Th P12 07

Using Gas Chimney Detection to Asess Hydrocarbon Charge and Top Seal Effectivness - Offshore, Namibia

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SUMMARY

Gas chimney processing was performed on a 3D seismic data in deep water of Namibia. The purpose of the study was to prioritize identified prospects and understand the petroleum system better.The study area is unexplored, but recent offset drilling has identified mature, oil-prone source rocks underlying Upper Cretaceous clastic reservoirs. Gas chimneys were observed below shallow amplitude anomalies attributed to gas in the 3D seismic data. The primary question was whether these disturbed zones represent valid hydrocarbon migration or are due to degradation of the seismic signal below the shallow gas anomaly. Second, if valid then from what interval are the chimneys originating, how are they involved in the charging of the identified prospects, and do they provide clues to the character of leakage from the traps?

Results demonstrate that shallow disturbances represent valid gas chimneys. In a typical slope canyon prospect, Middle Cretaceous source rock is providing hydrocarbon charge to the prospective Upper Cretaceous reservoir objectives. Up dip a broad gas cloud overlies the reservoir, indicating the reservoirs are fully saturated with hydrocarbons and the lighter components are leaking. This implies, that if the migrating hydrocarbons are mixed phase, the objective reservoirs may be oil prone.

Introduction

Gas chimney processing was performed on a 3D seismic data acquired over a large area of the deepwater of Namibia. The purpose of the study was to prioritize identified prospects and understand the petroleum system better. The study area is unexplored, but recent offset drilling has identified mature, oil-prone source rocks underlying Upper Cretaceous clastic reservoirs. Gas chimneys were observed below shallow amplitude anomalies attributed to gas in the 3D seismic data. The primary question was whether these disturbed zones represent valid hydrocarbon migration or are due to degradation of the seismic signal below the shallow gas anomaly. Secondary questions follow if the chimneys do indicate hydrocarbon migration, then from what interval are the chimneys originating, how are they involved in the charging of the identified prospects, and do they provide clues to the character of leakage from the traps

Methodology

Gas chimneys are recognized in seismic data as vertically aligned zones of chaotic, often low amplitude, reflectivity. Gas chimney processing is a method for highlighting these gas chimneys (Meldahl, et al., 2001; Aminzadeh & de Groot, 2006). The processing uses examples of gas chimneys, picked by an interpreter, and a set of directional seismic attributes, to train a neural network to find similar features in the seismic data. The result can be overlain on the seismic data to visualize their distribution more clearly. By determining the origin of the gas chimneys, we can predict which source rock intervals are expelling hydrocarbons (Ligtenberg & Thomsen, 2003). By mapping the hydrocarbon migration pathways, we can determine how potential reservoir intervals are being charged, and how these reservoirs are potentially leaking vertically to form seeps at the sea floor, or paleo-seeps in the subsurface (Ligtenberg, 2005). The results of the gas chimney processing can be used to refine 2D or 3D basin models to understand the petroleum system and prioritize exploration plays (Connolly, et. al., 2013).

Results

The chimney processing was generally successful in highlighting hydrocarbon migration pathways. Chimneys in the Upper Cretaceous to Lower Tertiary interval were generally substantiated by their pockmarked morphology, link to shallow AVO anomalies, and origination from a suspected source rock interval. The suspected gas chimneys below shallow gas anomalies were determined to be valid instances of vertical hydrocarbon migration and more aerially restricted than the overlying gas bright spots.

A good example to show the chimney results is taken from a mapped canyon in the northern part of the survey (Figure 1). The mapped surface is the suspected top reservoir (A.). The canyon head is to the east. A sweetness type Attribute (RMS Amplitude / Frequency) over a -40m to 40m window highlights the suspected thickest channel complexes within the upper section of this canyon (Red in B). If we overlay the chimney probability results for the interval 200 meters above the top reservoir (C), we can determine the character of top seal leakage from the reservoir. High probability chimneys are in green to yellow. The chimney results show very little chimney activity over the down dip portions of the main channel complexes. Chimneys we do observe are on the flanks of the main channel complexes. This indicates effective top seal over the main reservoir interval in this portion of the canyon. Chimneys on the flank of the channel complexes may indicate vertical hydrocarbon migration that is bypassing the reservoir. In contrast we observe a broad zone of gas chimneys above the suspected reservoir in the up dip part of the canyon. This “gas cloud” indicates that the reservoir is leaking the lighter hydrocarbon components (gas) and is probably fully saturated with hydrocarbons (Heggland, 2013). Traps that leak at a single point source or along a fault surface are much more likely to be breached.

Other canyon sand traps exist with and without the same chimney characteristics. This difference enables the ranking of prospects and the selection of high graded prospects for a first well.

