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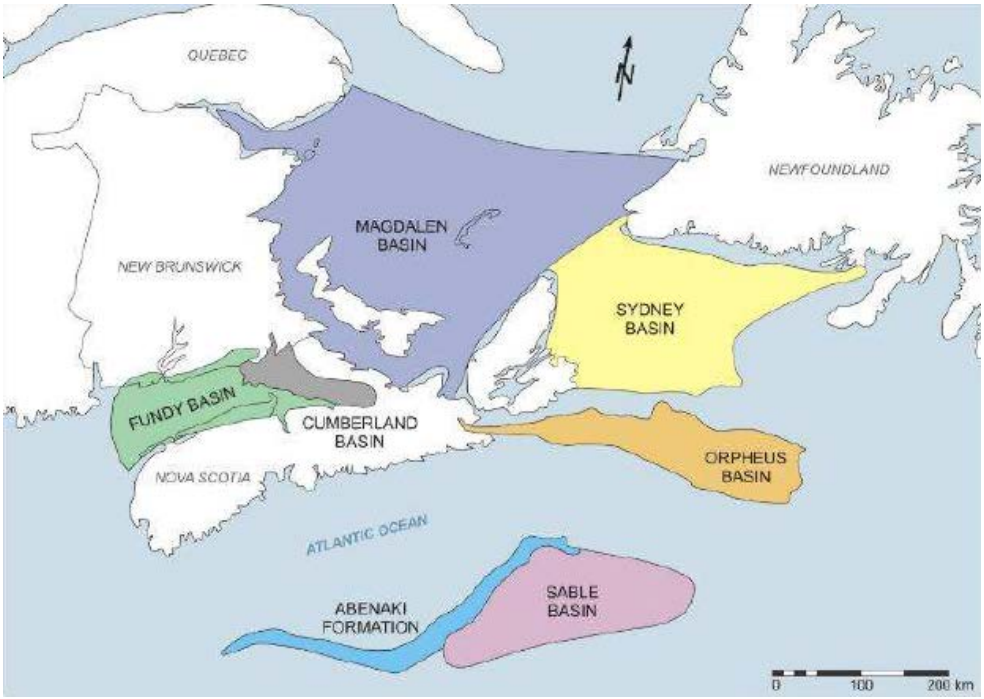

Field Trip 1

The Paleozoic & Mesozoic basins of Atlantic Canada

Nova Scotia, August 18-19, 2018

ISBN: 0-9810595-9

Paleozoic & Mesozoic basins of Atlantic Canada

Field Trip Leaders:

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Dr. Grant Wach is Professor of Petroleum Geoscience and Stratigraphy at Dalhousie University. A specialist in Reservoir Characterization and Stratigraphy, his interest in complex oil reservoirs began at Syncrude, in the oil sands of Alberta. Prior to Dalhousie he was with Exxon (now ExxonMobil) and was Geoscience Research Associate at Texaco (now Chevron) involved with exploration and commercialization with business units around the globe. He has conducted research on, and led field schools and courses in exploration, development and reservoir characterization in several countries. In 2012 he was the first recipient of "Professor of the Year" award from the AAPG Foundation. Professor Wach has an Honours B.A. (Geography/Geology) from the University of Western Ontario, a M.Sc. (Geology) from South Carolina, and a D.Phil. (Geology) from the University of Oxford.

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Dr. Dave Keighley, PhD, P. Geo, obtained his BSc at the University of Manchester, UK, before working on the service side of the oil industry for five years, including a highly successful period as a consultant with Shell Expro in London UK. After receiving the Governor General's Gold Medal for his PhD thesis at the University of New Brunswick, Canada, he returned to the UK to undertake post-doctorate studies with the University of Liverpool Strat Group. These Shell-sponsored studies focussed on conventional petroleum reservoir modelling using field analogues from an Eocene lake basin in Utah. Dave later returned to New Brunswick, first as Hydrocarbons Geologist for the provincial government, working on the oil-shale-bearing Albert Formation, before going back to the Department of Earth Sciences at the University of New Brunswick, this time as faculty. His NB and Utah research has now diversified to incorporate inorganic geochemistry and microbial – sediment interactions in ancient lakes. He has published over 35 refereed and government papers and has provided numerous field trips for industry and professional associations both in Europe and North America.

