Conjugate Margins Conference | Halifax 2008

Program Abstracts

August 13-15, 2008
Dalhousie University
Halifax, Nova Scotia, Canada

Atlantic Canada Opportunities Agency
Agence de promotion économique du Canada atlantique
Canada

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Conjugate Margins Conference | Halifax 2008

"Sharing Ideas – Embracing Opportunities"

Program & Abstracts

13 – 15 August 2008
Dalhousie University
Halifax, Nova Scotia
Canada

EDITOR: David E. Brown

Conjugatemargins.com

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Neil Watson – Consultant

The Halifax 2008 Steering Committee extends our sincerest thanks and appreciation to all our sponsors and supporters for their generous financial and in-kind support in helping to make this Conference a reality and success.

DIAMOND - $20,000 +

Nova Scotia Offshore Energy Technical Research Association (OETRA)
- *Foundation Funding*

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- *Foundation Funding, Core Workshop, CNSOPB Reception*

Nova Scotia Department of Energy
- *Foundation Funding*

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We sincerely thank all our sponsors, partners and supporters who contributed to the success of the

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Conjugate Margins Conference | Halifax 2008

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Central Atlantic
Conjugate Margins Conference
Halifax 2008

Venue and Events Addresses

BUILDING	VENUE / ROOM	EVENT
Marion McCain Building 6135 University Avenue Halifax, Nova Scotia (902) 494-1106	Scotiabank Auditorium Lobby	Oral Sessions Registration Pick-Up
Dalhousie Student Union Building 6136 University Avenue Halifax, Nova Scotia, B3H 4J2 (902) 494-1106	McInnes Room	Receptions Poster Session Seismic Data Room
Dalhousie University Club Alumni Crescent off of South Street Halifax Nova Scotia, B3H 3J5 (902) 494-6511 or 494-1925	Great Hall - 2nd Floor	Daily Lunches
Canada-NS Offshore Petroleum Bd. **Geoscience Research Centre (GRC)** Suite 27, 201 Browlow Avenue Dartmouth, Nova Scotia, B3W 1W2 (902) 468-3994	-- --	CNSOPB Reception Core Workshop
Howe Hall 6230 Coburg Road Halifax, Nova Scotia, B3H 4J5 (902) 494-2108	Student Residence	Student Breakfast
Marriott Harbourfront Halifax 1919 Upper Water Street Halifax, Nova Scotia, B3J 3J5 (902) 421-1700	Halifax Ballroom	Lobster Banquet

Marion McCain Bldg.

Student Union Bldg. (SUB)

University Club

Marriott Harbourfront

CNSOPB - GRC

Howe Hall

Schedule of Events

Friday, August 8

• Field Trip #1 (Arrival)	--	Saint John, N.B.

Saturday, August 9

• Field trip #1 (Day 1)	All Day	St. Martins, New Brunswick

Sunday, August 10

• Field trip #1 (Day 2)	All Day	Parrsboro, Nova Scotia

Monday, August 11

• Field trip #1 (Day 3)	All Day	Parrsboro, Nova Scotia
• Short Course #1 (Day 1)	0900-1700	Life Sciences Biology / Earth Sciences Wing Milligan Rm. LSC 8007, 8th Floor
• Short Course #2 (Day 1)	0900-1700	Life Sciences Biology / Earth Sciences Wing GIS Lab LSC 2012, 2nd Floor **AND** Life Sciences Oceanography Wing Gordon Riley Conf. Rm. LSC 3652, 3rd Floor

Tuesday, August 12

• Field Trip #1 (day 4)	All Day	Parrsboro-Halifax Nova Scotia (End)
• Field Trip # 2 (1 day)	0800-1800	Halifax Area, Nova Scotia
• Core Workshop	0900-1600	CNSOPB GRC, Dartmouth, NS
• Short Course #1 (Day 2)	0900-1700	Milligan Rm. LSC 8007, 8th Floor
• Short Course #2 (Day 2)	0900-1700	Gordon Riley Conf. Rm. LSC 3652, 3rd Floor
• Poster Set-Up	1330-1700	Dal SUB, McInnes Rm., 2nd Floor
• Registration Pick-Up	1700-2100	McCain Bldg., Lobby
• Welcoming Reception & Ice-Breaker	1700-2100	Dal SUB, McInnes Rm., 2nd Floor

Wednesday, August 13

• Session 1A – Margin Evolution	0800-1205	McCain Bldg., Scotiabank Auditorium
• Session 1B – Margin Evolution	1330-1700	McCain Bldg., Scotiabank Auditorium
• Poster Display & Seismic Data Room	All Day	Dal SUB, McInnes Rm., 2nd Floor
• CNSOPB Reception & Core Display	1730-2100	CNSOPB GRC, Dartmouth, NS

Thursday, August 14

• Session 1C – Margin Evolution	0800-1205	McCain Bldg., Scotiabank Auditorium
• Session 2A – Petroleum Systems	1330-1205	McCain Bldg., Scotiabank Auditorium
• Poster Display & Seismic Data Room	All Day	Dal SUB, McInnes Rm., 2nd Floor
• Halifax Harbour Tour & Banquet	1730-2300	Marriott Harbourfront Hotel, Halifax Ballroom

Friday, August 15

• Session 2B – Petroleum Systems	0800-1205	CNSOPB GRC, Dartmouth, NS
• Session 2C – Petroleum Systems	1330-1700	CNSOPB GRC, Dartmouth, NS
• Poster Display & Seismic Data Room	All Day	Dal SUB, McInnes Rm., 2nd Floor
• Farewell Gathering	1700-1900	Dal SUB, McInnes Rm., 2nd Floor
• Poster Break-Down	1900-1930	Dal SUB, McInnes Rm. 2nd Floor

Acknowledgements & Thanks

We wish to express our sincere thanks and gratitude to the many individuals and organisations that offered time, energy and support for the Conference. We first wish to thank our fellow Committee members and Trudy Lewis and the staff of Lewis Conference Services for all their hard work in helping make Halifax 2008 a reality.

Two years ago, Nova Scotia's Offshore Energy Technical Research Association (OETRA) recognised the importance of the idea for this event and provided very generous support for the event. Both the Nova Scotia Department of Energy (NSDOE) and the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB) also appreciated the strategic importance of the Conference for the offshore petroleum industry and further buttressed the Conference's financial and human resources.

We also wish to draw attention to a number of people who were most helpful in assisting us is 'spreading the word' about the Conference throughout the world: Ian Davison, Gabor Tari, Mark Rowan Jonathan Redfern, Webster Mohriak and Tako Koning. Paul Post deserves special recognition in drawing upon his considerable knowledge and experience in successfully organising several GCS-SEPM Perkins Research Conferences. Michal Nemčok was a tireless supporter and promoter of Halifax 2008 to North American and European colleagues and companies. Susan Eaton offered her considerable journalistic expertise with promotion of the Conference.

We are pleased to have provided delegates with an exceptional selection of Field Trips, Short Courses and Workshops. Some of these did not take place but nevertheless we are grateful to all leaders, instructors and presenters who early on, planned and organised these events. We thank you all for your time and effort.

We gratefully acknowledge the important role professional societies played in assisting with national and international promotion of the event including the Canadian Society of Petroleum Geologists (CSPG), American Association of Petroleum Geologists (AAPG), Petroleum Exploration Society of Great Britain (PESGB), Moroccan Association of Petroleum Geologists (MAPG), Atlantic Geoscience Society (AGS), Houston Geological Society (HGS), and the Gulf Coast Society of SEPM (GCS-SEPM), and the International Year of the Planet. We appreciate their generous support, resources and efforts in contributing to make Halifax 2008 a success. Below we list all these colleagues and their organisations.

- **NS DOE & OETRA:** Alison Scott, Sandy MacMullin, Kim Doane, Wanda Barrett, Bruce Cameron
- **CNSOPB:** Diana Dalton, Steve Bigelow, Tim Church, Brian Altheim, Mary Jean Verrall, Nancy White, Mary Noel and the staff at the Geoscience Research and Data Management Centres.
- **CSPG**: Colin Yeo, Kim MacLean, Heather Tyminski, Tim Howard, Aston Embry, Ian MacIlreath, Tony Cadrin, Craig Lamb, Jeff Packard
- **AAPG:** Carol McGowan, Jim Blankenship, Beverly Molyneux, Dana Free, John Armentrout, John Hogg, Warren Workman, Debbi Boonstra, Lee Billingsley
- **AGS:** David Keighley, Rob Raeside, David Mosher, Michael Parsons
- **MAPG:** Haddou Jabour, Mahmoud Zizi, Al moundir Marabet
- **GCS-SEPM:** Norm Rosen
- **HGS:** Bill Dickson
- **US-MMS:** David Cooke
- **Canadian Federation of Earth Sciences:** Elisabeth Kosters
- **Dalhousie University:** Carl Breckenridge, Keith Taylor, Martin Gibling, Dave Scott, Peter Wallace, Tom Duffett, Charlie Wall, Katie Hackett and student volunteers

We are of course indebted to our industry and government sponsors and supporters, and our colleagues working with them who helped guide and support our requests for financial resources. And finally, we want to thank you, our fellow delegates and presenters, many of you who have travelled from around the world, for attending Halifax 2008. We hope that new friendships you've made, and the old ones rekindled, will reflect the conference theme of *"Sharing Ideas - Embracing Opportunities"* that will facilitate exploration success in your respective homelands for the benefit of all.

