PETROLEUM GEOSCIENCE FIELD METHODS: TRINIDAD
SUMMARY REPORT

Submitted to:

Offshore Energy Research Association of Nova Scotia (OERA)

to fulfill the requirements of the Graduate Student Research Travel Program

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March 2014

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INTRODUCTION

The Petroleum Geoscience Field Methods course at Dalhousie University focuses on petroleum systems of onshore and offshore geology by integrating field work, laboratory outcrop, core, and log analyses. The course is a collaboration between Atlantic Canadian Universities (Dalhousie and Acadia), the University of the West Indies (UWI), and professionals from Petrotrin and the Geological Society and Trinidad and Tobago (GSTT). The students and professionals are encouraged to work together, providing new learning opportunities for all participants. The course is divided into three phases: (1) pre-travel reports and presentations reviewing Caribbean geology, tectonics, and petroleum systems; (2) in-Trinidad field work, laboratory sessions, and exercises; (3) post-travel summary presentation.

Figure 1: (left) Students, GSTT and Petrotrin professionals at Mayaro examining on deltaic depositional environments. (right) Mayaro where students described sediments, structure, and recorded scintillometer measurements (pseudo gamma ray).

Figure 2: (left) La Fillette Bay provides students an example of a failed petroleum system with overmature source rock visible in outcrop. (right) Review of the Morne L'Enfer Formation with Dr. Hasley Vincent (University of West Indies) at the Caroni Delta, a modern analog.

The outcrops, depositional environments, and active petroleum systems of Trinidad are excellent analogues for the offshore geology and petroleum systems of the Scotian Basin, offshore Nova Scotia. The major basins for both regions include linked fluvial-estuarine, shelf-margin delta, and deepwater depositional systems, leading to a wide variety of petroleum plays. Trinidad and Nova Scotia have experienced compressional and extensional tectonic regimes during their formation, which affected the development of their respective petroleum systems significantly. Abnormal pressures occur in potential and producing reservoirs of Trinidad and offshore Nova Scotia.

Topics covered in both the classroom and field include:

- tectonics and structural basin formation
    - Caribbean tectonics and seismicity
    - El Pilar fault system
    - tectonic and geological setting of Trinidad
    - Caribbean volcanoes
- overpressure, source rock, and hydrocarbon maturation
    - overpressure, mud volcanoes, and shale tectonics
    - Cretaceous source rocks: Trinidad & Venezuela
    - oil and gas generation in the Southern Basin, Trinidad
    - petroleum biodegradation: Pitch Lake, Trinidad
- depositional systems
    - modern fluvial and deltaic settings
    - mangrove ecosystems
    - fluvial-estuarine and deltaic reservoirs
    - shelf-margin delta and slope reservoir characterization
    - sequence stratigraphy: accommodation space
    - micropaleontology and paleobiology
- health and safety

TRIP ITINERARY

DAY 1 Saturday February 15

Travel from Halifax – Toronto – Trinidad

DAY 2 Sunday February 16

Arrive in Port of Spain (Piarco) at 5:54am
STOP 1: (8:30 - 11:00am): Asa Wright – Rain Forest Ecosystem & Overview of Caribbean And Trinidad Tectonics
STOP 2: (1:30 - 2:30pm): La Fillette Bay – Petroleum Systems
Field Exercise: Structural and Metamorphic Interpretation, Failed Petroleum System, Passive Margin
STOP 3: (3:00 - 5:00pm): Maracas Bay – Swim and Late (2nd) Lunch
STOP 4: (5:30pm): Port of Spain Lookout – Overview of Trinidad Geology & Gulf of Paria
Arrive at Pax Guesthouse, check in (6:30pm), and dinner (7:30pm)

DAY 3 Monday February 17

Depart Pax Guesthouse (7:00am)
STOP 1: (8:30am - 12:00pm): Vessigny, Guapo Bay – Sequence Stratigraphy
Field Exercise: Log and Measure Section (Scintillometer)
STOP 2: (1:00 - 3:00pm): Stollmeyer's Quarry – Fluvial Estuarine Channel Complexes & Compartmentalization
Field Exercise: Reservoir Characteristics
STOP 3: (4:00 - 5:00pm): Pitch Lake, LaBrea – Biodegredation & Migration
Return to Pax Guesthouse (7:00pm) and dinner (7:30pm)
Evening Exercise: Reserve Estimates of Stollmeyer's Quarry

