Correlation of the Pore Pressure Gradient and Maturity of the Niobrara Formation Across the Powder River Basin, Wyoming* 

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Abstract

This study presents the results obtained from the Petroleum System Modelling (1D) performed at different well locations across the Powder River Basin (PRB), Wyoming. The forward simulation technique was applied to correlate the variability of the pore pressure gradient in relation to thermal maturity and hydrocarbon generation in the Niobrara Formation. Calibration and generation of the petroleum systems models involved consideration of the following: 1) Thermal aspect, 2) Lithologic composition 3) Porosity and Permeability, 4) Pore pressure gradient (this calibration was carried out by using the pore pressure gradient obtained from pore pressure prediction (Yale et al., 2018)); and 5) Source rock properties.

The results showed that the variations in the thermal evolution of the organic matter within the Niobrara Formation across the PRB have important implications for pore pressure variability, being suggested as one of the main mechanisms of pore pressure generation. In areas where the organic matter was affected by high thermal stress (such as northeastern part of PRB), increased pore pressure, hydrocarbon generation pressure, and overpressure are observed. Inversely, areas where the organic matter was subjected to low thermal stress, the pore pressure, hydrocarbon generation pressure, and overpressure are lower. The driving mechanism is likely the generation of liquid and gaseous hydrocarbons from primary and possibly secondary cracking of organic matter. In areas where the Niobrara Formation has a high level of maturity, secondary cracking would have been contributing to hydrocarbon generation post Late Paleocene. The evolution of the fluid-flow system is caused by the addition of hydrocarbons to the fluid phase as part of the catagenetic process due to continuous burial and increasing thermal exposure converting the fluid-flow system to a multiphase regime. Based on the 1D petroleum systems modeling results, it is suggested that, in more mature areas, high levels of overpressure was developed after 62 Ma, coinciding with the onset of hydrocarbon generation, corresponding to a vitrinite reflectance of ~0.55%Ro.

A change in the lithostatic pressure caused by uplifting is also affecting pore pressure. In general, a decrease in the pore pressure is observed with uplift. However, depending on the magnitude of the uplift and sealing capacity of the facies above, below, and within the Niobrara
Formation, the overpressure can be preserved or increased. In this particular case, it is important to consider that the sealing capacity (which is a function of the permeability and pore throat size) of intervals within and above and below the Niobrara Formation plays a significant role in overpressure preservation. A high sealing capacity reduces the ability of fluids to be expelled from the rock, and sealing capacity is mainly controlled by permeability changes in the Niobrara Formation (and in the formations above and below) from one location to another. The permeability derived from 1D petroleum systems modeling (required for pore pressure gradient calibration) suggests that there is a reduction in permeability of approximately 30% from the wells in the central and deeper part compared to the wells in the south and east areas of the PRB. Furthermore, permeability variations were observed within the formations above and below of the Niobrara Formation from one location to another. These variations can cause significant changes in pore pressure.

**Selected References**


This study presents the results obtained from the Petroleum System Modelling (1D) performed at different well locations across the Powder River Basin (PRB), Wyoming. The forward simulation technique was applied to correlate the variability of the pore pressure gradient in relation to thermal maturity and hydrocarbon generation in the Niobrara Formation. 

The driving mechanism is likely the generation of liquid and gaseous hydrocarbons from primary and possibly secondary cracking of organic matter. In areas where the Niobrara Formation has a high level of organic matter within the Niobrara Formation is dominated by Amorphous Organic Matter (AOM) with a kerogen classified as Organofacies Class B, which has been analyzed by other labs.

Analyzed by other labs, the Niobrara Formation shows a positive correlation between increasing maturity and increasing depth. When the pore pressure gradient (psi/ft) data are incorporated, a good correlation is generally observed with some variation.

Conclusions
- In areas where the organic matter is altered by high thermal stress, increased pore pressure, hydrocarbon generation, and overpressure are observed. Some of the wells in these areas contain significant amounts of hydrocarbons within the Niobrara Formation.
- Taking into consideration the effects of high thermal stress on the composition of organic matter, the pore pressure gradient in the Niobrara Formation is significantly affected.
- The pore pressure gradient varies significantly from one location to another. These variations can cause significant changes in pore pressure.

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