Central Atlantic
Conjugate Margins Conference
Halifax 2008

August 12, 2008

Dear Colleagues;

Welcome to the Central Atlantic Conjugate Margins Conference - Halifax 2008!

Halifax 2008 has been created as an outstanding opportunity to bring together researchers and explorers to discuss the results of hydrocarbon exploration and research within the Central Atlantic conjugate margin basins. We believe that it is vital to collaborate on our knowledge of these basins using the latest concepts and interpretations of divergent margin basin evolution and their petroleum systems.

Our goals are to promote an increased understanding of the hydrocarbon prospectivity of the margins, reduce exploration risk, and see more exploration success. We want to create a pan-Atlantic gathering focusing on topics directly impacting hydrocarbon exploration, and to appeal to those exploring and researching the frontier basins along these margins. The Conference has two main oral and poster sessions that will run consecutively over three days: *Margin Evolution & Development* and *Basin Petroleum Systems.*

Halifax 2008 provides the opportunity for delegates to participate in a wide variety of events: conference field trips on Mesozoic basins and sections in Nova Scotia and New Brunswick; short courses on *Practical Salt Tectonics* and *Petroleum Systems Modelling* along with a Core Workshop with presentations and displays cores from the Western Atlantic Margin that rounds out the Technical Program. We are particularly excited about the Seismic Data Room where full-scale seismic lines from the latest industry deep crustal and regional programs in the Central Atlantic Realm will be displayed.

The Tuesday evening Reception will be held amongst the posters and related displays to encourage discussions and networking, as will be the daily refreshment breaks. Wednesday evening everyone is welcome to the Reception at the new CNSOPB Geoscience Research Center. No conference is complete without a centerpiece banquet. In true Nova Scotia style, we invite all attendees to participate Thursday on the Harbor Cruise and in a fabulous Lobster Feast where they will experience fine local cuisine and entertainment.

Your presence here is confirmation that many believe the basins of the Central Atlantic realm have an excellent potential for new petroleum discoveries and will provide new insights on crustal rifting and the early development of passive margins and their petroleum systems. Thank you for travelling to Halifax to share your ideas with fellow delegates and we hope your stay in Nova Scotia is productive and enjoyable. In keeping with our conference theme, we encourage you all to *Share Ideas and Embrace Opportunities*!

On behalf of the Conference Committee members and all our sponsors, welcome and thank you!

David E. Brown & Grant D. Wach
Conference Chairs, Halifax 2008

Welcome!

Thank you for coming to the Halifax 2008 - Central Atlantic Conjugate Margins Conference.

This is an exciting moment in the history of global energy development, and the timing of this conference is well placed; offshore Nova Scotia at the brink of a new phase of hydrocarbon exploration.

As energy prices continue to climb, new shallow and deep water plays like those found along the conjugate margin on both sides of the Atlantic Ocean are becoming increasingly attractive.

Higher prices are bringing a global push for new sources of hydrocarbons - and the geology of the Triassic to Tertiary-aged plays in offshore Nova Scotia, like that found along the US Atlantic margin and the conjugate margin offshore Northwest Africa, are moving into the spotlight.

Here are some current signs of this:

Nova Scotia's Sable Offshore Energy Project, which supplies up to 15 per cent of the New England gas market, will soon be joined by gas production from EnCana's Deep Panuke project in 2010.

In June, our Offshore Board issued a call for bids for two industry nominated parcels, one in shallow water and one in deeper water in the Jurassic Abenaki formation.

In July, only two weeks later, U.S. firms Ammonite and Catheart won the rights to explore two other parcels, with plans to drill two vertical exploration wells at each location in the near future. These parcels are near ExxonMobil's Sable Project, in an area where oil and gas production was not considered economically feasible in the 1970s.

But a new energy economy is emerging, and with it comes challenges and opportunities. Our offshore is one such opportunity - and momentum is clearly building. As Minister, it's my job to ensure that we continue to stimulate interest and activity in the industry with new science, new policies, new regulation, and strategic marketing.

In the next year and a half, I am pleased say Nova Scotia is investing nearly $19 million towards new petroleum geoscience research, data and analysis, and another $4 million towards marine energy environmental research.

Vast amounts of Nova Scotia's potential offshore energy reserves remains underexplored and undeveloped - and we are putting significant investment into the geoscience to show off that potential. This is a big economic opportunity, right at North America's doorstep.

To continue this exciting trend toward renewed interest in our offshore, we need to collaborate on our understanding of our common geology. And that is why we are so pleased to have you here.

The Halifax 2008 Central Atlantic Conjugate Margins Conference is a great opportunity to exchange and develop new ideas on margin evolution throughout the Central Atlantic conjugate margin basins…as we climb the next wave of offshore activity. Thank you for coming, and enjoy the conference!

Richard Hurlburt,
Minister of Energy for Nova Scotia

NOVA SCOTIA

Energy

CANADA – NOVA SCOTIA OFFSHORE PETROLEUM BOARD
6th Floor TD Centre 1791 Barrington Street Halifax Nova Scotia B3J 3K9 Tel 902-422-5588 Fax 902-422-1799 www.cnsopb.ns.ca

August 2008

Dear Conference Delegates:

On behalf of our Board members and staff, I am delighted to welcome you to Halifax for the Central Atlantic Conjugate Margins Conference – Halifax 2008. We are pleased to be a sponsor for this important event, which brings delegates together from around the world to study the Atlantic realm's shared geological inheritance and better understand its petroleum endowment.

Part of our Board's role is the collection, interpretation and distribution of offshore geoscientific information. In recent years, we have taken a new strategic direction that focuses on this mandate. With support from the governments of Nova Scotia and Canada, we recently expanded our Geoscience Research Centre (GRC) and launched our digital Data Management Centre (DMC).

Another important investment we have made is in our people. The Board is proud of the work its Resources and Rights Group plays in improving the understanding of offshore Nova Scotia's petroleum geology. For example, over the last year our staff prepared geoscientific assessments to support the first Board-led Call for Bids; and, in October 2007, the Board released an updated deep water resources assessment which reconfirmed the existence of significant hydrocarbon potential offshore Nova Scotia.

I would also like to acknowledge the hard work of conference co-Chairs David E. Brown, the senior petroleum geologist with the Board, and Dr. Grant Wach, Dalhousie University, for their leadership in putting together this event. This conference would not have taken place without their vision, persistence and energy.

In closing, we look forward to welcoming you to use our facilities and join us at the GRC for our reception on the evening of Wednesday, August 13.

Wishing you an interesting and successful conference!

Sincerely,

Diana Lee Dalton

Diana Lee Dalton
Chair and Acting CEO

DALHOUSIE UNIVERSITY
Inspiring Minds

Office of the President

August 12, 2008

Dear Conference Delegate:

I warmly welcome you to the Central Atlantic Conjugate Margins Conference at Dalhousie University. Founded in 1818, Dalhousie is Atlantic Canada's leading research university. With nearly 200 programs, Dalhousie attracts students from around the world and has an international reputation for excellence in research.

Our first Professor of Geology was appointed in 1879. From those early days of a one-person department, Earth Sciences has grown remarkably and now offers a wide range of research programmes ranging from micro-paleontology through seismic processing and with strengths in geochronology, geodynamics, analogue modeling, marine geology, salt tectonics and sedimentology to name just a few.

Dalhousie University believes that industry, government and academia must work together to ensure that all benefit from opportunities in the energy sector. We have forged key industry and government partnerships with Shell, Schlumberger, the Nova Scotia Department of Energy and the Geological Survey of Canada for example. Through interdisciplinary work and collaboration, Dalhousie is integrating a broad range of research and education components to meet demands for energy expertise in Canada and abroad. *Energy@Dal* represents a collaborative teaching and research community. This integrated approach to research, education and external partnerships is contributing to successful exploration and development of our onshore and offshore petroleum resources.