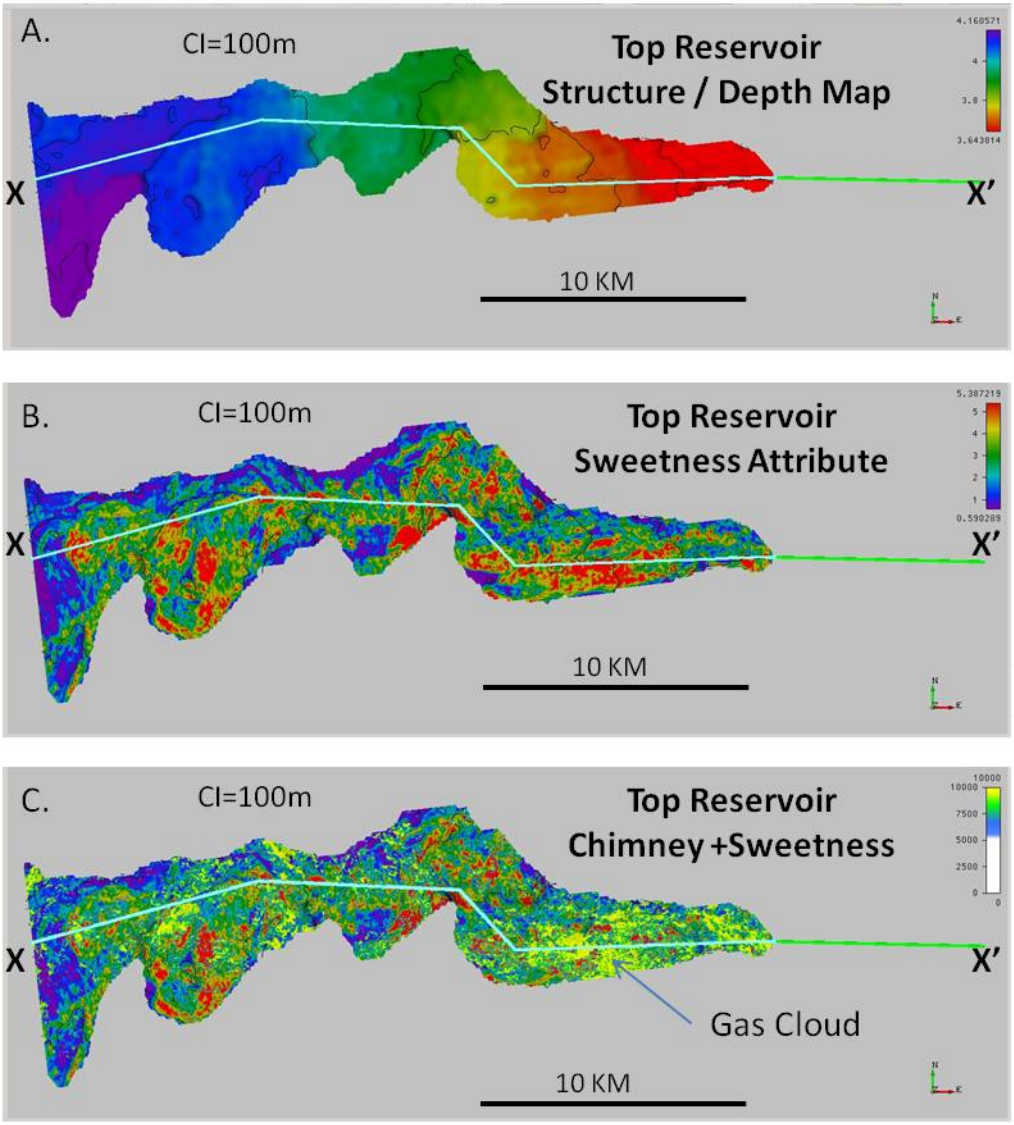

Figure 1 *Structure depth horizon for a typical Upper Cretaceous canyon in deepwater, Namibia (A). The horizon is mapped on the top reservoir. Sweetness Attribute (Instantaneous Amplitude / Instantaneous Frequency) shows a meandering channel complex in the upper part of the canyon (B). Chimney probability results in the interval 200 meters above the top reservoir (C) shows the character of top seal leakage above the reservoir. The gas cloud in the up-dip portion of the canyon indicates fully saturated reservoir (effective top seal).*

A dip line along this same canyon (Figure 2) shows the character of the seismic data (A). Interpreted horizons are at the top reservoir (light blue) and the suspected Middle Cretaceous (Cenomanian) source rock interval (light green). Seismic dip line with chimney probability overlain (B) shows chimneys originate from the Cenomanian source rock interval, indicating effective hydrocarbon charge to the suspected reservoir. In the down dip part of the canyon the chimneys terminate at the reservoir, indicating the hydrocarbons are absorbed by the reservoir. If the chimneys were through going, the quality of the reservoir would be more suspect. Up dip a broad gas cloud overlies the reservoir. This indicates, as we have discussed, that the reservoirs are likely fully saturated with hydrocarbons and the lighter components are leaking. This implies, that if the migrating hydrocarbons are mixed phase, the objective reservoirs may be oil prone.

