Petroleum system analysis of western Newfoundland

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Petroleum systems analysis:

A functioning petroleum system contains six elements: source rock, trap, seal, reservoir, a thermal history that allows for generation from source rocks, and migration pathways that connect the generating source rock to the trap. The starting point in many analyses is the source rock: is a source rock present with sufficient oil- or gas-prone organic matter to generate significant amounts of hydrocarbons, and is it sufficiently thermal mature to generate these hydrocarbons? If so, where and when did generation take place? How might those carbons have migrated to traps? This conceptual framework guides exploration to the areas, types of traps and stratigraphic intervals that are most likely to host economic quantities of hydrocarbons.

Since 1990 some of these elements have been identified in the western Newfoundland Appalachians, but an overall framework has not yet been developed. It is clear – based on an oil discovery in the Garden Hill well and numerous oil seeps – that at least one viable source rock exists. But a number of elements have not been established: what formation has generated? Where and when did the mature source rock generate? How did oil migrate to its present location, and when did this occur relative to the major deformation events (Taconian, Salinian, Acadian, Carboniferous) that have affected the west Newfoundland Appalachians?

Proposed work program:

This proposal advocates a four-stage program to build a database and models for source rocks and hydrocarbon generation in western Newfoundland.

1) Systematic sampling of potential source rocks: It is important to sample sections where the stratigraphy is well established. The following fine-grained sedimentary units will be targeted, focusing on sections with established biostratigraphic control.

- Humber Arm Allochthon
    - Cow Head Group: Green Point Formation and Shallow Bay Formation in their type areas on the Northern Peninsula (Measured sections in reports of James & Stevens).

    - Northern Head and Curling Groups: shales of the Irishtown, Cooks Brook and Middle Arm Point Formations in their type areas in the Bay of Islands (Measured sections in thesis work of J. Botsford)
    - Undivided Humber Arm Allochthon: units from measured sections on the Port au Port Peninsula (thesis work of Ryan Lacombe)

- Shelf succession
    - Labrador Group: Forteau Formation (inner Parsons Pond area; thesis work of Shawna White)
    - Port au Port Group: Petit Jardin Formation, Big Cove Member (coastal outcrop on Port au Port Peninsula)
- Foreland basins successions
    - Table Head Group (M. Ordovician), Table Cove Formation (Coastal and quarry outcrop on Port au Port Peninsula)
    - Goose Tickle Group (M. Ordovician), Black Cove Formation (Coastal and quarry outcrop, Stevenville area)
    - Long Point Group (Late Ordovician), Winterhouse Formation. Although not in a favourable structural location to source the Garden Hill oil, a small number of samples from this unit will be included in case it has source potential.

2) Source rock and oil analyses: Source rock samples from well cuttings and outcrops will be analyzed. Two levels of analysis will be undertaken: a) total organic carbon (TOC), Rockeval and vitrinite reflectance analysis will be carried to establish the quality and thermal maturity of potential source rocks (250 samples); and b) biomarker and isotope analysis will be carried out to identify specific characteristics of the source rock that can be used in oil-to-source correlation (40 samples).

Biomarker and isotope analysis will be carried out on live oil and oil seep samples for oil-to-source correlation.

3) Identification of oil families and oil-to-source correlation: This analysis will use the detailed geochemical composition of oils to develop associations between individual samples, in other words to identify oil families. Families will then be correlated to specific source rocks.

Identification of oil families and correlations will be based on similarities in certain biomarkers that are not sensitive to thermal maturity and on the carbon isotopic composition of thermally stable organic compounds.

Common outcomes of such an analysis are to (1) associate oils with particular source rocks, which can provide important constraints on hydrocarbon migration routes, or (2) identify an oil family with no clear source rock, which would suggest that a hitherto unknown source rock exists in the basin. An additional outcome can be to characterize the thermal maturity at which the oil was generated, which further constrains the timing of oil generation and migration routes.

4) Basin modeling: Hydrocarbon generation and migration models will be developed to estimate the timing, volumes and migration vectors for hydrocarbons. Input to the models will be (a) source rock data derived from the data base developed in this project, (b) data on stratigraphy derived from coastal exposures and wells, and (c) timing of structural events, based on structural data and models developed by John Waldron (University of Alberta) and students.