Energy-related research is of vital geopolitical, socioeconomic and environmental importance. At Dalhousie we recognize that energy and the environment are inexorably linked. The reservoirs we extract oil and gas from are the same reservoirs needed to store excess CO_2. Mitigation technologies are being developed through our Carbon Storage Research Consortium (CSRC). Besides ongoing research and educational programs in petroleum geoscience, the Dalhousie researchers are developing new research initiatives into ocean tracking, tidal power and wind energy. Dalhousie aspires to be a true leader in energy research and education!

We hope you enjoy your stay in Halifax. It is our pleasure to be your hosts.

Sincerely,

Tom Traves

Tom Traves
President and Vice-Chancellor

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Tel: 902.494.2511 • Fax: 902.494.1658 • www.dal.ca

Program & Events

Friday, August 8, 2008

FIELD TRIP #1
Tropical to Subtropical Syntectonic Sedimentation in the Permian to Jurassic Fundy Rift Basin, Atlantic Canada, in Relation to the Moroccan Conjugate Margin

- Field Trip Leaders: Paul E. Olsen, LDEO, Columbia University, Palisades, New York and Mohammed Et Touhami, LGVBS, Département des Sciences de la Terre, Université Mohamed Premier, Oujda, Morocco
- Participants Arrive in Saint John, New Brunswick
- Duration: 4 days

Saturday, August 9, 2008

FIELD TRIP #1
Day 1 of 4 - ***Tropical to Subtropical Syntectonic Sedimentation in the Permian to Jurassic Fundy Rift Basin, Atlantic Canada in Relation to the Moroccan Conjugate Margin***

Sunday, August 10, 2008

FIELD TRIP #1
Day 2 of 4 - ***Tropical to Subtropical Syntectonic Sedimentation in the Permian to Jurassic Fundy Rift Basin, Atlantic Canada in Relation to the Moroccan Conjugate Margin***

Monday, August 11, 2008

FIELD TRIP #1
Day 3 of 4 - ***Tropical to Subtropical Syntectonic Sedimentation in the Permian to Jurassic Fundy Rift Basin, Atlantic Canada in Relation to the Moroccan Conjugate Margin***

FIELD TRIP # 3
Onshore equivalents of the Cretaceous reservoir rocks of the Scotian Basin: detrital petrology, tectonics and diagenesis

- Field Trip Leaders: Georgia Pe-Piper, Saint Mary's University, Halifax, Nova Scotia and David J.W. Piper, Geological Survey of Canada, Dartmouth, Nova Scotia
- Departure Time: 0800 in front of Dalhousie Student Union Building, University Avenue
- Duration: 1 day

SHORT COURSE #1
Practical Salt Tectonics: Short Course Emphasizing the Geometry & Evolution of Salt Structures

- Instructor: Mark G. Rowan, Rowan Consulting, Inc., Boulder, Colorado
- Duration: 2 days
- Time: 0900 to 1700
- Location: Dalhousie University Life Sciences Bldg (Milligan Room, LSC 8007 8th Floor)

SHORT COURSE #2
Petroleum Systems Modelling

- Instructors: Hans Wielens, Geological Survey of Canada–Atlantic, Dartmouth, Nova Scotia & Marcos Zentilli, Dalhousie University, Halifax, Nova Scotia
- Duration: 2 days
- Time: 0900 to 1700
- Location: Dalhousie University Life Sciences Bldg., GIS Lab, LSC 2012, Biology/Earth Sciences Wing, 2nd Floor <u>AND</u> Gordon Riley Oceanography Conf. Rm., LSC 3652, Oceanography Wing, 3rd Floor

Tuesday, August 12, 2008

0900 to 1700 Short Courses

1330 to 1700 Poster Set-up

1700 to 2100 Registration & Pre-Registration Pick-up, Marion McCain Bldg. Lobby

FIELD TRIP #1
Day 4 of 4 - *Tropical to Subtropical Syntectonic Sedimentation in the Permian to Jurassic Fundy Rift Basin, Atlantic Canada in Relation to the Moroccan Conjugate Margin*

- Ends at 1600 to 1700 Dalhousie Student Union Building

SHORT COURSE #1
Day 2 of 2 - Practical Salt Tectonics*: A 2-day Short Course Emphasizing the Geometry and Evolution of Salt Structures*

SHORT COURSE #2
Day 2 of 2 - *Petroleum Systems Modelling*

WORKSHOP #1
Cores of Offshore Nova Scotia Clastic and Carbonate Reservoirs, Facies & Sequences

- Organizers: Les Eliuk, Geotours / Dalhousie University, Halifax, Nova Scotia and Andrew MacRae, Saint Mary's University, Halifax, Nova Scotia
- Duration: 1 day
- Time: 0900 – 1600 (Lunch included)
- **Location: CNSOPB Data Management Centre, Dartmouth, Nova Scotia**
- Bus departure time 0800 (in front of Dalhousie Student Union Building, University Avenue)
- Bus return time 1600 (to Dalhousie Student Union Building, University Avenue)

1700 to 2100 Registration Pick-up.

WELCOMING RECEPTION & ICE-BREAKER

Sponsor: bhpbilliton resourcing the future

1700 to 2100 Dalhousie University – Dalhousie Student Union Building (SUB - 2nd floor)

1700 to 2100 Seismic Data Room and Poster Session OPEN – McInnes Room - Dal SUB

Wednesday, August 13, 2008

Session 1A - Margin Evolution & Development

Scotiabank Auditorium

Sessions 1A-1C Sponsor: bhpbilliton resourcing the future

0730 –	Registration Opens (Dalhousie Student Union Bldg. "SUB" - 2nd Floor Lobby)
0800 to 0810	Welcome & Introduction
0810 to 0840	**Keynote Address** **DEPTH-DEPENDENT EXTENSION AND MANTLE EXHUMATION: AN EXTREME PASSIVE MARGIN END-MEMBER OR A NEW PARADIGM?** **<u>Karner, Garry D.</u>**
0840 to 0905	CONTINENTAL BREAK-UP MECHANISM; LESSONS FROM SLOW-, INTERMEDIATE- AND FAST-EXTENSION SETTINGS <u>Nemčok, Michal</u>; Stuart, C.; Rosendahl, B. R.; Welker, C.; Smith, S.; Sheya, C.; Sinha, S. T.; Choudhuri, M.; Yalamanchili, S. V. ; Allen, R.; Reeves, C.; Sharma, S.; Srivastava, D.; Venkatraman, S. and Sinha, N.
0905 to 0930	U.S. EAST COAST: CONTINENTAL MARGIN EVALUATION WITH NEW TOOLS, DATA AND TECHNIQUES <u>Dickson, William</u>; Odegard, Mark; and Post, Paul J.
0930 to 1000	***Refreshment Break*** ***Seismic Data Room & Poster Session - OPEN***
1000 to 1025	MESOZOIC SEAFLOOR SPREADING HISTORY OF THE CENTRAL ATLANTIC OCEAN <u>Bird, Dale E.</u>; Hall, Stuart A.; Burke, Kevin; Casey, John F. and Sawyer, Dale S.
1025 to 1050	VARIATIONS IN CRUSTAL THICKNESS AND EXTENSIONAL STYLE ALONG THE SCOTIAN MARGIN, ATLANTIC CANADA: CONSTRAINTS FROM SEISMIC DATA AND 3D GRAVITY INVERSION <u>Dehler, Sonya A</u>. and Welford, J. Kim
1050 to 1115	NEW PROFILE MODELS OVER THE U.S. EAST COAST CONTINENTAL MARGIN <u>Odegard, Mark</u>; Post, Paul J. and Dickson, William
1115 to 1140	SYSTEMATIC VARIATIONS IN BASEMENT MORPHOLOGY AND RIFTING GEOMETRY ALONG THE NOVA SCOTIA AND MOROCCO CONJUGATE MARGINS Wu, Yue; <u>Louden, Keith</u> and Tari, Gabor
1140 to 1205	THE POST-RIFT EVOLUTION OF THE ATLANTIC MARGIN OF NW AFRICA: A NOT-SO-QUIET PERIOD OF EXHUMATION AND EROSION <u>Bertotti, Giovanni</u>; Andriessen, Paul; Barrie, Ibrahim; Beunk, Frank; Ghorbal, Badr and Wijbrans, Jan
1205 to 1330	**LUNCH (Dalhousie University Club – 2nd Floor)**

Session 1B - Margin Evolution & Development

Scotiabank Auditorium

1330 to 1400 **Keynote Address**
THE MESOZOIC ATLANTIC CANADA OFFSHORE MARGIN: HISTORY OF EXPLORATION, PRODUCTION AND FUTURE EXPLORATION POTENTIAL
Hogg, John R. and Enachescu, Michael E.