DAY 4 Tuesday February 18

Depart Pax Guesthouse (7:00am)
STOP 1: (10:30am – 3:30pm): Cedros Bay – Deltaic Systems, Sequence Stratigraphy & Trace Fossils
Field Exercise: Log and Measure Sections (Permeameter and Scintillometer)
STOP 2: Los Bajos Fault (if time permits)
Return to Pax Guesthouse (7:00pm) and dinner (7:30pm)
Evening Exercise: Bonasse Log and East Field Correlation

DAY 5 Wednesday February 19

Depart Pax Guesthouse (9:00am)

STOP 1: (10:00 - 12:00pm): Naparima Hill, San Fernando – Central Range, Source Rock, and Migration, Trap & Seal

STOP 2: (2:00 - 3:00PM): Piparo, Digity, or Devil's Woodyard – Mud Volcanoes, Migration and Overpressure

STOP 3: (5:30-7:30PM): Technical Session & Dinner (Valpark Chinese Restaurant)

Return to Pax Guesthouse (7:00pm) and dinner (7:30pm)

Evening Exercise: Well Log and Seismic Correlation, and update/review field notes

DAY 6 Thursday February 20

Depart Pax Guesthouse (7:00am)

STOP 1: (9:00 - 3:30pm): Mayaro – Shelf Margin Deltas, Active and Abandonment Phases

Field Exercise: Log and Measure Sections (Permeameter and Scintillometer)

Return to Pax Guesthouse (7:00pm) and dinner (7:30pm)

Evening Exercise: Mayaro Log Correlation and complete any outstanding assignments and field notes

DAY 7 Friday February 21

Depart Pax Guesthouse (8:15am)

STOP 1: (8:45 - 3:00pm): Petrotrin, Point-a-Pierre – Geological Lab & Biostratigraphy

Field Exercise: Core Logging Exercise

STOP 2: (3:30 - 6:30pm): Caroni Swamp – Mangrove Ecosystems, Shelf Margin Deltas & Accommodation Space, Caroni Basin

Field Exercise: Distributary Channel Morphology

Return to Pax Guesthouse (7:00pm) and dinner (7:30pm)

DAY 8 Saturday February 22

Travel from Trinidad – Toronto – Halifax

BENEFITS OF TRAVEL

Trinidad is an exceptional research area and a natural laboratory for the study of petroleum geoscience with excellent outcrop including exposed reservoirs, oil seeps, mud volcanoes, and Pitch Lake. Trinidad is 4700 km^2, which is similar in size to Halifax Regional Municipality (5400 km^2), and all outcrops of interest are easily accessed with daily trips. The country is an active petroleum producer and exporter with offshore platforms visible from several field locations, and data from onshore and offshore is available for study. The petroleum industry of Trinidad is well informed about their complex onshore and offshore geology. There is a long history of academic, governmental, and industrial collaboration between Dalhousie University, Nova Scotia, and Trinidad. These connections provide valuable opportunities for students and young professionals from both countries to learn from each other.

The outcrop visited demonstrated many petroleum system elements including source rock, reservoir, seal, migration pathways, and traps (Figure 3). The basins of Trinidad predominantly comprise deltaic, pro-deltaic, and deepwater sediments, which are the same sediment types observed in the Scotian Basin. Structural complexities affecting reservoir connectivity, such as faults, are present throughout the Scotian Basin however it is difficult to establish fault behaviour because they are inaccessible. Faults present in deltaic deposit outcrops of Trinidad provide an opportunity to examine similar fault structures, and better predict the Scotian Basin faults as a result of this comparison (Figure 4).