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Dr. Ricardo L. Silva has been investigating several aspects of the Central Atlantic organic-rich Jurassic carbonate series, integrating several different techniques such as Sedimentology, Geochemistry and Palynofacies. His research is focused in Mesozoic carbonate related sequence stratigraphy, palaeoenvironmental/palaeogeographical interpretation and source rock characterization of organic-rich marine and non-marine carbonate/shale series, including multi-parameter unconventional petroleum systems characterization. He has been Researcher at the University of Lisbon (Technician Fellowship, Geology Center), Federal University of Rio de Janeiro (Invited Researcher, Petroleum and Environmental Geochemistry Group, Environmental Organic Geochemistry research line), and Coimbra University (Researcher and Project member, IMAR-CMA). He is an Adjunct at Dalhousie University.

with contributions from TAYLOR CAMPBELL, CHARLIE CARLISLE, DR. LES ELIUK, ANNE HARGREAVES, ALEX HARNETT, EMMA XINYUE HU, TREVOR KELLY, DR. YAWOOZ KETTANAH, JENNIFER LEE, TRUDY LEWIS, KENNETH MARTYNS-YELLOWE, NATASHA MORRISON, DARRAGH O'CONNOR, NAOMI PLUMMER, PHILIP SEDORE, CARLA SKINNER, MAYA SOUKUP, DR. HASLEY VINCENT, DR. JOHN WALDRON, CONNOR WENTZELL, CARLOS WONG

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Trip Itinerary

2 NIGHTS, 18-19 AUGUST 2018

START: HALIFAX (Saturday Morning)

END: HALIFAX at the Opening Reception at Dalhousie University (Sunday Evening).

Weather, Wind & Tides will control outcrop locations

DAY 1: SATURDAY AUG 18TH TRAVEL AND MARITIMES BASIN PETROLEUM SYSTEMS — Departure Time: 7:00 AM Low Tide: 12:23 PM High Tide 18:30 (Range: 11.3m)

- Pick up in Halifax (7AM) and Halifax airport (7:30) on the way to Amherst Nova Scotia Transport will be in vans **Travel time: 1h 30min / 115km**
  Rest Stop (Buy Lunch materials) (09:00-10:00) Masstown market near Truro
  Safety overview

  Minudie **Travel time: 1h 30min / 120km**
- 11:30-13:00 Lunch on the Outcrop (Purchased earlier at Masstown Market)
  - Cumberland Basin- salt withdrawal basin

- Joggins Fossil Cliffs - UNSECO World Heritage Site 13:30-17:00
  - Fluvial and lacustrine facies Joggins Formation Sandstone (reservoir) and coal (source rock)
- 17:00 Dinner: Lobster or steak dinner at Joggins Fossil Center (provided)

- Hotel: Holiday Inn Hotel Centre Truro | Email: celeste.baxter@hitrurohotel.com
  Direct Line 902-897-8000 | Hotel Switchboard: 902-895-1651 | Cell: 902-456-5167
  437 Prince Street | Truro | Nova Scotia | Canada | B2N 1E6

Travel time: 130 min /130 km

DAY 2: SUNDAY AUG 19TH FUNDY BASIN PETROLEUM SYSTEMS — High Tide: 08:05 AM Low Tide: 14:20PM (Range: 12.5m)

- Fundy Basin - geologic evolution and petroleum systems
  - Depart Hotel at 08:00 **Travel time: 20min / 20km**
  - Rest Stop Buy Lunch materials (08:30) Masstown market near Truro
- 10:00 Five Islands Provincial Park **Travel time: 45min / 50km Safety overview**
- Late Triassic to Early and Middle Jurassic aeolian, playa lake
- Failed Rift - North Mountain Basalt (202–201Ma)
- Lunch on the outcrop (Purchased at Masstown Market)

- 14:30 Return to Halifax for 17:00 start of Opening Reception at Dalhousie University

Travel time: 2hours / 165km

Safety

Safety should be the number one concern for anyone preparing to go into the field. Any accident can be 100% preventable if the proper precautions are taken.

Sun Safety + Exposure

Sun Safety is a practice of taking simple steps to reduce overexposure to UV rays while in the outdoors. Winds and rain on the coastal sections can rapidly affect a given area. Carry a rain jacket in your pack.

Some preventive measures to be taken include:

- Using Sun screen or Sunblock at least 30 SPF
- Wearing Long sleeves that are light (cotton)
- Wearing wide brimmed Hats
- Sun glasses: - Choose glasses that have darker lenses and scratch resistant coatings.
- Taking shade when required
- Drink Water frequently

Personal Safety

During the field seminar proper footwear, headwear, safety vests, ear and eye protection are to be worn. Carry a personal first aid kit and be aware of who are the first aid specialists. Read the accompanying safety information.

Outcrop Safety

Intertidal exposures are often rocky with loose boulders and can be slippery with algae. Exercise extreme ***CAUTION***! Participants should take precaution while around cliff section and stay away from weathered regions of outcrop, for fear of falling debris. Participants who are not directly involved in examining the cliff face should stand back to minimize the chance of possible injury.

Tides

Tides in Nova Scotia are also a key concern. Nova Scotia tides can range from 0.5 metres to 16 metres at their highest (Burntcoat Head). Over a low gradient slope, the tides can quickly drown sections of the mudflats, along the Bay of Fundy. Participants and leaders should be aware of the tides always. The field activities are coordinated to proceed on a falling tide to ensure safe, dry, exercises but variable winds can impact the tides.