1400 to 1425 LOW-T THERMOCHRONOLOGY PROVIDES NEW INSIGHTS IN THE MESOZOIC TO PRESENT
Ghorbal, Badr; Bertotti, Giovanni; Foeken, Jurgen; Stuart, Fin and Andriessen, Paul

1425 to 1450 GEOTECTONIC SCENARIOS FOR THE EVOLUTION OF THE SOUTH ATLANTIC BRAZILIAN MARGIN: LEFT-LATERAL LOWER CRETACEOUS OBLIQUE RIFTING FOLLOWED BY UPPER CRETACEOUS TO PRESENT ONGOING COMPRESSION
De Lima, Claudio Coelho; Lopes, Marcos Fetter; Gontijo, Rogerio and Pessoa Neto, Otaviano Da Cruz

1450 to 1515 REVISITING CRETACEOUS TECTONISM AND VOLCANISM IN THE LAURENTIAN SUB-BASIN AND ORPHEUS GRABEN, OFFSHORE NOVA SCOTIA
Bowman, Sarah; Pe-Piper, Georgia and Piper, David J.W.

1515 to 1545 ***Refreshment Break***
Seismic Data Room & Poster Session - OPEN

1545 to 1610 40AR-39AR STUDY OF THE FREETOWN LAYERED IGNEOUS COMPLEX (FLIC), FREETOWN, SIERRA LEONE, WEST AFRICA: IMPLICATIONS FOR THE INITIAL BREAK-UP OF PANGAEA TO FORM THE CENTRAL ATLANTIC OCEAN
Barrie, Ibrahim Jorgor; Wijbrans, Jan R.; Beunk, Frank F.; Bertotti, Giovanni; Andriessen, Paul A.M.; Strasser-King, Victor E.H. and Fode, Daniel V.A.

1610 to 1635 THE INS AND OUTS OF BUTTRESS FOLDS: EXAMPLES FROM THE INVERTED FUNDY RIFT BASIN, NOVA SCOTIA AND NEW BRUNSWICK, CANADA
Baum, Mark S.; Withjack, Martha Oliver and Schlische, Roy W.

1635 to 1700 SECOND-ORDER SEQUENCES AND THEIR APPLICATION FOR EXPLORATION IN THE DEEP-WATER SCOTIAN SLOPE
Davies, Andrew; Etienne, James L.; Simmons, Mike D.; Davies, Roger B.; Sharland, Peter R.; and Sutcliffe, Owen E.

RECEPTION - CNSOPB DATA MANAGEMENT CENTRE RECEPTION & CORE DISPLAY

SPONSORED BY CNSOPB

1730 – **Buses depart Dal SUB for CNSOPB Data Management Centre, Dartmouth, N.S.**

1800 to 2100 **Reception, Buffet & Core Display: Offshore Nova Scotia Clastic & Carbonate Reservoirs, Facies & Sequences**

2100 – **Buses return to Dalhousie Student Union Building**

Thursday, August 14, 2008

Session 1C - Margin Evolution & Development

Scotiabank Auditorium

0730 – Registration Opens (Dalhousie Student Union Bldg. “SUB” - 2nd Floor Lobby)

0800 to 0810 Welcome & Introduction

0810 to 0840 **Keynote Address**
SLOPES, BASIN FLOORS, DIAPIRS, AND CANOPIES: REGIONAL-SCALE SALT-SEDIMENT INTERACTION IN THE NORTHERN GULF OF MEXICO AND THE SCOTIAN OFFSHORE
Rowan, Mark G.

0840 to 0905 SEISMIC STRATIGRAPHY, SALT STRUCTURES AND THERMAL AND PETROLEUM SYSTEMS MODELS ACROSS THE CENTRAL NOVA SCOTIA SLOPE BASIN
Louden, Keith; Mukhopadhyay, P.K.; Wu, Yu; Negulic, Eric and Nedimovic, Mladen

0905 to 0930 BASIN-SCALE SALT TECTONIC PROCESSES AND SEDIMENT PROGRADATION IN THE SLOPE AND DEEPWATER BASIN OF THE NORTH-CENTRAL SCOTIAN MARGIN
Adam, Jürgen; Kreszek, Csaba; MacDonald, Cody; Campbell, Clarke; Cribb, Jonathan; Nedimovic, Mladen; Louden, Keith and Grujic, Djordje

0930 to 1000 ***Refreshment Break***
Seismic Data Room & Poster Session - OPEN

1000 to 1025 4D PHYSICAL MODELLING OF SALT TECTONICS IN SABLE SUB-BASIN, SCOTIAN MARGIN
MacDonald, Cody; Campbell, Clarke; Cribb, Jonathan; Adam, Juergen; Nedimovic, Mladen; Louden, Keith and Kreszek, Csaba

1025 to 1050 THERMAL EFFECTS OF SALT ON THE PETROLEUM SYSTEM: EVIDENCE FROM FISSION TRACK THERMOCHRONOLOGY, FLUID INCLUSIONS AND BASIN MODELLING
Zentilli, Marcos; Wielens, Hans; Grist, A.M. Sandy; Kettanah, Yawooz; Negulic, Eric and Brown, Evan T.

1050 to 1115 PREDICTIVE TRENDS IN SALT MORPHOLOGY DERIVED FROM SYSTEMATIC ASSESSMENT OF MERGED 3D SEISMIC COVERAGE OVER ENTIRE BASINS
Bird, Tim John; Johnstone, David and Martin, Mark

1115 to 1140 THE EVOLUTION OF THE PERDIDO FOLD BELT IN THE CONTEXT OF SALT TECTONICS OF THE NORTHWESTERN MARGIN OF THE GULF OF MEXICO – INSIGHTS FROM NUMERICAL MODELING
Gradmann, Sofie and Beaumont, Christopher

1140 to 1205 SEDIMENTARY BASINS IN THE CENTRAL AND SOUTH ATLANTIC CONJUGATE MARGINS: DEEP STRUCTURES AND SALT TECTONICS
Mohriak, Webster Ueipass; Brown, David E. and Tari, Gabor C.

1205 to 1330 LUNCH (Dalhousie University Club – 2nd Floor)

Session 2A - Petroleum Systems
Scotiabank Auditorium

Sessions 2A-2C Sponsor: Husky Energy

1330 to 1400 **Keynote Address**
PETROLEUM SYSTEMS OF THE U.S. CENTRAL ATLANTIC MARGIN
Post, Paul J. and Sassen, Roger

1400 to 1425 UNUSUAL JURASSIC CONDENSATE OF THE HUDSON CANYON AREA, U.S. ATLANTIC
Sassen, Roger; and Post, Paul J.

1425 to 1450 BALTIMORE CANYON UNTESTED GAS POTENTIAL
Epstein, Samuel Abraham; and Clark, Donald

1450 to 1515 PALEOCEANOGRAPHIC AND PALEOENVIRONMENTAL IMPLICATIONS FOR HYDROCARBON EXPLORATION OF THE CONTINENTAL SLOPE OFF NOVA SCOTIA
Jansa, Lubomir F.

1515 to 1545 ***Refreshment Break***
Seismic Data Room & Poster Session - OPEN

1545 to 1610 THE PENICHE BASIN: TECNO-SEDIMENTATION AND EXPLORATORY ASPECTS
França, Almério Barros; Gontijo, Rogério Cardoso and Bueno, Gilmar Vital

1610 to 1635 GEOLOGICAL EVOLUTION AND HYDROCARBON POTENTIAL OF THE HATTON BASIN (UK SECTOR), NE ATLANTIC OCEAN
McInroy, David and Hitchen, Kenneth

1635 to 1700 REVISITING THE EAST GEORGES BANK BASIN, OFFSHORE NOVA SCOTIA - WHAT THE EXPLORATIONISTS SAW TWO DECADES AGO
Koning, Tako

BANQUET & HALIFAX HARBOUR BOAT TOUR

RPS Energy

SPONSORED BY RPS ENERGY

1730 – **Buses depart for downtown Halifax**

1800 to 1930 **Halifax Harbour Boat Tour**

1930 to 2230 **Lobster Banquet in the Halifax Ball room at the Marriott Harbourfront (1919 Upper Water Street)**

2230 to 2300 **Buses return to Dalhousie Student Union Building**

Friday, August 15, 2008

Session 2B - Petroleum Systems

Scotiabank Auditorium

0730 – Registration Opens (Dalhousie Student Union Bldg. "SUB" - 2nd Floor Lobby)

0800 to 0810 Welcome & Introduction

0810 to 0840 **Keynote Address**
GEOLOGY AND HYDROCARBON POTENTIAL OF THE NW AFRICAN ATLANTIC MARGIN
Davison, Ian

0840 to 0905 MID TO LATE CRETACEOUS STRUCTURAL AND SEDIMENTARY ARCHITECTURE AT THE TERRA NOVA OILFIELD, OFFSHORE NEWFOUNDLAND - IMPLICATIONS FOR TECTONIC HISTORY OF THE NORTH ATLANTIC
Sinclair, Iain K.; and Withjack, Martha O.

