The Shelf to Deep-Water Transition – Using Analogues to Understand the Pressure Regime in Undrilled Labrador Basins, Labrador Sea, Canada*

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Abstract

The future of exploration in Labrador is focused on transitioning from the shelf in to the deep-water region following the progress of exploration in other similar settings. Understanding the pressure history in such a frontier area must be built on robust use of analogues, i.e. Mid-Norway or geological modelling (Swarbrick et al, 2002). Mid-Norway has shown that significant discoveries can be made in such deep-water settings as in the deep-sea Nise Formation Fan reservoirs.

Introduction

The Labrador Shelf extends from the Davis Strait in the north through the Saglek Basin and down to the Hopedale Basin in the south, along the NE margin of East Canada. The majority of wells have been drilled in the Hopedale Basin. The water depths of wells drilled to-date are typically 100-200m, with only rare wells such as Hopedale E-33 and South Labrador N-79 drilled in water depths > 500m.

Mud-weights in many of the Labrador Shelf wells are low; however, there are occurrences in wells such as Pothurst P-19 of very high kicks taken, implying under-balanced drilling and misunderstanding of the pore pressure regime in these Basins. This is a common feature of many Basins in East Canada e.g. Orphan, Flemish Pass and Jeanne d'Arc where many wells are similarly associated with kicks. A better understanding of the prevalent pore pressure regime is clearly required across the region.

Moreover, as identified above, in areas such as Saglek and Hopedale Basins, the wells are shelfal to upper slope in terms of structural position and with the focus to move in to deeper water targets in the future. Following the announcement on September 13, 2011 to shoot large-scale multi-client 2D seismic survey of offshore Newfoundland and Labrador into the deep water, understanding the shelf-to-deep water transition becomes even more crucial (Figure 1).

Discussion

As an example, recent purchases of deep-water acreage in the Scotian Shelf area highlight the need for accurate understanding of pore pressure. Between 2002 and 2004 industry drilled seven deep-water wells on the Scotian Slope with one gas discovery (Annapolis), one gas show (Newburn) and four dry wells (Balvenie, Crimson, Weymouth and Torbrook). The seventh well, Annapolis B-24, was a precursor to the discovery well that was abandoned due to a shallow gas kick. Four previous wells were drilled between 1982-1986 that were dry and abandoned e.g. Shubenacadie, Shelburne, Evangeline and Tantallon. Clearly, the geopressure regime has affected of the safe drilling of wells but also may play a significant role in explaining the number of dry holes in the deeper water by influencing migration and fluid flow via vertical and lateral seals.

Therefore, as there is no well calibration in the Saglek and Hopedale Basins in the deep water, this paper presents results from the drilling of other worldwide deep-water areas that form useful analogues. One of these analogue areas is Mid-Norway. This area consists of the Halten Terrace shelf area, where over 150 wells have been drilled approximately. The targets here are predominantly the Jurassic reservoirs that form the Kristin and Smorbukk accumulations for instance. These reservoirs are often heavily fault compartmentalized and as such, although stratigraphy older, are similar to the Lower to Mid-Cretaceous faulted syn-rift sediments of the Bjarni Formation in Labrador. In Mid-Norway, these faults define a series of structurally bound pressure cells. These reservoirs are overlain in Mid-Norway by the argillaceous Lange Formation, an equivalent of the Markland formation. These shales are typically > 100oC in Mid-Norway and as such have been affected by chemical compaction, influencing the pressure regime.

More recently, the deep-water Mid-Norway Voring Basin has seen exploration focus, with water depths of up to 1.5km (Figure 2). Here, the sediments are typically Cretaceous and Tertiary in age and include formations such as the Nise and Egga Sandstone Formation sands and the Brygge and Kai shales. Although some rifting is present in the Upper Cretaceous, these sediments are largely un-faulted and correspond to the post-rift Mokami Formation shales and Cartwright sands of the Labrador region. The Nise Formation consists of deep-sea fan deposits; these fans are locally amalgamated such that the overpressures in the aquifer are the same or similar, and are considered to form part of a hydrodynamic system, where pressures are escaping laterally, despite the deep burial depth. In more stratigraphically isolated parts of the fans, overpressures can be similar to the encasing shale pressures. These differential pressures enhanced seal capacity and establish the opportunity for hydrodynamic trapping; similar deep-water fan complexes are observed in the recently shot seismic in the Labrador area. The Base Tertiary Ormen Lange Field reservoir is hydrodynamic, with a tilted contact, affecting estimates of reserves and field development.

