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Crestal faulting: Trap integrity loss and gas migration in the Migrant Structure, Sable Subbasin, Offshore Nova Scotia.

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Summary

Globally, shelf margin deltas like the Mississippi, Amazon, Niger and the ancient Sable Delta host some of the world's largest gas accumulations. They prolific hydrocarbon reservoirs often localized due to gravity-driven extension, syntectonic sedimentation and movement of salt in the subsurface (Cummings & Arnott 2005; Adam et al. 2006). Their interaction impacts syn-depositional fault evolution and the formation of structures typically comprised of a reservoir rock with porosity and a seal rock (Vendeville 1991; Adam et al. 2006) with the capacity to store hydrocarbons.

Offshore Nova Scotia, hydrocarbon resources have been explored for since 1959. A report of hydrocarbon well failure analysis by the Canada Nova Scotia Offshore Petroleum Board (CNSOPB) highlights the absence of effective seal against faults to be the chief reason most wells targeting rollover structures offshore Nova Scotia fail to find producible quantities of hydrocarbons. Rollover anticlines are syn-depositional structures that develop on the downthrown side of deltaic growth faults. They are prolific for trapping significant and commercial volumes of hydrocarbon with ~75% of the significant/commercial discoveries offshore Nova Scotia related to this type of structure.

Theory / Method / Workflow

Located in the Sable Sub-basin (Figure 1), the Migrant structure is a fault controlled, four-way dip anticlinal closure, which formed as one of a series of related structures during sediment loading and salt mobilization in the Cretaceous. The Migrant N-20 well was drilled to test for hydrocarbons trapped in Late Jurassic to Early Cretaceous deltaic and fluvial-deltaic reservoirs in the structure.

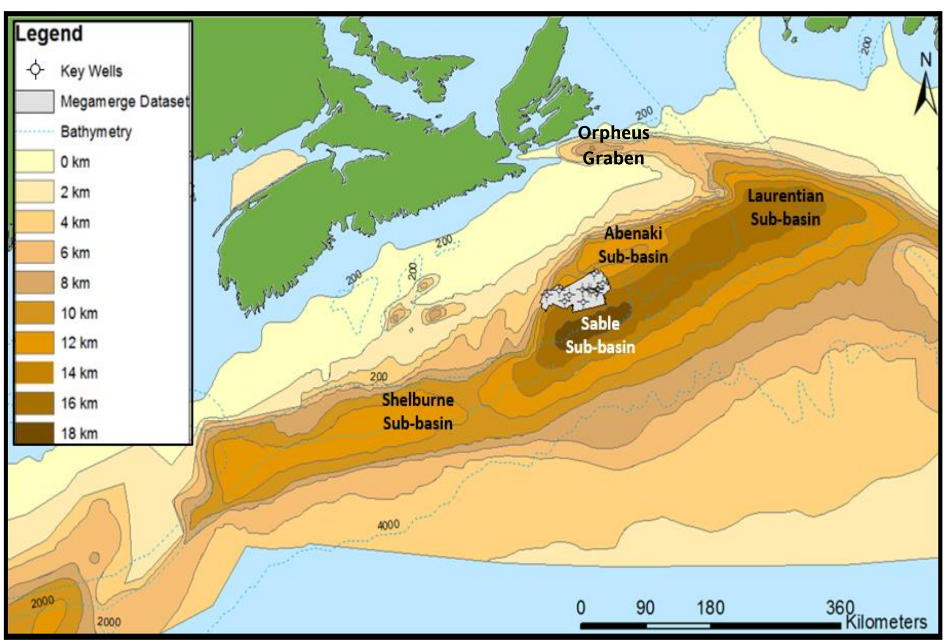

Figure 1: A thickness map of the Scotian Basin (after Wade 2000). The 3D Sable Megamerge seismic volume used for this study is in grey.

Drill stem test (DST) indicates that the well tested gas from a deep sand reservoir (DST 2; Table 1) with a reported flow rate of 10 million standard cubic feet per day to the surface, with associated decline over the duration of the test. The operator considered this declining flow rate non-commercial. Further geologic analysis showed diminishing net porous sand with little evidence of extensional crestal faulting deep in the core of the Migrant Structure.

Table 1: The Migrant N-20 well DST test intervals **(Tetco, 1978).**

Test Type	Top	Bottom	Units	Notes	Formation Tested
DST #1	4333.09	4361.74	M	Misrun	Mic Mac Fm.
DST #2	4333.09	4361.74	M	Flowed gas	Mic Mac Fm.
DST #3	4270.3	4273.35	M	Misrun	Mic Mac Fm.
DST #4	4270.3	4273.35	M	Misrun	Mic Mac Fm.
DST #5	4270.3	4273.35	M	No revovery	Mic Mac Fm.
DST #6	4205.7	4213	M	Misrun	Mic Mac Fm.
DST #7	4205.7	4213	M	Misrun	Mic Mac Fm.
DST #8	4205.7	4213	M	No revovery	Mic Mac Fm.

Integration of 3D seismic with well data (Figure 2), allows us to investigate the characteristics of the Migrant structure as a potential hydrocarbon trap. Through a combination of pressure data at Migrant in relation to similar rollover structures in the area and 3D geocellular model of the Migrant Structure populated with input parameters including shale volume, we examine the inferred mechanism for leakage at Migrant (the crestal fault) through a constructed fault plane profile (Allan, 1989).