Introduction

The field trip will provide an overview of the Paleozoic and Mesozoic basins of the Maritimes of Atlantic Canada. We will begin in the Cumberland Basin examining fluvial sediments of the Cumberland Basin, a salt withdrawal basin where rates of accommodation were so rapid that trees of the Carboniferous forest were preserved upright. Syndepositional collapse structures, channel bodies and coal deposits of the Carboniferous section will be viewed along the cliffs of the Joggins UNESCO World Heritage site. The trip will then continue to examine the rift succession of the Mesozoic Fundy Basin. We will study the Triassic succession of fluvial sediments, followed by aeolian strata with 5m dune sets, capped by playa lake deposits. The succession ends with the flood basalts of the failed Fundy rift at the beginning of the Jurassic. The petroleum systems inherent to each basin will be demonstrated and their relationships to the offshore conjugate basins. Our research is directed towards understanding the basin evolution and inherent petroleum systems offshore Atlantic Canada and the conjugate margins, namely Morocco, United Kingdom, Portugal, Spain and Ireland (Figure 1).

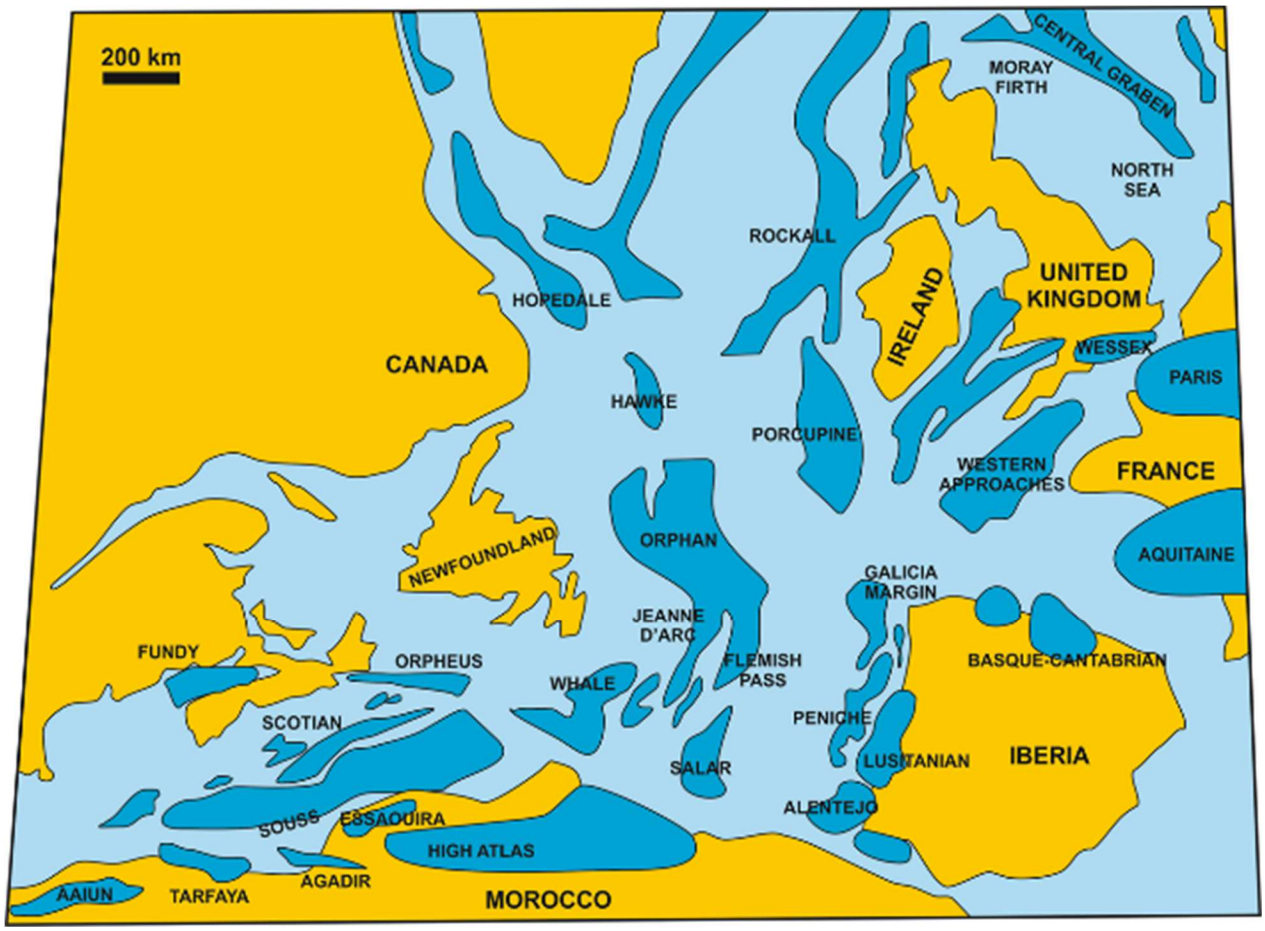

Figure 1. Late Triassic- Basins formed by the rifting and seafloor spreading that lead to the opening of the Atlantic Ocean (Wade and MacLean, 1990).