Also recognized from the recent seismic is a variation in the depth of Base Tertiary; this will affect the degree of loading produced by the recent burial and influence pressures at depth. Simple relationships based on rates of sedimentation (Swarbrick et al., 2002) have been used successfully in Basins in the Tertiary North Sea and Jeanne d'Arc to predict theoretical shale pressures that match kicks taken in wells. This approach can be potentially used in the Labrador Basins to similar give an indication of shale pressures, based on picking the seismic Base Tertiary reflector.

Conclusions

In areas where well calibration is not possible, an approach based on theoretical shale models coupled to analogues can provide a basis for understand the pressure regime in undrilled environments such as the Labrador Shelf. This paper will demonstrate that using analogues such as the Mid-Norway shelf to deep-water transition can aid safe drilling in Labrador. An example of applying analogue studies is the kick taken in the Pothurst P-19 well. By calculating the rate of sedimentation for the overburden above the Palaeocene Cartwright Formation in which the kick was taken and utilising the relationship in Swarbrick et al (2002) linking pore pressure profiles and to the sedimentation rate provides a first order approximation of the kick pressure. Analogues can also be used to provide insight into the petroleum system, in terms of seals, migration and fluid flow. For instance, observable deep-sea fan complexes can act as migration conduits.

Acknowledgements

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Reference Cited

Swarbrick, R.E., M.J. Osborne, and G.S. Yardley, 2002, Comparison of overpressure magnitude resulting from the main generating mechanisms: AAPG Memoir 76, p. 1-12.

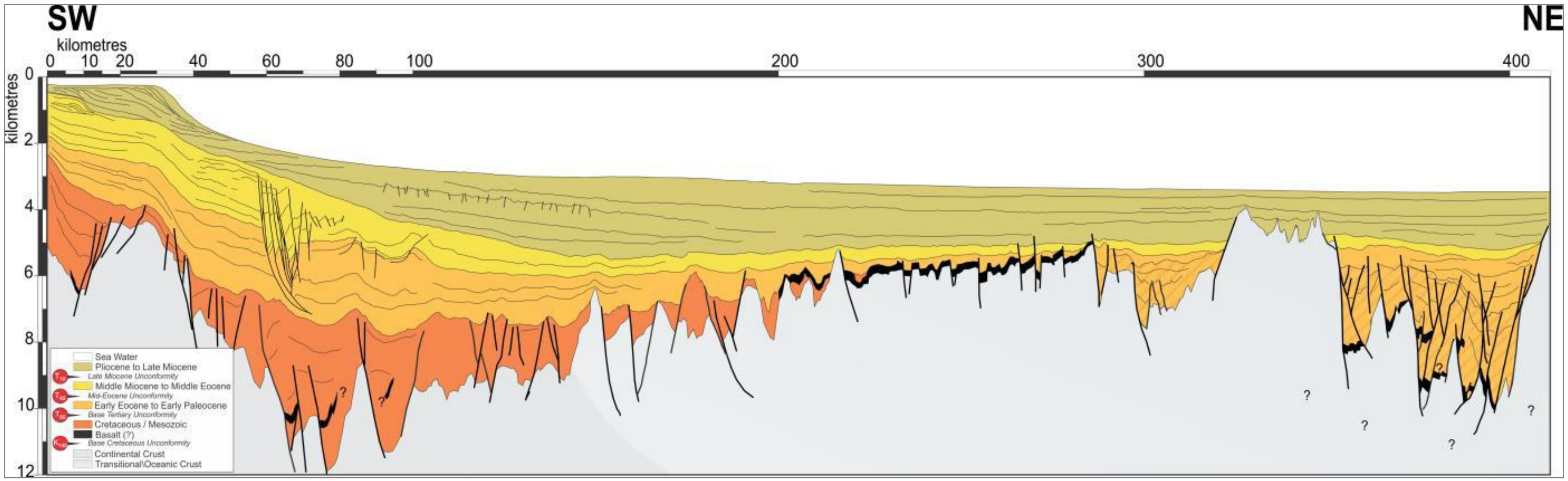

Figure 1. Schematic based on a 2D seismic line showing main stratigraphic and structural relationships from shelf to deep water. Internal framework based on well ties from the shelf.

