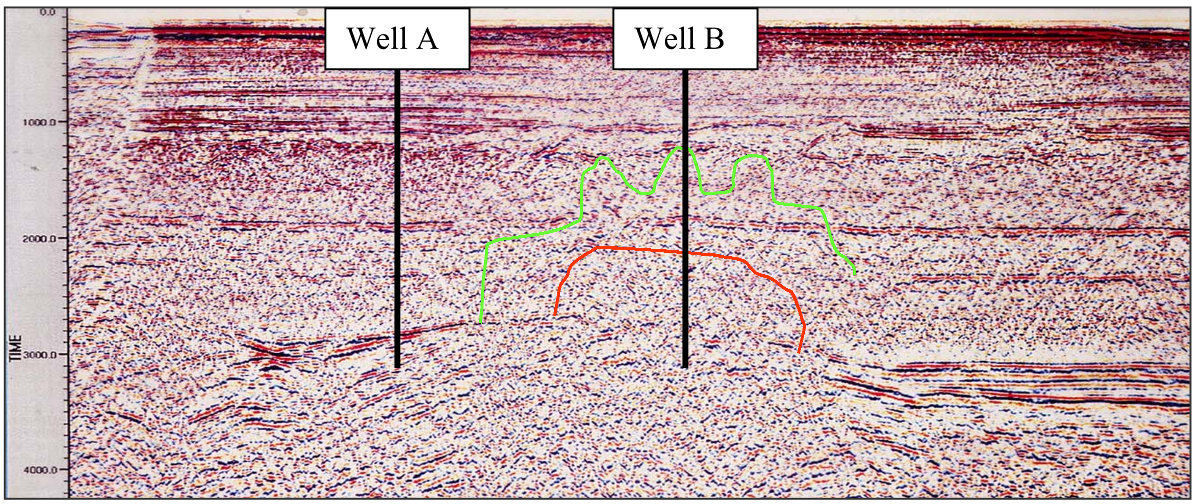

Figure 2. Scaled seismic section illustrating the noisy zone above the Gullfaks South Field. The noise zone is interpreted as a gas chimney because it is believed that gas in sediments is causing the noise. Mud gas parameters from wells (in projected positions) inside and outside the noise zone is illustrated in Figure 3.

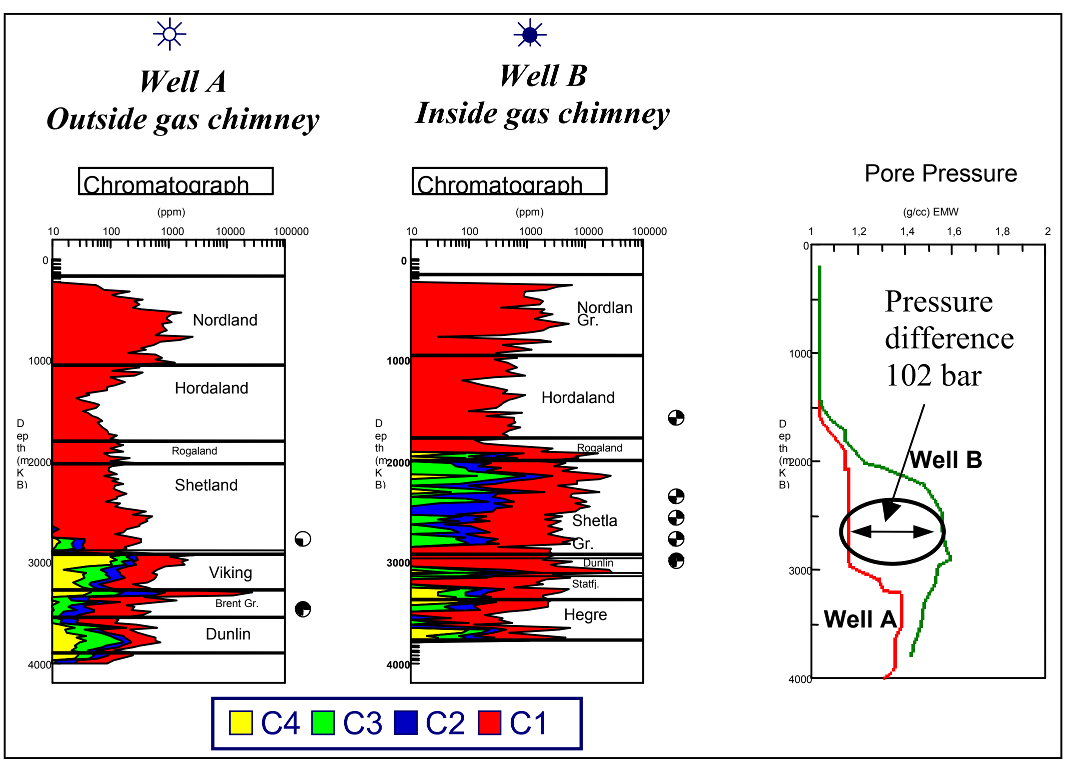

Figure 3.Gas chromatography and pressure variations in well pars inside (Well B) and outside (Well A) a gas chimney. The well inside the gas chimney has higher mud gas readings, more heavy com-ponents (C2 to C5), more shows and higher pressure than the well outside.