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Risking Vertical Fault and Top Seal Using Gas Chimneys

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SUMMARY

Gas chimneys and related hydrocarbon migration pathways have been highlighted in seismic data using a supervised neural network, to visualize them in 3D and map their morphology. Using this information on over 125 fields and dry holes (containing effective reservoir)traps were divided into top seal and fault traps. Fault traps have been divided into three classes. Fault Flank Trap where the fault is involved in charging the trap from the flank are low risk high integrity traps. Fault Seal Traps show clear evidence of chimneys related to deep seated faults which terminate at the reservoir interval. They are high integrity traps. Fault Leak Traps have fault related chimneys observed at the crest of the structure. They are moderate to low integrity traps (LIT-MIT), and represent higher risk for vertical seal integrity. Top seal traps have been divided into four classes based on the nomenclature of Cartwright et. al. Gas Cloud Traps are low risk, but moderate integrity traps. Seepage Pipe Traps, Blowout Pipe Traps, and Mud Volcano Traps have increasing risk of seal failure, but can hold economic quantities of hydrocarbons, if buried or being recharged.

Many Tertiary, Mesozoic, and Paleozoic petroleum systems are dominated by vertical hydrocarbon migration from deep thermally mature source rocks. On seismic data the vertical migration paths are generally recognized as vertically aligned zones of chaotic often low amplitude reflectivity described variously as gas chimneys, seepage pipes, blowout pipes, gas clouds, or acoustic turbidity zones. The paths are often associated with other seismic seepage-related features such as mud volcanoes, fault related pock marks, and hydrocarbon related diagenetic zones (HRDZ's).

The diffuse character and weak expression of gas chimneys in seismic data make them difficult to map. Thus a method for detection of gas chimneys in post stack 3D data was developed to improve the identification of gas chimneys in seismic data, to map their distribution, and to allow them to be visualized in three dimensions. This chimney probability volume is produced by a neural network from multiple seismic attributes extracted at examples of gas chimneys picked by a human interpreter (Meldahl et al. 2001). The results of the chimney processing must be validated, since vertically chaotic seismic events can be caused for other reasons.

Gas chimney detection methods were originally used to highlight subtle vertical seepage pipes, mud volcanoes, and gas clouds. However it was soon recognized that the methodology could be used to highlight more subtle hydrocarbon migration related to faulting, and thus be used in assessing vertical fault seal risk (Ligtenberg, 2005). Heggland (2005) has evaluated the character of gas chimneys above structural traps to predict vertical seal integrity. This classification has been expanded to include the character of gas chimneys above and below the field or dry hole. Over 125 case studies have been acquired over oil and gas fields or discoveries and dry holes drilled on valid structures with effective reservoir. Traps with suspected lateral leakage were excluded. Based on these studies, prospects whose reservoirs which have a direct connection to chimneys are divided into Fault and Top Seal Traps.

Fault traps have been divided into three classes. The first class is the **Fault Flank Trap** where the fault is involved in charging the trap from the flank. These traps are high integrity traps (HIT) and are generally filled to spill or to their intersection with the charging fault. The second class is the **Fault Seal Trap**. These structures show clear evidence of chimneys related to deep seated faults which terminate at the reservoir interval or in the sealing interval above the reservoir. These traps are High Integrity Traps (HIT's) and often filled to spill. The third class is the **Fault Leak Trap**. These traps have fault related chimneys observed at the crest of the structure. They are moderate to low integrity traps (LIT-MIT), and represent higher risk for vertical seal integrity. The amount of leakage along the fault and timing of leakage is critical for risking these traps. Chimney data must be integrated with fault stress and pore pressure predictions.

Top seal traps have been divided into four classes based on their morphology using the nomenclature of Cartwright (2007). The first class of top seal traps is the **Gas Cloud Trap**, in which there is a broad diffuse low amplitude zone above the trap. Gas Cloud Traps are generally Moderate Integrity Traps (MIT's), thus having hydrocarbon column heights less than structural closure, but is low risk. The second class of top seal traps is the **Seepage Pipe Trap**. Seepage pipes (Cartwright, 2007) are cylindrical pipes tens of meters to hundreds of meters in width which do not have amplitude anomalies associated with them. They are not a significant seal risk. The third class of top seal traps is the **Blowout Pipe Trap**. Blowout pipes are similar in morphology to seepage pipes, but have amplitude anomalies associated with shallow gas-charged sands or chemosynthetic build-ups. Blowout pipes represent a more significant potential for seal breach. The fourth class of top seal trap is the **Mud Volcano Trap**. Mud volcanoes are cylindrical features with zones of disruption measuring up to a kilometer in width. They are often distinguished by radial fracturing, and are a significant risk for seal breach when they are active, but can seal when inactive and deeply buried.

There is often some ambiguity in classifying a trap, since intermediate cases can often be recognized. The aerial extent of possible overlying waste zones and shallow thief reservoirs also needs to be assessed. However, this classification can be used as a valuable guide for risking prospects and provide input into basin models. We are currently in the process of developing a catalog of examples that can be used as analogs and provide input to database for more quantitative assessment of seal risk and hydrocarbon column assessment.

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Top Seal Traps

Fault Traps

Figure 1. Shows classification of traps with associated gas chimneys with expected seal risk and seal integrity.