Scotian Basin

The Scotian Basin is located offshore Nova Scotia (Figure 2); larger than the Gulf of Mexico, covering an area of approximately 300,000 km^2. Half of the basin lies on the present-day continental shelf under 200m of water, with the remainder on the continental slope in 200 to 4,000 m of water. It is a classic passive conjugate margin, representing over 250 million years of sedimentation (Mesozoic to Cenozoic). The basin comprises a series of subbasins and platforms; the Shelburne Subbasin, La Have Platform, Sable and Abenaki subbasins, Banquereau Platform, Orpheus Graben and Laurentian Subbasin (Figure 2). The Scotian Basin was initiated during the Triassic syn-rift to lower Jurassic post-rift phase on the Atlantic margin, with terrestrial siliciclastic sediments and evaporites marking this phase (Figure 3). In the Middle Jurassic, the Abenaki carbonate platform developed with an enigmatic succession of platform carbonates juxtaposed with sandstone and shale of the Sable Delta complex (Eliuk and Wach, 2008). Most of the succession is a passive margin basin fill of sandstone and shale sequences deposited in response to global relative changes in sea level. In the later Jurassic and Cretaceous the Sable and Laurentian deltas produced transgressive and regressive packages of deltaic, shelf margin and slope deposits (Wade and MacLean 1990; Kidston et al., 2002) (Figure 3). To date, studies along the Scotian margin have been segmented in accordance with the awards of exploration blocks, with much of the data and results remaining proprietary within companies. The Play Fairway Analysis (Beicip-Franlab, 2011) project identified rich hydrocarbon potential resources offshore of Nova Scotia (121 Tcf of gas and 8 billion barrels of oil). The PFA also mapped large potential traps that could contain gas, condensate and/or oil. These results reignited industry's interest in this area, illustrated by record bids for deep water exploration blocks by Shell in 2011 ($970,000,000- 4 blocks) and BP Exploration in 2012 ($1,049,999,999- 4 blocks).