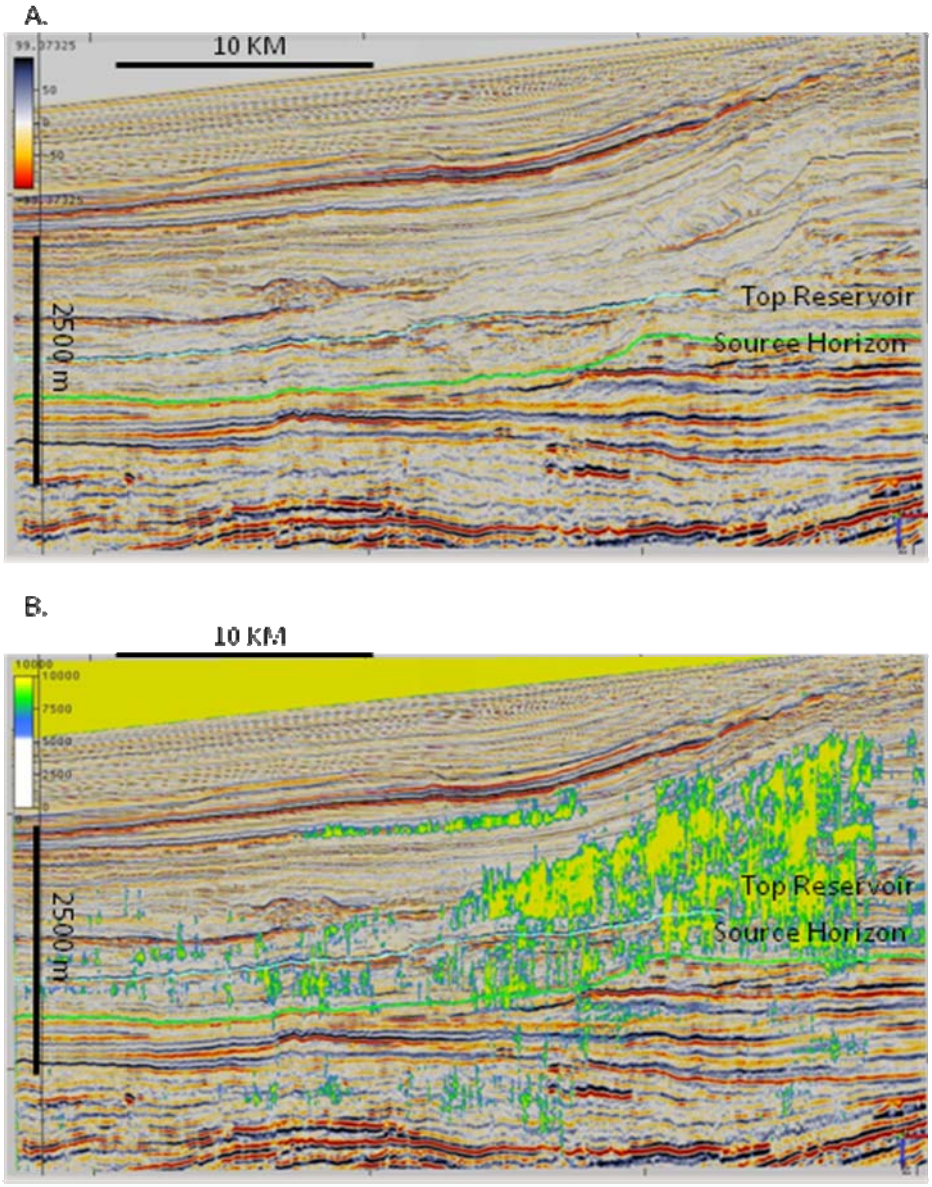

Figure 2 *Seismic dip line through typical Upper Cretaceous canyon.(A). Interpreted horizons are at the top reservoir and the suspected Middle Cretaceous (Cenomanian) source rock interval. Seismic dip line with chimney probability overlain (B) shows chimneys originate from the Cenomanian source rock interval, indicating effective hydrocarbon charge to the suspected reservoir. In the down dip part of the canyon the chimneys terminate at the reservoir, indicating the hydrocarbons are absorbed by the reservoir. Up dip a broad gas cloud overlies the reservoir, indicating the reservoirs are fully saturated with hydrocarbons and the lighter components are leaking.*

Conclusions

In conclusion, the gas chimney processing appears to be an effective tool for assessing hydrocarbon charge risk and top seal effectiveness for this exploration play in the deepwater of offshore, Namibia. The predictions need to be tested by drilling.

Chimney processing results for a typical slope canyon prospect indicate a Middle Cretaceous (Cenomanian) source rock is providing hydrocarbon charge to the prospective Upper Cretaceous reservoir objectives. Chimneys, which originate in the Cenomanian interval, generally terminate in the reservoir interval, indicating the reservoir can effectively absorb the migrating hydrocarbons. Up dip a broad gas cloud overlies the reservoir, indicating the reservoirs are fully saturated with

hydrocarbons and the lighter components are leaking. This implies, that if the migrating hydrocarbons are mixed phase, the objective reservoirs may be oil prone.

Acknowledgments

We would like to thank Chariot Oil & Gas Limited for sponsoring this study and permission to show the seismic data.

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