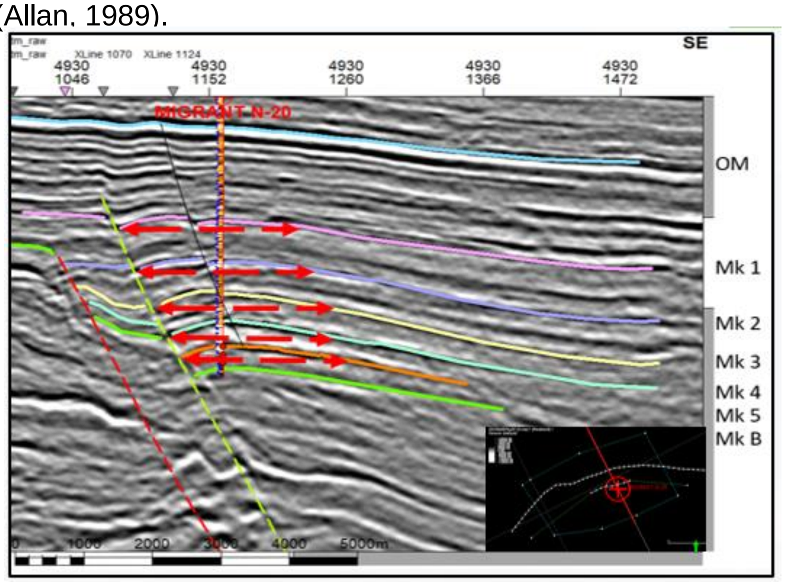

Figure 2: A seismic section of the Migrant area showing the interpreted horizons. The red arrows have been added to show the relationship between the various closure areas under each horizon.

Results, Observations, Conclusions

Results from this study indicates a low sand/shale ratio deep in the Migrant Structure with diminished crestal fault influence (Martyns-Yellowe, 2021; Figure 3). Localized trapping of hydrocarbons supports the corresponding increase in pressure deep in the structure (Figure 4). The shallow and intermediate sections of the structure is characterized by increased crestal fault displacement with increased lithological juxtaposition. In this level, petrophysical analyses results reveal sporadic gas shows suggesting some degree of hydrocarbon migration (Richards et al., 2008).

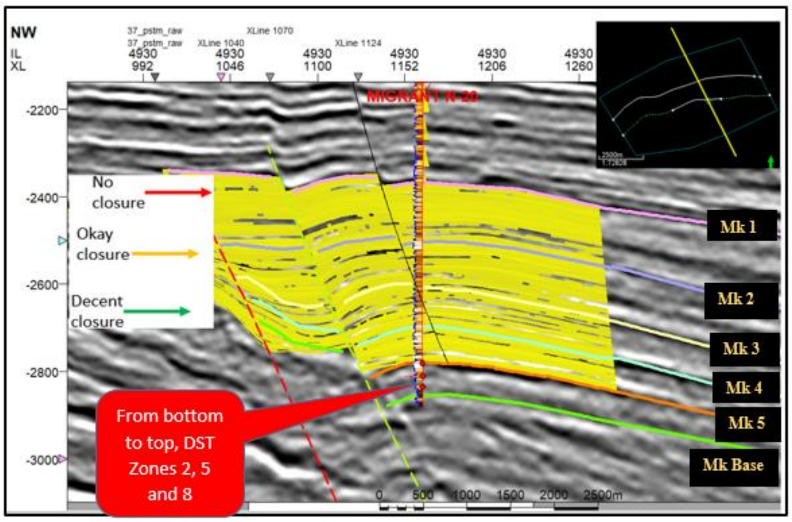

Figure 3: A modelled cross-section of the Migrant Structure populated with sand and shale properties from well log value reveals the magnitude of crestal faulting through the offset of sand-shale pairs.

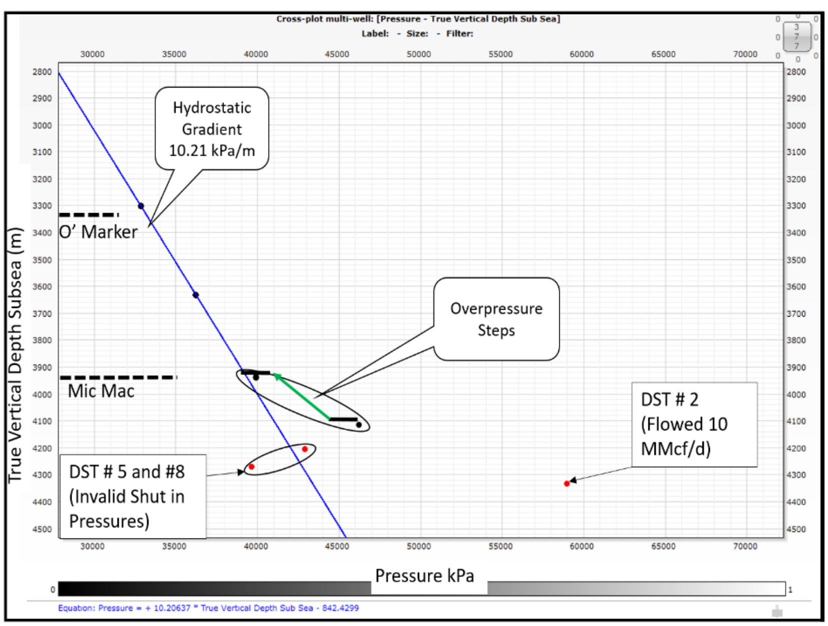

Figure 4: Pressure elevation plot of the Migrant N-20 RFT data points (black) with DST point data in red.

In conclusion, the aerial closure and fault relationship in the deeper sections of the Migrant Structure indicates that most of the zones in the shallow and intermediate intervals at Migrant would likely have been filled to the structural saddle point in the absence of the crestal fault or presence of shales that are thicker than fault displacement. The interpretations and results from this study may be useful for predicting the trapping potential of untested rollover structures in the Sable Subbasin as well as future exploration and development of rollover structures in ancient deltaic systems. These results may be applicable to fluid injection into aquifers for geothermal energy production and emerging carbon storage.

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