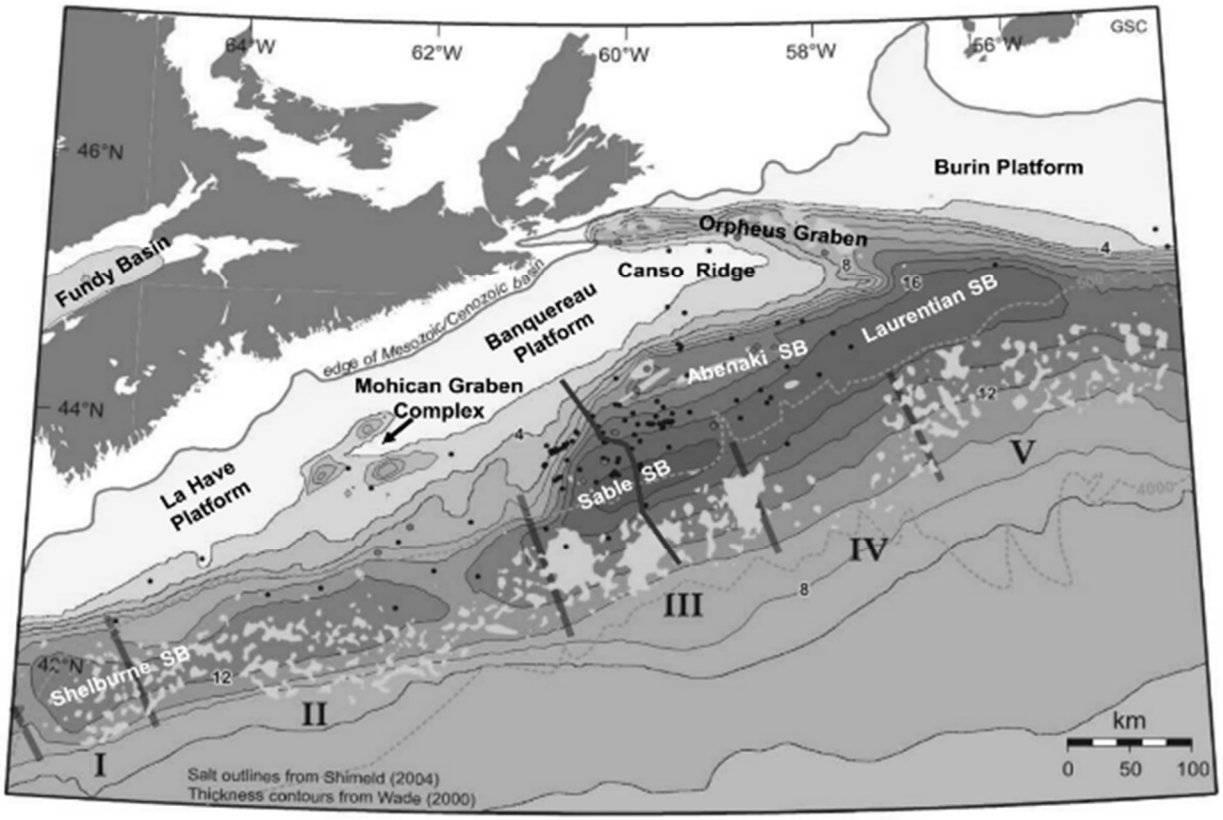

Figure 2. Major tectonic elements of the Scotian Basin showing depth to basement in kilometers (black) and bathymetric contours (grey). The black dots are wells, with the grey dots wells that penetrated salt. The pale grey areas represent earliest Jurassic age Argo formation salt structures, with the Roman numerals indicating the salt/basement regions as defined by Kidston *et al.* (2002) and Shimeld (2004) (retrieved from www.cnsopb.ns.ca, modified from Wade, 2000).

Hydrocarbon exploration offshore Nova Scotia is cyclic and began in 1959; nonetheless, the Scotian Basin remains virtually unexplored given the low number of exploration wells (130 out of 210) and their concentration in the central Sable Subbasin. Drilling focused on the successful rollover anticlinal plays (with significant gas finds), yet the source and timing of hydrocarbon generation and migration pathways are not fully understood (www.cnsopb.ns.ca). Source rock is a fundamental component of petroleum systems as it is the element which under favorable conditions will produce and expel hydrocarbons; coupled with reservoir distribution they are the two key risk elements of the Scotian Margin (Figure 3).

