# Dalhousie University- Petroleum Geoscience Field Methods- Trinidad Summary Report

Submitted to:

Offshore Energy Research Association of Nova Scotia (OERA)

To fulfill requirements of the Undergraduate Student Research Travel Program

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April 2014

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**Introduction:**

The Petroleum Geoscience Field Methods course offered at Dalhousie University, in Halifax, Nova Scotia allows for petroleum systems of onshore and offshore geology to be understood through the integration of literature review, field outcrops, core and log analyses (Figure 1) The collaboration between Atlantic Canadian Universities (Dalhousie and Acadia), the University of West Indies (UWI), as well as professionals from the Geological Society of Trinidad and Tobago and Petrotrin allows for valuable learning opportunities for all parties and for knowledge to be shared amongst participants. The course is broken up into three specific components: before heading to Trinidad, pre-travel reports and presentations must be completed and presented covering an array of topics from the geological history of the Caribbean, tectonics and the petroleum systems which comprise Trinidad; while in Trinidad field work, laboratory and evening exercises are conducted; and a presentation of the trip is presented after returning to Halifax. Whilst in Trinidad, the students are encouraged to work in collaboration with the professionals from Trinidad, as well as the Trinidadian petroleum geoscience students to learn new applications of methods and concepts taught in the classroom. The main focus of this course is to emphasize the importance of onshore analogues to understand offshore petroleum systems, which are comparative to those offshore Nova Scotia. Nova Scotian and Trinidian basins have both experienced compressional and extensional regimes during their evolution, allowing the elements of their petroleum systems to be created. Both basins also contain fluvial-estuarine, shelf-margin delta and deepwater depositional systems allowing an array of petroleum plays to be had.

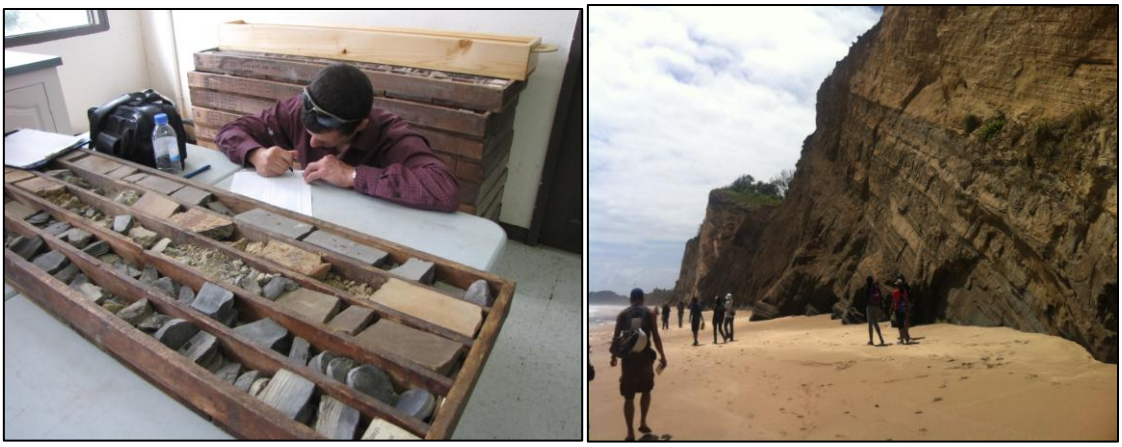

**Figure 1: (Left) Dalhousie student at Petrotrin core lab. Students analyzed and described core on the last day of the trip. (Right) Petrotrin and Dalhousie students at Mayaro Beach. Deltaic sequences and abandoned deltaic lobes were studied and described.**

The topics covered in both the field and in the classroom include:

**Basin Tectonic and structural setting:**

- Caribbean tectonics and seismicity
- Caribbean volcanoes

**Source rock, maturation and overpressure:**

- Overpressure, mud volcanoes and shale tectonics
- Petroleum biodegradation
- Cretaceous source rocks
- Oil and gas generation in the Southern Basin and analogies to Nova Scotia

**Depositional systems and modern day analogues**

- Sequence stratigraphy and accommodation space
- Micropaleontoogy and paleobiology
- Modern fluvial and deltaic settings
- Fluvial-estuarine and deltaic reservoirs

**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 only 4700km$^2$, similar to the area of Halifax Regional Municipality (5400km$^2$). Since the island is relatively small, it allows for easy transportation to multiple outcrops in one day. It is an active petroleum producer and exporter with offshore drilling platforms visible from many of the visited locations. Trinidad is an ideal location to study petroleum geoscience because the island offers exceptional outcrops the demonstrate all of the elements important in creating a successful petroleum system, including: source, seal, reservoir, trap and migration. Some examples of petroleum system elements that can be observed in outcrop throughout Trinidad include; thick reservoir and seal packages of deltaic deposits, mud-volcanoes displaying active overpressure in the region; over mature organic rich source rock in the Northern Range; high amount of tectonic activity that can be observed from all of the regional faulting; as well as a significant amount of oil seeps. To better understand these petroleum system elements, modern wetlands and deltaic systems from which these elements were derived were studied throughout the trip and these present day depositional models were used to better understand the formation of the outcrops.