0905 to 0930 RESERVOIR CONNECTIVITY ANALYSIS, HYDROCARBON DISTRIBUTION, RESOURCE POTENTIAL & PRODUCTION PERFORMANCE IN THE CLASTIC PLAYS OF THE SABLE SUBBASIN, SCOTIAN SHELF
Richards, Bill; Fairchild, Lee H.; Vrolijk, Peter J.; and Hippler, Susan J

0930 to 1000 ***Refreshment Break***
Seismic Data Room & Poster Session - OPEN

1000 to 1025 REGIONAL SETTING OF THE LATE JURASSIC DEEP PANUKE FIELD, OFFSHORE NOVA SCOTIA, CANADA - CUTTINGS-BASED SEQUENCE STRATIGRAPHY AND DEPOSITIONAL FACIES ASSOCIATIONS ABENAKI FORMATION CARBONATE MARGIN
Eliuk, Leslie

1025 to 1050 LITHOLOGY-BASED, HIGH-RESOLUTION SEQUENCE STRATIGRAPHIC FRAMEWORK OF LOWER CRETACEOUS, MIXED CARBONATE-SILICICLASTIC SEDIMENTS, ATLANTIC COASTAL PLAIN, EASTERN UNITED STATES
Sunde, Richard A.; and Coffey, Brian P.

1050 to 1115 DISTRIBUTION OF DIAGENETIC MINERALS IN LOWER CRETACEOUS SANDSTONES WITHIN A DEPOSITIONAL FACIES AND SEQUENCE STRATIGRAPHIC FRAMEWORK: GLENELG, THEBAUD, AND CHEBUCTO FIELDS, OFFSHORE SCOTIAN BASIN
Karim, Atika; Pe-Piper, Georgia; and Piper, David J.W.

1115 to 1140 HYPERPYCNAL RIVER FLOODS AND THE DEPOSITION OF LOWER CRETACEOUS SANDS, SCOTIAN BASIN
Piper, David J.W.; Karim, Atika; Pratt, Heidi; Noftall, Ryan; Gould, Kathleen; Foley, James and Pe-Piper, Georgia

1140 to 1205 RIVER SOURCE AND DISPERSION OF LOWER CRETACEOUS SANDS, SCOTIAN BASIN
Pe-Piper, Georgia; Triantafyllidis, Stavros and Piper, David J.W.

1205 to 1330 LUNCH (Dalhousie University Club – 2nd Floor)

Session 2C - Petroleum Systems
Scotiabank Auditorium

1330 to 1400 **Keynote Address**
PETROLEUM SYSTEMS DEVELOPED ALONG THE NW AFRICA OFFSHORE MARGIN: CHALLENGES FACING EXPLORATION & PRODUCTION COMPANIES
Chaney, Alistair John

1400 to 1425 CONTROLS ON FACIES DISTRIBUTION AND RESERVOIR DEVELOPMENT OF UPPER TRIASSIC RIFT CONTINENTAL SYSTEMS IN INTERMONTANE RIFT SETTINGS: A COMPARATIVE STUDY OF EXTENSIVE OUTCROPS IN SW MOROCCO
Redfern, Jonathan; Mader, Nadine; Fabuel Perez, Ivan; Hodgetts, David and El Ouataoui, Abedelmajid

1425 to 1450 FUTURE PROSPECTS OF OIL AND GAS WITHIN SELECTED TARGET AREAS OF SCOTIAN SHELF AND SLOPE, OFFSHORE NOVA SCOTIA, EASTERN CANADA: EVALUATION BASEDON PETROLEUM SYSTEMS RISK ASSESSMENT
Prasanta K., Mukhopadhyay (Muki) and Harvey, Paul, J.

1450 to 1515 CONTINENTAL RIFT BASIN FILLS: EVOLUTION FROM OPENED TO CLOSED STAGE (WOLFVILLE/ BLOMIDON FM, NOVA SCOTIA)
Leleu, Sophie

1515 to 1545 ***Refreshment Break***
Seismic Data Room & Poster Session - OPEN

1545 to 1610 PERMO-TRIASSIC BASINS FROM IRELAND TO NORWAY: BASIN ARCHITECTURE AND CONTROLS
Shannon, Patrick M. and Stolfova, Katerina

1610 to 1635 EARLY INFILL OF THE TRIASSIC FUNDY BASIN: ARCHITECTURE OF THE WOLFVILLE FORMATION AND FLUVIAL EVOLUTION
Leleu, Sophie; Hartley, Adrian J.; Jolley, David W. and Williams, Brian P.J.

1635 to 1700 RESERVOIR QUALITY, DIAGENETIC HISTORY AND PROVENANCE OF THE LATE TRIASSIC SANDSTONES OF THE WOLFVILLE FORMATION, BAY OF FUNDY, NOVA SCOTIA, CANADA
Kettanah, Yawooz; Kettanah, Muhammad and Wach, Grant D.

FAREWELL GATHERING & RECEPTION

1700 to 1900 Farewell Gathering – McInnes Room (Dal SUB)

1700 to 1900 Seismic Data Room and Poster Session OPEN – McInnes Room (Dal SUB)

1900 to 1930 Poster Breakdown

Abstracts – ORAL Sessions

Wednesday, August 13, 2008

Session 1A - Margin Evolution & Development

DEPTH-DEPENDENT EXTENSION AND MANTLE EXHUMATION: AN EXTREME PASSIVE MARGIN END-MEMBER OR A NEW PARADIGM?

Karner, Garry D.[1]

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The discovery of exhumed continental mantle rocks and lack of magmas in ocean continent transitions, the existence of top-basement detachments, and the recognition of an "extension discrepancy" across many passive continental margins, as exhibited by preferential thinning of lower crust and the rapid thinning of continental crust in the absence of obvious faulting, have seriously challenged the accepted paradigms for the formation of passive continental margins and the way in which continental lithosphere is deformed in extension. Recent studies have clearly demonstrated that rifting, that is, the offset across high-angle basin bounding normal faults, is only a minor component in the thinning of continental lithosphere. During extension, early fault controlled subsidence tends to be limited to the proximal regions of passive margins while later brittle deformation dominates the distal regions. Kinematic considerations of passive margin subsidence require preferential bulk thinning of the lower crust and lithospheric mantle relative to the upper crust, an observation supported by seismic refraction results across the West African margin and the Exmouth Plateau, northwest Australia. Age considerations indicate that this depth-dependent extension (DDE) of the lithosphere is the significant process for thinning continental crust from its 30-40 km pre-rift thickness to a thickness of ~10 km, but surprisingly, depositional environments seem to be characterized by shallow water and quiescent conditions, as evidenced by Tithonian carbonates of the Iberian margin now at abyssal depths. Such extension partitioning requires a lateral strain balance, which may take the following form: 1) a counterbalancing of upper crustal extension leading to late-stage brittle deformation in the vicinity of the ocean-continent transition zone (e.g., the low angle detachment systems of the distal Iberian margin), and/or 2) the lateral emplacement and exposure of serpentinized and magmatically modified continental mantle and lower crust out from under the adjacent continental lithosphere.

While isostatic considerations of DDE allow the distribution and amplitude of syn- and post-extension accommodation to be calculated, a geological understanding of the thinning process and the modes of crustal and mantle deformation cannot be addressed. Thus, the fundamental question remains: what mechanism(s) allow the continental lithosphere to be thinned from ~30 km to ~10 km and thence to the point of rupture? It has been suggested, using field observations from the exposed Tethyan margin in the Swiss Alps and geodynamic modeling, that the Iberia-Newfoundland system is the result of a complex rifting history that can be described as a sequence of different modes of extension. This sequence initiates with a broadly-distributed brittle deformation (stretching phase) and is followed by strain localization and crustal thinning along upper crustal and mantle ductile shear zones decoupled along a mid-crustal décollement, localized and controlled by a relatively weak middle crustal rheology (thinning phase). If and when coupling of the thinned upper and lower crust occurs (*i.e.*, once the crust has reached a thickness of ~10 km), crustal embrittlement and continued extension leads to the formation of crustal-scale detachments along downward-concave faults that are conducive to mantle exhumation (exhumation phase). While this sequencing is a working hypothesis for how continental lithosphere extends, the view is that the final crustal architecture of at least the Iberia-Newfoundland margin is controlled by the stacking of these different modes of extension. Thus, given the field and drilling observations from the Iberia-Newfoundland and Tethyan margins, the proxy for extensional strain partitioning in the crust is the existence of syn-extensional sags and the exhumation of lower crust and continental mantle. The width of these exhumed zones may be 100's km wide and contain organized

magnetic anomalies. However, these magnetic anomalies are likely a consequence of mantle exhumation and serpentinization rather than mid-ocean ridge basalt production at the spreading center.