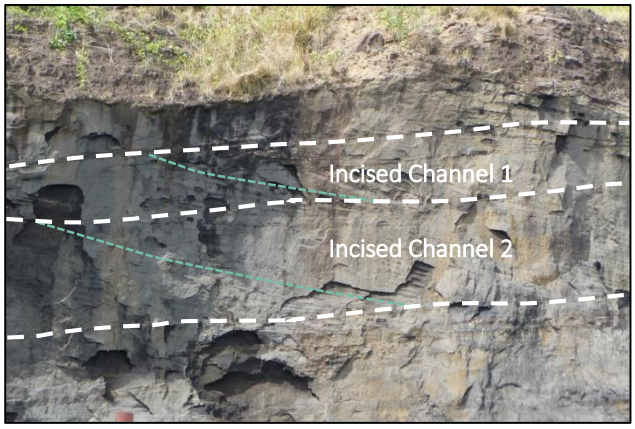

Figure 3: Stollmeyer's Quarry with heavy oil sands deposited in incised channels of the Morne L'Enfer Formation. Multiple channels form reservoirs, and are separated by thin clay layers at the channel base (<10cm) that act as barriers to flow – oil can be scene seeping from the base of each channel. Faults through some channels serve as migration pathways for the oil. The channels are topped with a "mud-plug", deposited during a transgressive systems tract, which provides an overall top seal.

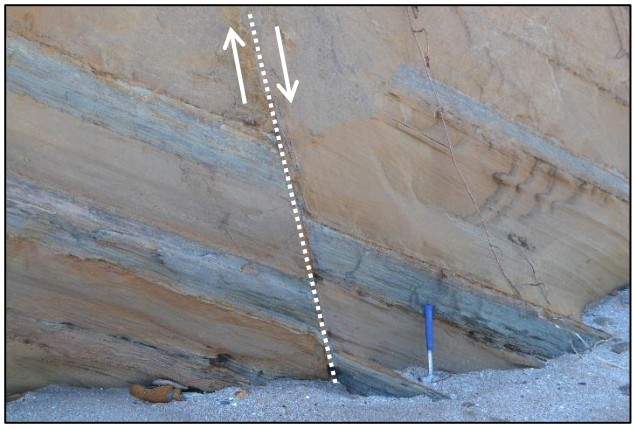

Figure 4: Mayaro coast outcrop fault demonstrating fault displacement as a result of tectonic influence. Sandstone (beige/tan) is upper-very fine to lower-fine grained, and offshore are producing hydrocarbon reservoirs. Siltstone (grey) contains minor upper-very fine grained sands, and are seals for the sandstones.

OUTCOMES OF TRAVEL

Studying analogous outcrops are a vital tool for characterizing offshore geology, where data limits our ability to understand geological complexities. Offshore Nova Scotia has 231 wells dispersed over the nearly 300,000 km^2 of the Scotian Basin, making the region essentially unexplored. Nova Scotia does not have outcrop representative of the deltaic deposits in the offshore, therefore a reservoir model explaining the reservoir connectivity is difficult to construct with confidence.

Applying knowledge gained from the Pliocene Gros Morne and Mayaro formations of Trinidad to the Scotian Basin can increase confidence in modelling reservoir compartments and the role of fault behaviour. The Pliocene Gros Morne and Mayaro formations are separated on the basis of sediment consolidation, which can be difficult to distinguish in the field. Both formations were deposited in a shelf-margin depositional system, with two phases of deltaic deposition represented: active phase and inactive phase. The active phase is characterized by slumping and deformation of bedding; few trace fossils are present due to stress. The inactive phase, abandonment phase, is characterized by bioturbation and well-developed ophiomorpha, and hummocky stratification indicating the delta front was reworked.

Evidence of overpressure is observed throughout Trinidad, but in particular the Southern Basin, where it was initially observed near oil/gas seeps related to mud volcanoes and shale diapirs. Onshore outcrops of the Mayaro Formation shows evidence of overpressure with soft-sediment deformation structures. Flame structures were observed, and are a result of rapid sedimentation of sand being deposited onto silt, which is fluid-rich and less dense (Figure 5). Several of the flame structures observed were truncated.

Figure 5: (left) Flame structure in siltstone formed as overlying sand was rapidly deposited. Note chaotic bedding within sandstone on either side of the structure, and the top of the structure has been truncated off by another sandstone unit; scale in photo is 10cm. (right) Asymmetrical flame structure in siltstone (grey) within sandstone (tan); hammer for scale - 30cm.