The primary producing basins of Trinidad comprise reservoirs of deltaic, pro-deltaic and deepwater sediments, all of which can be found offshore Nova Scotia. Trinidadian outcrops, such as those at Mayaro beach and Stollmeyer's Quarry (Figure 2) provide examples of structural and stratigraphic complexities that affect the connectivity of reservoirs that are not visible in the subsurface data of the Scotian Basin. These structural and stratigraphic complexities include sealing faults (Figure 3). The

faults that can be observed in the deltaic deposits of Trinidad further our understanding of their formation and teach us to better predict the location of similar faults within the Scotian Basin. This understanding of the complexity and heterogeneity of the easily accessible outcrops gives good insight into the character of the offshore geolog, both offshore Trinidad and Nova Scotia. This is an issue in Nova Scotia since there are no outcrops seen onshore with similar characteristics to what is happening offshore.

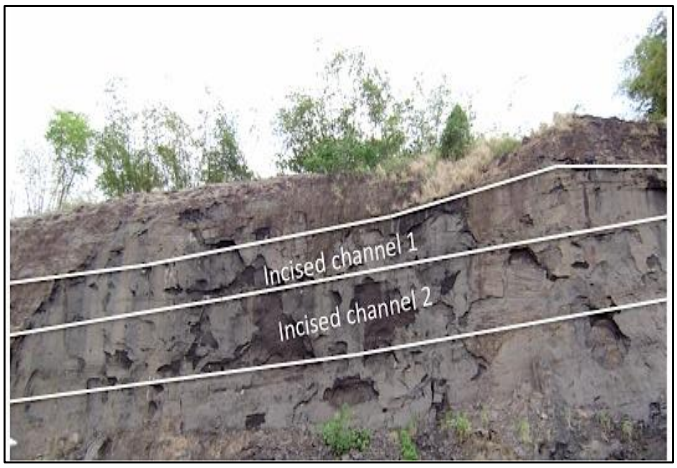


**Figure 2: Stollmeyer's Quarry demonstrating heavy oil sands deposited in the incised channels of the Morne L'Enfer Formation. The reservoirs are separated by thin clay layers at each channel base, creating a barrier to oil flow, which can be observed from seeping at the base. Migration pathways can also be observed from the faults present in the area.**

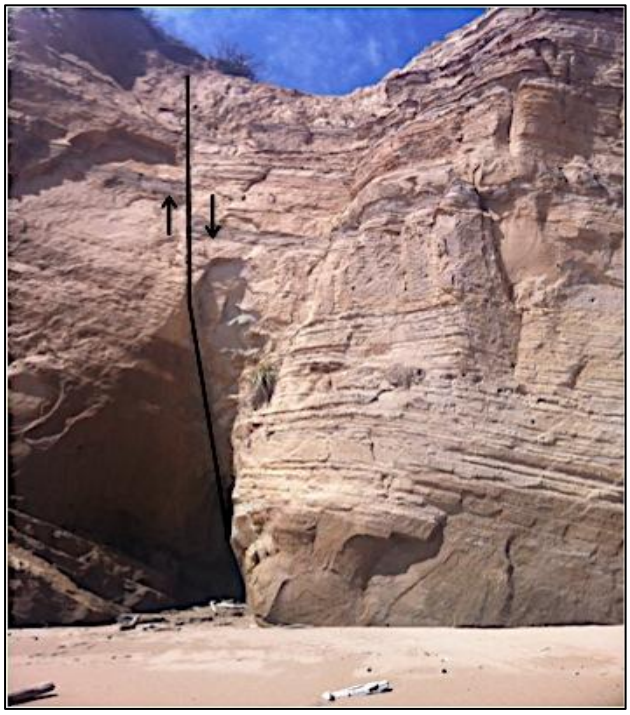

**Figure 3: Outcrop at Mayaro demonstrating a normal fault with a thin layer of mud in-between making this a sealing fault. The Mayaro Formation, which is being produced from similar reseroivrs offshore.**

**Outcomes of Travel:**

By studying the outcrops that demonstrate active elements of a petroleum systems analogous to Nova Scotia, provides insight on characterizing offshore geology, where limited data hinders the ability to understand the structural and geological complexities. Since Nova Scotia does not have representative outcrops of the petroleum system elements, such as deltaic reservoir deposits, the reservoir connectivity is difficult to understand and reservoir models of the Scotian Basin are difficult. The major outcome of studying the extensive outcrops around Trinidad is that subsurface, offshore geology can be characterized and better understood.