Many passive continental margins are characterized by such observations, for example, Galicia Bank and the Iberian margin, the Exmouth, Queensland and Marion Plateaus, the Woodlark basin, the West African margin, and the Norwegian margin. While the geological details and sedimentary facies differ between the various margins, the style of deformation is remarkably similar. It would appear that what was once considered an extreme end-member of passive margin formation (viz., the Iberian-Newfoundland margin) may instead be a template for the development of many hyperextended margins around the world, that is, continental lithosphere that has undergone 100's of percent of extension to the point of rupture. The modes of extension discussed above have immense implications for the heat flow history, environments of deposition, syn-extensional stratigraphy, and basin architecture of passive margin systems. A goal of this presentation is to show examples of depth-dependent extension and changing modes of crustal deformation. Our future challenge is to understand exactly how to link crustal deformation with lithospheric mantle thinning in a predictive way.

CONTINENTAL BREAK-UP MECHANISM; LESSONS FROM SLOW-, INTERMEDIATE- AND FAST-EXTENSION SETTINGS

Nemčok, M.[1], Stuart, C.[1], Rosendahl, B. R.[1], Welker, C.[1], Smith, S.[1], Sheya, C.[1], Sinha, S. T.[2], Choudhuri, M.[2], Yalamanchili, S. V. [3], Allen, R.[1], Reeves, C.[4], Sharma, S.[2], Srivastava, D.[2], Venkatraman, S.[5] and Sinha, N.[2]

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[2]Reliance Industries Ltd., Petroleum Business (E&P), Reliance Corporate Park, Block 5, A Wing, Navi Mumbai-400701, India
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Sea-floor spreading mechanisms vary among slow, intermediate and fast-spreading systems. Do continental break-up mechanisms vary for slow-, intermediate- and fast-extension systems?
Because the slow-extension break-up mechanism is established by studies of conjugate Iberia and Newfoundland margins of the Central Atlantic and European and Adria margins of the Liguria-Piemonte Ocean, this study focuses on intermediate and fast rates, which are known from Gabon-Cameroon and East India, respectively. The study draws from synthetic interpretation of ultra-deep reflection seismic, well, gravity, magnetic and outcrop-derived paleostress data.

The interpretation indicates that continental break-up is done by a single continental mantle unroofing mechanism in all systems, just progressively more masked by magmatism at faster-extension systems. Breaking-up of the intermediately fast Gabon system is characterized by upper continental crust partially decoupled from the continental mantle, while the fast E India system underwent decoupling and its lower crust underwent up-bulging in zones in immediate footwalls of main normal faults. Regardless of the extension rate, the upper crustal break-up is controlled by pre-existing anisotropies, which form a system of constraining "rails" for extending continental crust and which influence the local stress regime. Such local stress regime regains the regional character once the function of constraining rails vanishes during the unroofing of the upper continental mantle. Different regions reach different amounts of upper crustal stretching prior to break-up initiation. The break-up location is then controlled by the upper crustal energy balance principle of "wound linkage", trying to use the minimum physical work for linking major upper crustal "wounds" and developing the upper crustal break-up.

U.S. EAST COAST: CONTINENTAL MARGIN EVALUATION WITH NEW TOOLS, DATA AND TECHNIQUES

Dickson, William[1]; Odegard, Mark[2]; Post, Paul J.[3]

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[2]Grizzly Geosciences, Inc., 14019 SW Freeway, Suite 301-735, Sugar Land, TX 77478, USA
[3]U.S. Department of the Interior, Minerals Management Service, Office of Resource Evaluation, 1201 Elmwood Park Blvd. New Orleans, LA 70123, USA

Exploration discussions of the Central Atlantic margins typically omit the U.S. East Coast Continental Margin (ECUS) which has been dormant, without drilling since 1984, despite on-going E&P activities to the north (offshore Nova Scotia), south (offshore northern Cuba), and on the conjugate African margin (Morocco to Mauritania). Shell has documented its exploration success with new ideas and new technology. After a more than twenty year hiatus, we too have new data, technology and ideas along the ECUS, suggesting that timing is favourable for a thorough review.

Our data compilation began with advanced coverage of public domain bathymetry, gravity and magnetic data, all re-leveled, cross-correlated and merged. Our Central Atlantic data set includes five million-odd line-kms each of gravity and magnetic profiles plus a half-million data points. Each data set was carefully merged to regional backgrounds derived from multiple satellites. Stunning imagery of bathymetry, gravity, magnetic and auxiliary data were generated from the final 4 km (super-regional) and 1 km (basin-level) grids. Including multiple data attributes that are somewhat area-dependent, we generated about 40 images, each with specific and general interpretation value.

Evolution of passive margins and adjacent oceanic crust has been studied extensively since the mid-1980's, with continued academic work along the ECUS. The Minerals Management Service is conducting a re-analysis of pre-1985 drilling and seismic data augmenting the older ECUS literature. We make initial comparisons between published interpretations and our new imagery, presenting adjustments, revisions, extrapolations and some speculation. While the dominant structural features are largely unchanged, they are better delineated. This includes evidence of more subtle correlations with published depictions of play-defining features such as areas of salt tectonics and carbonate bank edges. The interaction of these features with plate tectonic elements is also better defined. Each of these observations is illustrated with specific imagery on which feature changes and extensions are highlighted.

MESOZOIC SEAFLOOR SPREADING HISTORY OF THE CENTRAL ATLANTIC OCEAN

Bird, Dale E.[1]; Hall, Stuart A.[2]; Burke, Kevin[2]; Casey, John F.[2]; Sawyer, Dale S.[3]

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The history of Mesozoic seafloor spreading in the Central Atlantic Ocean includes asymmetric spreading, between Chrons M25 and M0 (154 Ma to 120.6 Ma), and two ridge jumps at about 170 Ma and 160 Ma. We identify and map twenty-two Mesozoic Chrons, including several in the Jurassic Magnetic Quiet Zone (JQMZ), between the Atlantis and Fifteen Twenty fracture zones on the North American Plate, and between the Atlantis and Kane fracture zones on the African Plate. Chron M40 (167.5 Ma) is mapped about 65 km outboard of the conjugate Blake Spur and S1 magnetic anomalies, over the respective North American and African flanks of the ocean basin. Inboard of these prominent anomalies, the conjugate East Coast and S3 magnetic anomalies, are respectively located about 180 km and 30 km inboard of the BSMA-S1 pair. Therefore the ridge jump to the east between BSMA and ECMA anomalies at about 170 Ma theorized earlier is supported by this study. The Width of the African JMQZ is about 70 km greater (22%) than the North American JMQZ. A second ridge jump is suggested by additional, correlative anomalies over the African flank. Modeling results indicate that this jump occurred between 164 Ma and

159 Ma (Chrons M38 and M32). The ridge jumps can be related to plate interactions as North America separated from Gondwana. It has not escaped our attention that these ridge jumps, especially the latter, could correspond with the opening of the Gulf of Mexico.

VARIATIONS IN CRUSTAL THICKNESS AND EXTENSIONAL STYLE ALONG THE SCOTIAN MARGIN, ATLANTIC CANADA: CONSTRAINTS FROM SEISMIC DATA AND 3D GRAVITY INVERSION

Dehler, Sonya A.[1] and Welford, J. Kim[2]

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[2] Memorial University of Newfoundland, Dept. of Earth Sciences, St. John's NL, A1B 3X5

The opening of the North Atlantic Ocean produced a wide range of rifted margin geometries, with broad differences in subsidence patterns, crustal extension, and volcanism. The continental margin off Nova Scotia is interpreted as the transition from a volcanic margin in the southwest, along the US Atlantic margin, to a non-volcanic margin that extends to the east and north as far as Labrador. Other characteristics, such as the depth and width of the overlying sedimentary basin, also vary dramatically along the length of the margin. Seismic data have helped to establish the present-day geometry of the thinned continental crust along several cross-sections. Gravity data, which cover the entire margin and adjacent continental and oceanic regions, provide a means of extending these interpretations across the region. We examine regional crustal thickness and its links to variations in extensional style along the margin through a 3D inversion of gravity data, with constraints from previous and new seismic interpretations. The resulting pattern of crustal thickness highlights trends that may provide insight into the extensional processes associated with rifting of this margin.

