Heat flow calibration and hydrocarbon prospects as defined by petroleum system modelling within the western Sable Subbasin, Scotian Basin

Keith Louden[1], Prasanta Mukhopadhyay[2], Eric Negulic[3] and Mladen Nedimovic[3]
1) Department of Oceanography, Dalhousie University, Halifax, Nova Scotia B3H 4J1
2) Global Geoenergy Research Ltd., Halifax, Nova Scotia B3J 2A1
3) Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4J1

A number of 2D thermal and petroleum systems models have been determined across the central Scotian Slope Basin, in deep to ultra deep water. Models are calculated along three 2D MCS profiles (Lithoprobe line 88-1A and NovaSPAN lines 1400 and 1600) between the Torbrook C-15 and the Balvenie B-79 wells, for various potential source rocks and reservoirs. Sediment, salt, and basement structure in the models are constrained by picks of seismic horizons along the profiles. Imaging of deeper structures in depth sections is improved from previous studies, using pre-stack depth migration (NovaSpan 1400 and 1600) or pre-stack time migration and wide-angle velocity models (Lithoprobe 88-1A). Stratigraphic and lithologic interpretations of the profiles are based on neighboring wells and previous interpretations. Along all profiles, assumed salt flank and salt crest Late Jurassic and Early Cretaceous reservoirs form the primary exploration targets.

The first phase of modelling was done prior to acquisition of sea floor heat flow data and thermal constraints were based on limited vitrinite reflectance data from the Scotian Shelf. Models were built along 2D seismic profiles NovaSPAN line 1400 and Lithoprobe line 88-1A. For line 1400, assuming a medium basement heat flow, the Early Jurassic source rocks occur within the dry gas zone while both the Jurassic and Cretaceous Verrill Canyon source rocks remain within the oil window (0.5% to 1.35% Ro) and will have contributed major volumes of liquid hydrocarbons within various reservoirs. The Early Cretaceous reservoirs lie within a moderate pore pressure regime with a temperature <100 ^{o}C, while the Late Jurassic reservoirs would remain within the overpressure regime with a temperature >100 ^{o}C.

To help constrain the model predictions, shallow marine heat flow measurements were acquired in July 2008 using the Dalhousie seafloor heat flow probe with 32 sensors over a 6-m length. In total 47 successful measurements of both temperature gradient and thermal conductivity were taken including 40 stations along the three seismic profiles and 7 stations near the Torbrook C-15 well. Heat flow measurements along lines 1400, 1600, and 88-1A indicate a lower than expected regional basement heat flow. This suggests that previous models might have over-predicted temperatures and hydrocarbon maturation adjacent to salt structures. In contrast, measurements of elevated heat flow above salt structures compared with model predictions indicate that the models may have under-predicted maturation above shallow salt diapirs.

Thermal parameters in the second phase of modelling are constrained by the seafloor heat flow data. In addition to lines 1400 and 88-1A an additional model was built along NovaSPAN line 1600. These models show that lower temperatures associated with a lower basement heat flux has resulted in a downward shift in the maturation window from previous models. The Early Jurassic source rocks now are primarily located within the wet gas zone and the oil window is located throughout the upper Early Jurassic to the top Mid Cretaceous sediments. This deeper oil window suggests that the region may be more oil prone with less gas generation than suggested by previous models. More hydrocarbons may be present in deeper reservoirs as the lower temperatures will no longer result in the over-maturation of hydrocarbons from deeper sources. Significant local variations between measured and modelled heat flow still exist above salt bodies while background values in regions unaffected by salt are in good agreement. This suggests that potential 3D effects such as out of plane variations in salt geometry or convective processes may be affecting the measured heat flow values.