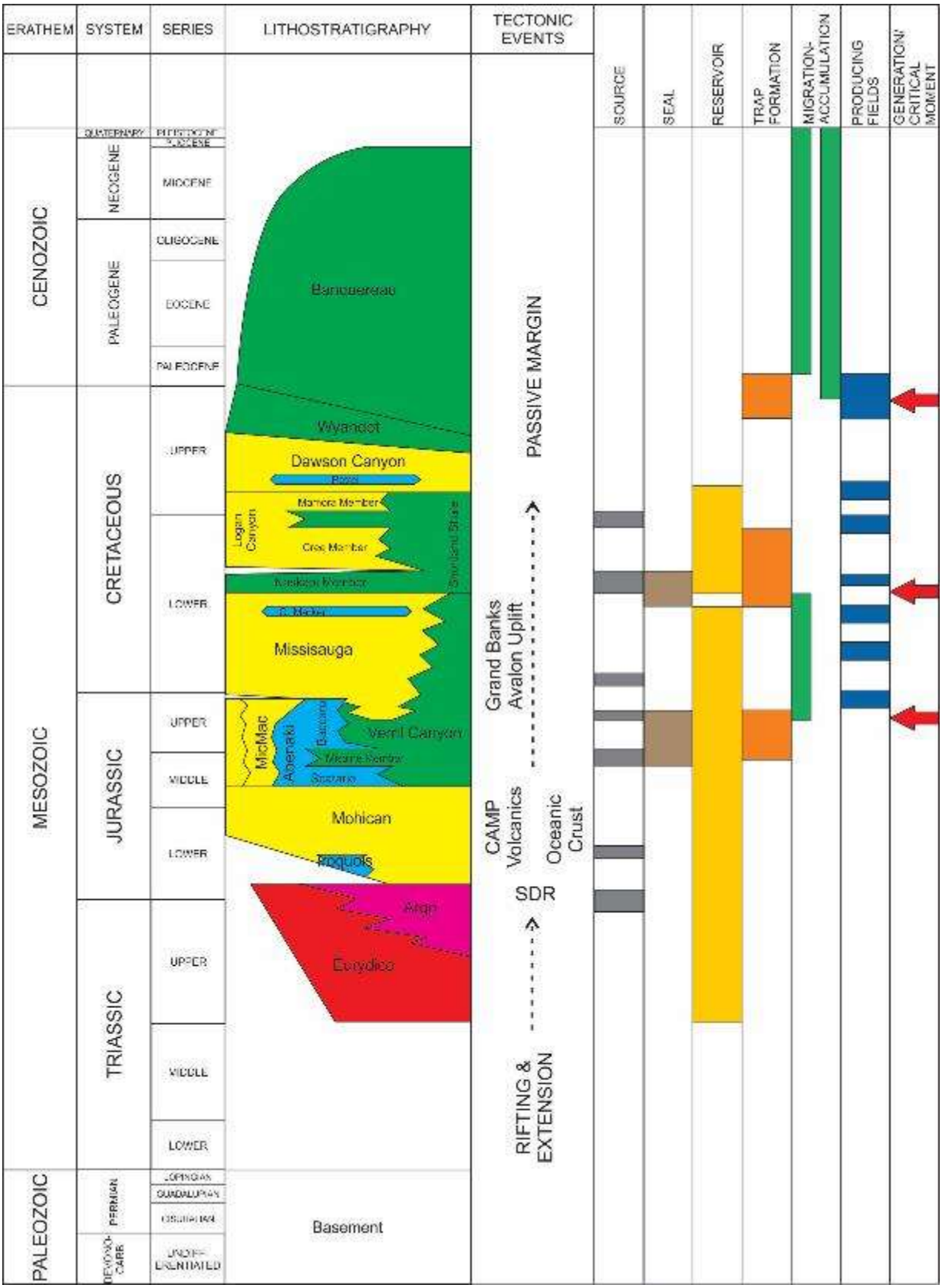

Figure 3. Lithostratigraphy, tectonic events and Petroleum Systems architectural elements of the Scotian Basin (Nova Scotia, Canada) (from Wach et al., 2014 and references therein).

The petroleum systems of the Scotian Basin remain enigmatic. The geological structures are complex and seismic imaging is difficult. Yet, in every petroleum basin the pattern of exploration is similar; high costs and risk are incurred until the key is found to unlock the petroleum system. For example, in the Gulf of Mexico the overpressure system was considered a “barrier” to exploration and was not tested. When finally drilled, a new exploration trend was discovered. The extensive Jurassic source rocks cropping out on the Western European and African conjugate margins suggest that Scotian margin exploration for hydrocarbons can test alternative (and new) play concepts, improving chances of success (Wach et al., 2014).

There are two developments in the Scotian Basin, both gas prone, being gradually decommissioned. The five field ExxonMobil Sable project (1999-present) produces from siliciclastic deltaic and shallow marine reservoirs with some condensate, with production scheduled to end later this decade. The Encana Deep Panuke project (2013-present) produced gas from the Late Jurassic Abenaki carbonate margin (Figure 3). A third project produced light oil and condensate from deltaic and shallow marine reservoirs in the now decommissioned Lasmo (later PanCanadian-Encana) Cohasset-Panuke project (1992-99), with Panuke directly overlying the Deep Panuke field (Figure 3).

This field trip will examine petroleum systems of the Maritimes, Fundy and Scotian basins (Figure 4, Figure 5 and Figure 6). The outcrops we will visit will provide analogs to the subsurface of the Scotian Basin.