For the post-travel report Taylor Campbell focused her paper on the sixth day spent at Mayaro beach.

Day 6 of the Trinidad Advanced Petroleum Geoscience trip of 2014 was dedicated to Mayaro Beach, located along the southeast coast of Trinidad, within the Southern Basin. The objectives of this trips were to compare shelf margin deltaic depositional environments to coastal deltas and to identify features associated with shelf margin deposition, such as; syn-depositional faults, which signifies sealing faults and the surrounding shale units fill the normal fualts, slumping, turbidite processes as well as de-watering structures. Some of the modifying processes of deltaic deposition include; tidal and wave processes represented by physical sedimentary structures that include, tidal bundles and hummocky and swaley cross-stratification. The primary objective for this day was to distinguish the difference between active and inactive phases of deltaic deposition.

The two formations that could be seen on the Mayaro Beach section are the Pliocene Mayaro and the Gros Morne formations. The outcrop that could be seen along the beach, defines shelf margin depositional systems. The first stage of the shelf margin deposition was the active shelf margin delta sedimentation, which was characterized by deformation of beds as well as abundant slump features throughout the outcrop along the beach. There was also very few trace fossils, indicative of high salinity and high-energy stresses within the system. There were many unidirectional ripples, syn-depositional faults, ball and pillow structures, and pinch out and swells, all indicating an active sediment supply on an unstable shelf. Most, if not all of the normal faults that were studied, were interpreted to be sealing faults. Most of these faults would be too small to appear on seismic scale; however they would affect the flow of hydrocarbon within a reservoir. This is important to consider while investigating a potential reservoir in an area with a lot of tectonic activity. Sequence stratigraphy interpretation of the succession of the active shelf margin part of the delta; demonstrate two progradational parasequences, otherwise known as a prograding parasequence set. These were characterized by containing shale and sand interbeds at the bottom of the section, prograding into a thick sand reservoir, then being sealed by a flooding surface, before shallowing upwards. The second prograding parasequence has the same characteristics, however the shale thickness decreases. Each parasequence was approximately 50-80m thick, composed of clays, silts and very fine sand. Drilling rigs can be seen directly offshore of the Mayaro Beach, which are all producing from similar prograding parasequences.

Ball and pillow structures formed as a result of sediment moving downslope (i.e shelf break), and when the sediments accumulated, it became overloaded and slumping created listric faults. Intraformtional conglomerates made up of rip-up clasts can also be seen in close assoication to the ball and pillow structures, produced as the sediments move downslope.

The abandonment phase of the delta was characterized by bioturbation, as well as the presence of well-developed *Ophiomorpha Nodosa* networks, demonstrating the salinity level increased to near normal marine conditions. There was also evidence of hummocky cross-stratification which is indicative of wave modification as the delta lobe became abandoned. The outcrop at Mayaro Beach demonstrates a deltaic system that transforms from a prodelta, to a delta front and ends with abandonment of the delta. In the upper Mayaro, accommodation space decrease as sediment supply increased, which initiated progradation of the deltaic system basinward, forming shelf margin deltas. As the shelf became unstable from rapid sediment supply, syn-depositional faulting and slumping took place along the northeast delta flank. To the north, away from active deltaic sedimentation, normal marine conditions and shoreface sedimentation took place.

The knowledge gained from the Pliocene Gros Morne and Mayaro formations at this location can be applied to the Scotain Basin increasing confidence in the modeling of reservoir compartments.

**Significance to Nova Scotia:**

This course relates to the work in which Taylor Campbell is working on as her undergraduate honors thesis at Dalhousie University. Her focus is on the seismic stratigraphy and attribute analysis of an offshore Nova Scotia location. The extensive outcrops around Trinidad, the elements of the petroleum system are better understood in terms of small scale features that may not always appear in seismic, however may still be present and affecting the connectivity of the reservoirs. These outcrops can be beneficial in understanding what could potentially be happening offshore Nova Scotia and aid in future exploration and development projects.

**Acknowledgments:**

I would like to thank and acknowledge OERA for their generous support and allowing myself the opportunity to travel to Trinidad and acquire all the knowledge that I did through field exercise and laboratory work. The knowledge I gained in Trinidad will aid in my studies of offshore Nova Scotia by understanding more about reservoir connectivity issues and how those can be applied to the offshore petroleum systems of Nova Scotia. There has been a significant increase in interest in exploration of the deepwater Scotian Basin. By studying outcrops analogous to the subsurface offshore Nova Scotia, knowledge of the petroleum systems can be acquired.