SIGNIFICANCE TO NOVA SCOTIA

Research currently being completed at Dalhousie University by Carla Dickson (M.Sc. Candidate) focuses on reservoir connectivity and overpressure in the Sable Subbasin of the Scotian Basin, integrating pressure information, wireline log, and seismic data (Figure 6). This work focuses on describing the reservoir architecture and the effect of faults on the formation of reservoir compartments using a variety of techniques. The role of faults is not well understood, and previous work has assumed all faults in the Subbasin are either (a) sealing, or (b) transmissive. The highly variable and unpredictable nature of overpressure in the basin suggests that faults have led to the formation of reservoir compartments, suggesting the faults are to some extent or entirely sealing while other are transmissive. By understanding the role of faults in the Mayaro Formation, Trinidad, which is an analogue for the deltaic formations of offshore Nova Scotia, the role of faults in the Mic Mac, Missisauga, and Logan Canyon formations can be better resolved. This will lead to

the development of a three-dimensional geometric model for the reservoir compartments and overpressure in the Sable Subbasin.

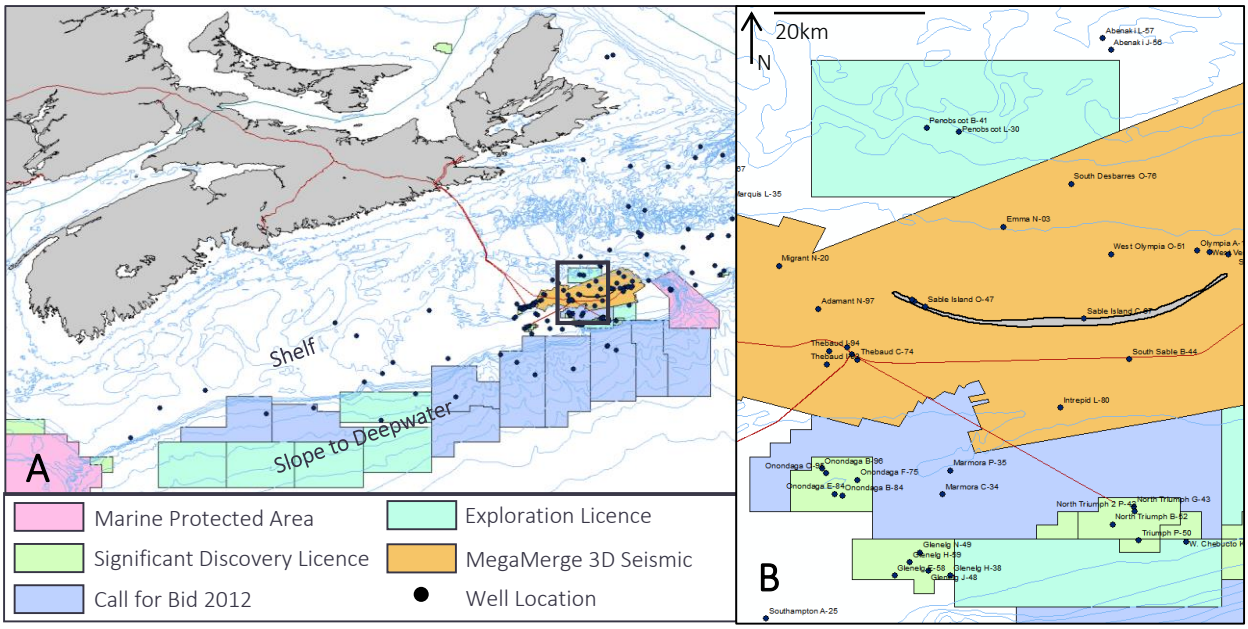

Figure 6: (left) Location of all wells and study area on Scotian Margin, black box, relative to Nova Scotia. Note location of MegaMerge 3D Seismic Dataset. (right) Study area including (north to south) Penobscot, West Sable, Thebaud, and Onondaga fields, with associated seismic, wireline, and pressure-related data.

ACKNOWLEDGEMENTS

I would like to thank the OERA for their generous support, allowing me the opportunity to complete field work in Trinidad, which will strengthen my thesis work on reservoir connectivity and overpressure in the Sable Subbasin, offshore Nova Scotia. There has been significant increase in exploration in the deepwater Scotian Basin, which is uncalibrated with very limited data available for analysis and interpretation. Information gathered from more developed areas, such as the Sable Subbasin, will be important as exploration continues in the Scotian Basin.