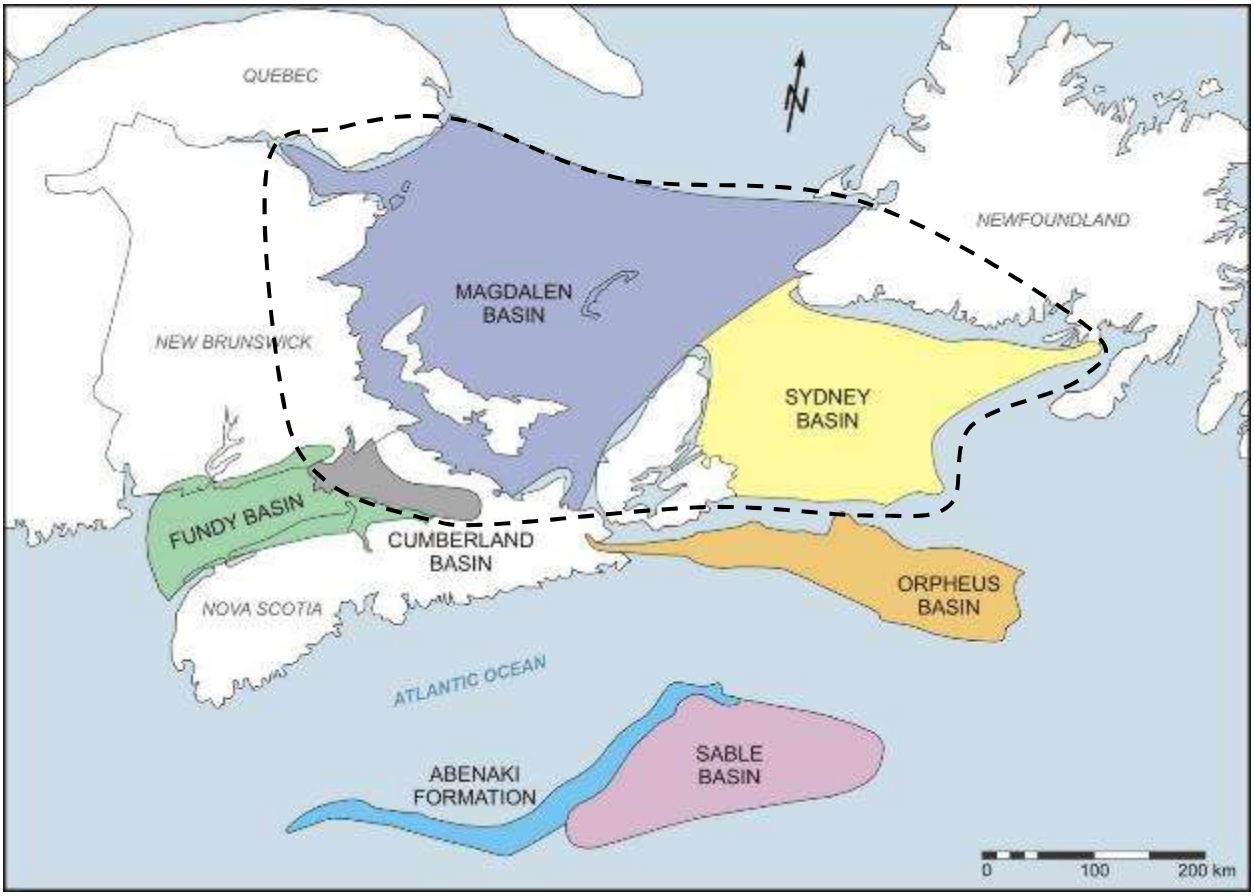

Figure 4. The Paleozoic and Mesozoic basins including the Maritimes Basin (dashed line). (from Pothier Wach and Zentilli, 2010, GeoCanada CSPG-CSEG, extended abstract; and Wach, Pothier and Zentilli, 2008 Basin and Reservoir Lab contribution).

Field Trip Map

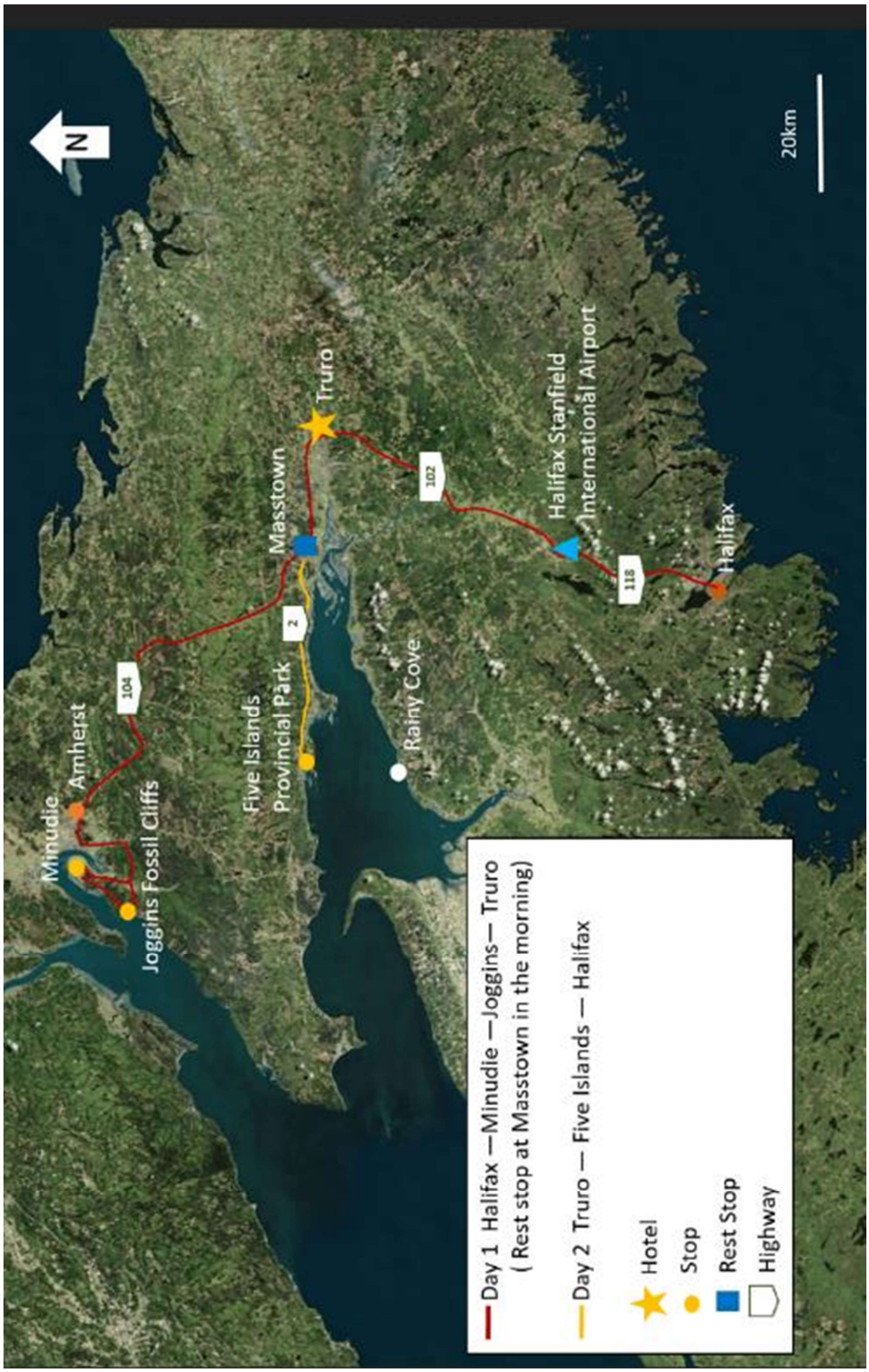

Figure 5. Overview map of the central Nova Scotia region and itinerary and stops for the field trip.