NEW PROFILE MODELS OVER THE U.S. EAST COAST CONTINENTAL MARGIN

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[2]U.S. Department of the Interior, 1201 Elmwood Park Blvd., LA, 70123, United States
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Profile-based models are excellent for incorporating multiple data sets to illustrate basin architecture. New models across the U.S. East Coast Continental Margin incorporate reprocessed seismic lines, depth-stretched with projected well data, stacking functions and published refraction velocities. Four dip profiles (ranging from 220-480 km each) were tied to a composite (~2,300 km) strike profile; then extended landward and seaward to model long-wavelength crustal variations (from unthinned continental to fully oceanic regimes) defined by our latest gravity and magnetic data.

The seismic interpretation constrains shallower horizons while deep crustal structure derives largely from potential field and published refraction data. Intermediate levels, especially acoustic basement, are revealed as other layers are defined. Models frequently constrain the nature and volume of intrusives such as the lamprophyre dike swarm cored Great Stone Dome (Schlee Dome), and allochthonous salt diapirs, as targeted in the profile model. The feature extents were then interpreted areally, away from seismic coverage, based on gravity and magnetic imagery.

Comparing our profiles with published interpreted and modeled seismic lines; *i.e.*, DNAG volumes, the authors note significant differences. Previously interpreted "salt structures" in the Georges Bank Basin (GBB) do not exist. Salt structures in the Baltimore Canyon Trough (BCT) appear limited to a small,

seismically defined diapir and the salt penetrated in the Hudson Canyon 676-1 well on the flank of Schlee Dome. We validated salt structures in the Carolina Trough (CT), although the CT appears to be more complex and separate from the Blake Plateau Basin and BCT. Sediment thickness maxima in the GBB were confirmed on one model and matched to gravity data that improves the definition of previously indicated sub-basins with some exploration potential. Ongoing work is extending the interpretation of the models across the entire margin and will no doubt reveal further interpretation changes.

SYSTEMATIC VARIATIONS IN BASEMENT MORPHOLOGY AND RIFTING GEOMETRY ALONG THE NOVA SCOTIA AND MOROCCO CONJUGATE MARGINS

Wu, Yue[1]; Louden, Keith[2]; Tari, Gabor[3]

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[3]OMV Exploration and Production, Gerasdorfer Strasse 151, Vienna, 1210, Austria

The Nova Scotia and Morocco margins formed within a complex transition region between volcanic-style margins to the south and non-volcanic margins to the north. We present new results including recent deep seismic profiles that help document the nature of this transition. Seismic profiles along and across the Nova Scotia margin show two abrupt transitions from south to north. The first transition represents a sharp reduction in syn-rift volcanism at ~64^{o}W, coincident with major changes in the East Coast Magnetic Anomaly (ECMA) and with the southern limit of the Slope Diapiric Province. The second transition at ~ 60^{o}W represents a further restriction in syn- and post-rift volcanism that leads to exposure of serpentinized mantle basement or creation of highly tectonized ultra-slow spreading oceanic crust. This transition is represented by a major change in basement morphology marked by an oblique zone of highly extended and faulted continental crustal blocks. It is also coincident with a transition in salt deformation from autochthonous diapiric structures to allochthonous canopies.

Revised plate reconstructions of maximum and minimum closure (*i.e.* before rifting and at final separation), constrained by a set of combined seismic profiles, show similar transitions along the Moroccan margin. The southern transition occurs at a major change in the West Africa Coast Magnetic Anomaly (WACMA) and the southern limit of the Morocco Salt Basin. Thus the two margins are basically non-volcanic except at their southern extremes. The second transition occurs at a major oblique basement structural high (Tafelney Plateau), which has been considered as a high relief accommodation zone (HRAZ), and contains highly extended faulted crustal blocks similar to those in conjugate position off central Nova Scotia. This transition marks a major change in rifting asymmetry and separates the margins into two fundamentally distinct segments.

THE POST-RIFT EVOLUTION OF THE ATLANTIC MARGIN OF NW AFRICA: A NOT-SO-QUIET PERIOD OF EXHUMATION AND EROSION

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The post-rift stage of passive continental margins is generally characterized by gentle subsidence decreasing through time. Until now, this is also thought for the Atlantic margin of NW Africa and, in particular, the Moroccan and Sierra Leone transects. In the last years, however, absolute ages obtained with a variety of thermochronometers ranging from ^{40}Ar/ ^{39}Ar to Apatite Fission Tracks and (U-Th)/He on apatites have documented fully unexpected vertical movements, incompatible with the simple scheme hitherto accepted. In Morocco, samples from areas considered as stable, such as the Meseta and the Anti Atlas have provided evidence for a stage of Early to Middle Jurassic subsidence followed by exhumation bringing sampled rocks at the Earth's surface before the late Cretaceous. At this time, relief developed during the exhumation must have been eroded away as shown by the flat and fairly regular basis of the Upper Cretaceous shallow water sediments. In Sierra Leone, the Freetown Layered Igneous Complex was emplaced at depths of at least a few kilometers at 210-190Ma and was then exhumed in a poorly constrained time span possibly in the Late Jurassic. The emerging picture is one where a very large segment of the rifted continental margin elongated parallel to the margin and located several tens of km E of the continent-ocean transition was exhumed during the post-rift evolution. Km-scale exhumation provoked major erosion and production of terrigenous sediments most of which were brought offshore forming the peculiar coarse-grained terrigenous intercalations in the otherwise monotonous succession encountered in the deep offshore.

Session 1B - Margin Evolution & Development

THE MESOZOIC ATLANTIC CANADA OFFSHORE MARGIN: HISTORY OF EXPLORATION, PRODUCTION AND FUTURE EXPLORATION POTENTIAL

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The Mesozoic Basins of the western Atlantic Margin are a result of intermittent rifting and separation of North America from Africa and Europe during the Late Triassic to Early Cretaceous. The extensional tectonics produced elongated, up to 20km deep, basins and subbasins, containing both synrift and syn-drift sedimentary sequences that contain excellent reservoir and source rocks. Numerous structural, stratigraphic and combination traps were formed during the synrift and post-rift stages.

Exploration in Atlantic Canada began in the late 1960's with sporadic successes and considerable exploration failures which have caused several boom and bust cycles. The late 1970's through to the mid-1980's was a time of significant discoveries in 1) Newfoundland's Jeanne d'Arc Basin with giant oilfields Hibernia, Terra Nova, Hebron and White Rose and 2) in the Sable Subbasin, offshore Nova Scotia with gas discoveries at Venture, Thebaud and North Triumph fields. As is typical in most basins, the largest fields were found quite early in the exploration cycle hosted in structural features, easily mapped with seismic data. The following exploration cycle, post 1988, was slowed by a combination of low resources prices and size potential of prospects seen on 2D seismic near the discovered fields.

By the late 1990's, a new round of exploration began in both Newfoundland and Nova Scotia that was focused on unexplored deepwater basins, the Flemish Pass and Orphan Basins off Newfoundland and the Scotian Slope basin. More than 256,105 km of new 2D seismic and 53,318 km km2 of 3D seismic surveys combined to give a much better understanding of the basins and detail structure and stratigraphy control. In the deepwater Nova Scotia one discovery was made at Annapolis, with the subsequent delineation well proving unsuccessful. More, recently, the first deep water, deep penetration well in the Orphan Basin was also an economic failure.

Future exploration in the Canadian East Coast Basins will focus around producing fields in Jeanne d'Arc Basin and new field wildcat work in the East Orphan, Laurentian and Hopedale basins, off Newfoundland and Labrador, while Nova Scotia offshore will witness a return to shelf exploration to support the pipelines. In the long-range we believe that the Industry will resume exploration in the Flemish Pass, Carson and Saglek basins of Newfoundland, the Scotian Slope Basin and Jurassic Carbonate Trend and in 2012, if the George's Bank moratorium is lifted, we will see exploration in the Georges Bank Basin adjacent to the US border.

Canada's Atlantic Margin remains an underexplored geological province with high risk and high reward situated in the proximity of world's largest oil and gas market, in a harsh environment that has been conquered in both the Jeanne d'Arc and Scotian basins by on the shelf technologies.

LOW-T THERMOCHRONOLOGY PROVIDES NEW INSIGHTS IN THE MESOZOIC TO PRESENT

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To constrain upward and downward vertical movements in NW Africa we have sampled for low-T thermochronology a 500km long transect from the Mediterranean coast to the Anti Atlas of Morocco. The analysis of this large data set has provided major surprises requiring a reconsideration of generally accepted ideas.