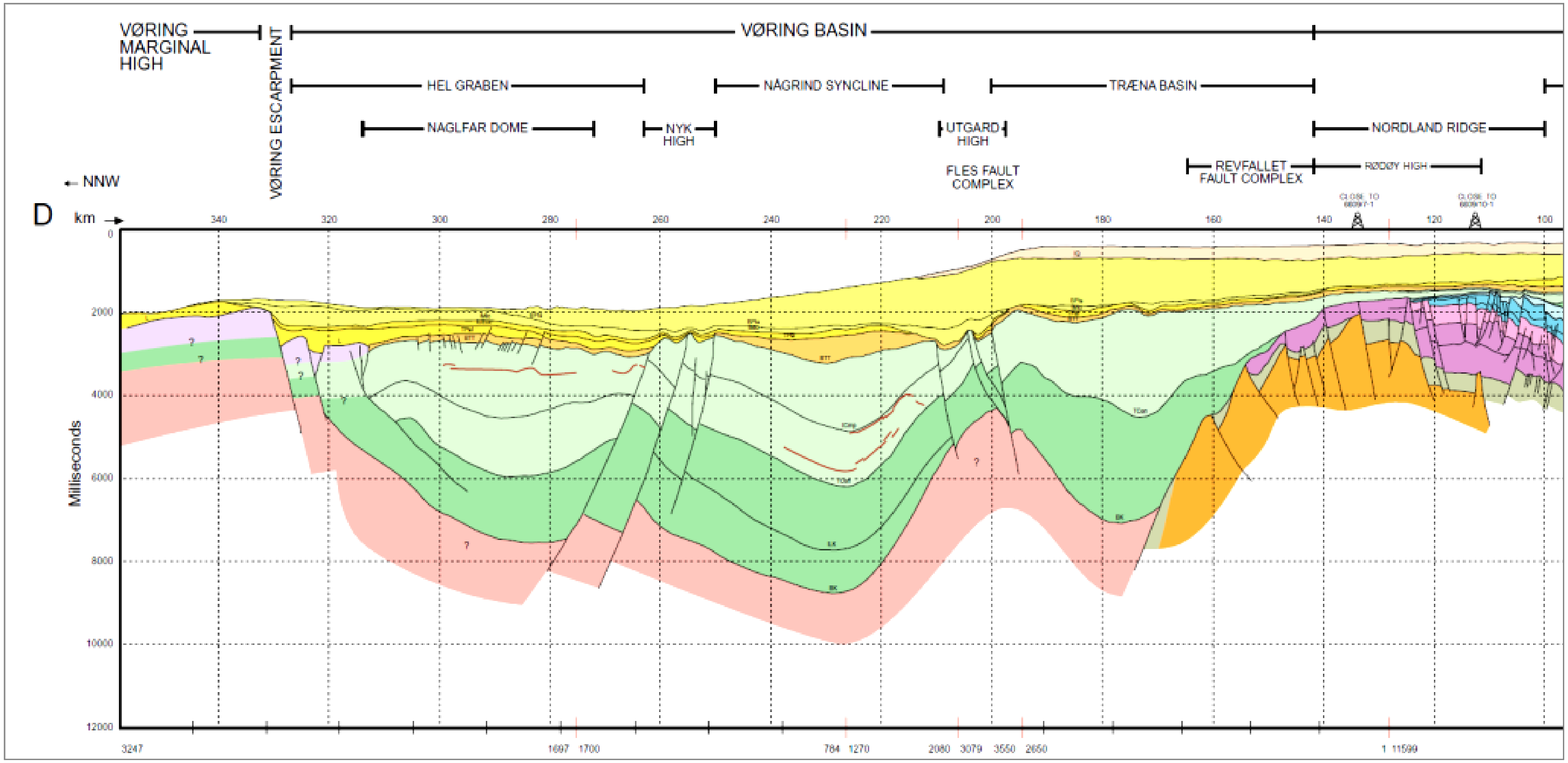

Figure 2. Schematic based on a 2D seismic line showing main stratigraphic and structural relationships west/east from Voring Basin (deep-water) to Nordland Ridge, Halten Terrace, Shelf.