Overview of Field Trip Stops

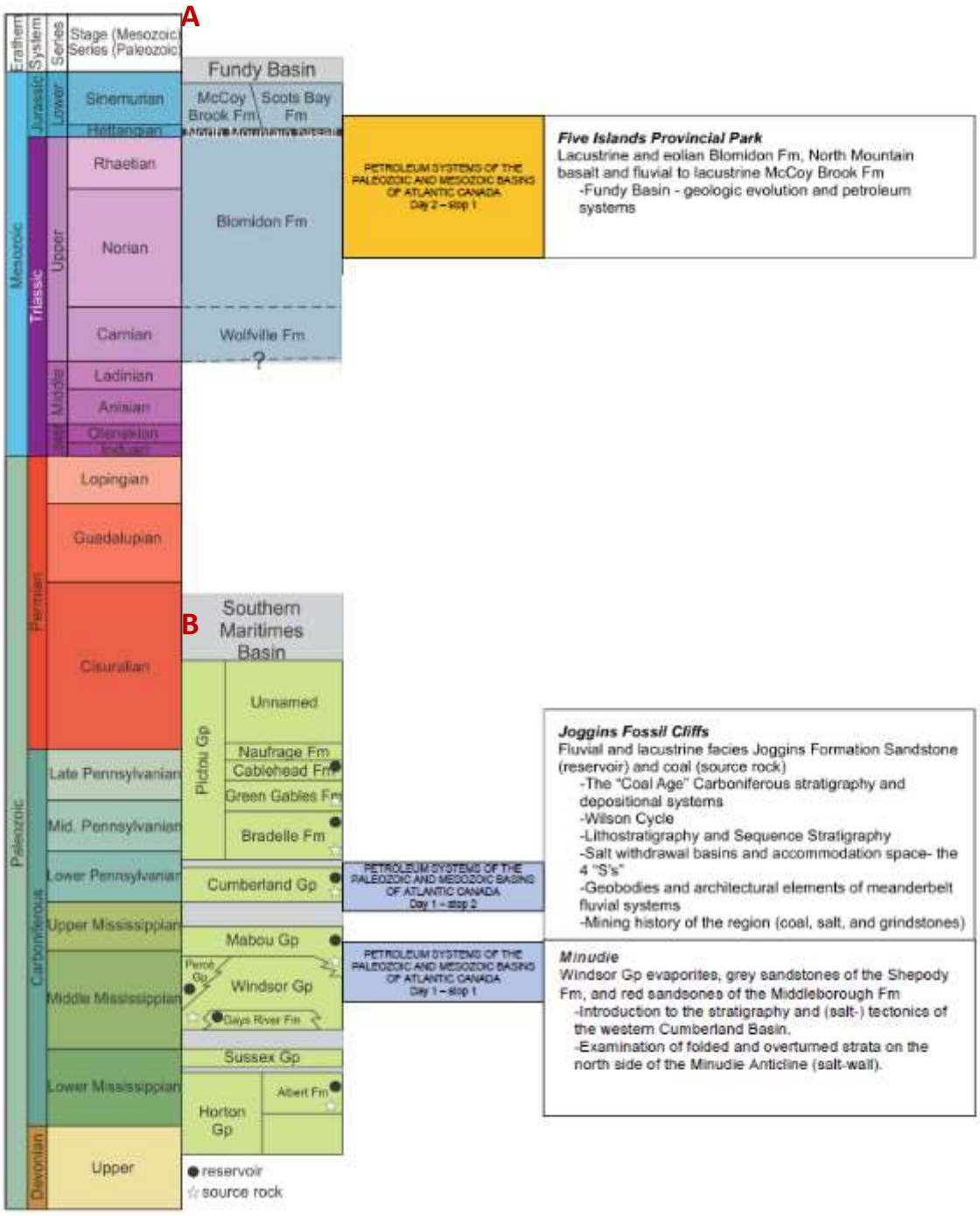

Figure 6. Simplified stratigraphic schemes of the Southern Maritimes and Fundy basins and overview of the scheduled stops. Gp – group; Fm – formation; Mid – middle (A. modified from Olsen and Et Touhami, 2008; B. from Dietrich *et al.*, 2011).

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