The data we have produced document an Early to Middle Jurassic stage of subsidence and of Late Jurassic to Early Cretaceous exhumation affecting a large elongated region stretching from the Moroccan Meseta to the Anti Atlas. These domains are typically considered as stable during the same time span. Late Jurassic to Early Cretaceous exhumation caused the erosion of a large amount of terrigenous sediments transported offshore and deposited in the otherwise monotonous and fine-grained succession of the Moroccan Atlantic passive continental margin.

Alpine deformations began in the Late Cretaceous and continue until present. They were initially associated with the development of large scale, WNW-ESE trending folds and then with localization of shortening and exhumation in the Atlas system.

GEOTECTONIC SCENARIOS FOR THE EVOLUTION OF THE SOUTH ATLANTIC BRAZILIAN MARGIN: LEFT-LATERAL LOWER CRETACEOUS OBLIQUE RIFTING FOLLOWED BY UPPER CRETACEOUS TO PRESENT ONGOING COMPRESSION

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We propose that the evolution of South Atlantic Brazilian margin was performed in two successive geotectonic scenarios. The first one was dominated by left-lateral Lower Cretaceous oblique rifting that culminated with South Atlantic seafloor spreading. This scenario produced right stepped NNE-SSW-trending blocks where kitchens are found.

The second scenario has been produced as the South America (SA) plate have been moving westwards with respect to the Africa plate. While moving, this plate is frontally or obliquely "colliding" against other plates (Nazca, Caribbean, Scotia) that are moving eastwards. This geotectonic scenario that began to be delineated in the Upper Cretaceous, was definitely established during the Tertiary and is prevailing in the Present. This scenario is analogous to a huge traffic accident that started in Mid-Upper Cretaceous and is still going on. As a result, the bulk of SA plate has been in horizontal compression since the Upper Cretaceous up until the Present. In such a mechanical environment, we infer that the intraplate deformation across the SA plate will be concentrated along its favorably oriented mechanical discontinuities. On the basis of this rational, the post-rifting evolution of the Brazilian Margin Basins and their petroleum systems should be influenced by compressional/strike-slip reactivation of rift-related and basement structures, modulated by salt tectonics. Results of analyses and modeling of a comprehensive geological and geophysical data set have supported this inference.

Given that intrinsically similar geotectonic scenarios (*i.e.* rifting followed by sea floor spreading; frontal or "collision") should be operating across the Central Atlantic conjugate margins as well, we speculate that using such a frame could help understanding the evolution of their petroleum systems eventually.

REVISITING CRETACEOUS TECTONISM AND VOLCANISM IN THE LAURENTIAN SUB-BASIN AND ORPHEUS GRABEN, OFFSHORE NOVA SCOTIA

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This study is concerned with the impact of Cretaceous tectonism and volcanism on the maturation and diagenesis of the petroleum system in the Orpheus Graben and the Laurentian sub-basin, components of the Mesozoic-Cenozoic Scotian Basin located offshore of Nova Scotia. The Laurentian sub-basin and Orpheus Graben have been strongly affected by early Cretaceous motion on the Cobequid-Chedabucto-Southwest Grand Banks fault system. The region is relatively unexplored although about a dozen wells have been drilled. Hydrocarbon shows are known from the eastern portion of the Laurentian sub-basin. Previous work has shown regional unconformities in Orpheus graben corresponding to the base-Missisauga Formation (base Cretaceous), base-Logan Canyon Formation (early Aptian) and top Cree Member (early Albian). Regional seismic reflection profiles from the shelf off southern Newfoundland and on the SW Grand Banks have been studied and similar unconformities have been mapped throughout the region. This sequence stratigraphic approach to seismic interpretation allows details of the lower Cretaceous stratigraphy determined from wells on the SW Grand Banks to be correlated and refined within many wells within the Orpheus Graben and Laurentian sub-basin. The precise stratigraphic position of volcanic products within the wells has been re-evaluated and the volcanic character of the rocks refined by study of cuttings and well logs. Volcanic products within the wells have been compared with detrital volcanic material found distally in the Scotian Basin. The timing of regional unconformities appears to mark the onset of different components of the volcanic system. Deformation on the unconformities and distribution of volcanism are related to the complex opening history of Europe from North America. The widespread volcanic activity indicates a regional and long-lived magma source, which would have manifested itself in an elevated heat flow in the area, which in turn influenced organic maturation and diagenetic processes in the petroleum system.

40AR-39AR STUDY OF THE FREETOWN LAYERED IGNEOUS COMPLEX (FLIC), FREETOWN, SIERRA LEONE, WEST AFRICA: IMPLICATIONS FOR THE INITIAL BREAK-UP OF PANGAEA TO FORM THE CENTRAL ATLANTIC OCEAN

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The break-up of Pangaea to form the Central Atlantic and its passive margins began in the Early Jurassic. Geo-tectonically, the break-up was notably characterized by the formation of the Central Atlantic Magmatic Province (CAMP), covering once-contiguous parts of North America, Europe, Africa and South America. The Freetown Layered Igneous Complex (FLIC) emplaced within the heart of CAMP and measuring on surface, 65 x 14 x 7 km, is the largest single layered igneous intrusive yet known on either side of the Central Atlantic. Geophysical investigations indicate that the intrusion extends offshore to a depth of about 20 km. Geologically FLIC is a rhythmically layered elongated ultramafic-mafic lopolith divisible into 4 major zones each comprising repeated sequences of troctolitic, gabbroic and anorthositic rocks. A first series of ^{40}Ar-^{39}Ar analyses of plagioclases, biotites and amphiboles from zones 1 and 2 yields plateau ages ranging from 196.3 ± 3 Ma to 228.6 ± 6 Ma Because ^{40}Ar-^{39}Ar dates of these minerals represent cooling ages, we interpret these dates as representing a minimum intrusion-age of the Complex

implying that its true emplacement age might be somewhat older than 230 Ma. Given that most established CAMP ages revolve around 200 Ma or younger, we hypothesize that FLIC represents a hitherto unknown pre-CAMP magmatic event that might have thermally triggered the initial break-up of Pangaea to form the Central Atlantic. This view is consistent with field-observations that the Complex is cross-cut by predominantly coast-parallel mafic dykes we attribute to the CAMP dyke-swarm. To ascertain the hypothesis, we are currently carrying out additional ^{40}Ar-^{39}Ar dating of zones 3 and 4 and the cross-cutting dykes to be followed-up by U-Pb zircon dating to establish, precisely, the true emplacement age of the Complex.

THE INS AND OUTS OF BUTTRESS FOLDS: EXAMPLES FROM THE INVERTED FUNDY RIFT BASIN, NOVA SCOTIA AND NEW BRUNSWICK, CANADA

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Buttress folds form in the hanging walls of non-planar normal faults during basin inversion. Slip occurs more easily along the lower, more gently dipping fault segments, whereas the upper, more steeply dipping fault segments act as buttresses, inhibiting slip and causing the hanging-wall strata to shorten and fold. We have determined the geometry of buttress folds using seismic (both offshore and onshore), field, aeromagnetic and DEM data from the inverted Fundy rift basin, Nova Scotia and New Brunswick, Canada.

The buttress folds exhibit a variety of geometries. Generally, the hinges of buttress folds parallel the strikes of the adjacent extensional faults. The tightest folds occur adjacent to the most steeply dipping upper fault segments, whereas broader folds occur adjacent to more gently dipping upper fault segments. Away from the steeply dipping upper fault segments, other folds occur as trains of hanging-wall synclines and anticlines, indicating that a detachment level exists at or above the lower, gently dipping fault segments. Other potential detachment levels include evaporite units in the hanging wall. Therefore, many of the buttress folds in the Fundy basin are a combination of buttress and detachment (buckle) folds.

Based on kinematically compatible slip vectors on differently oriented segments of the border-fault systems and results of experimental models of oblique inversion, the regional shortening direction during inversion of the Fundy basin was NE-SW. This inversion-related deformation is, at least partially, partitioned into pure-shear and simple-shear components. The fault-parallel buttress/detachment folds accommodate the pure-shear component, whereas left-lateral strike-slip or gently raking oblique-slip faults accommodate the simple-shear component. Thus, the buttress/detachment folds in the Fundy basin do not necessarily indicate the regional shortening direction. Instead, their trends reflect the variable local shortening direction associated with the pure-shear component of the deformation.

SECOND-ORDER SEQUENCES AND THEIR APPLICATION FOR EXPLORATION IN THE DEEP-WATER SCOTIAN SLOPE

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Large-scale changes in lithofacies and stratigraphic architecture resulting from relative sea-level changes have been a prime research focus for the past few decades. Within industry, prediction of hydrocarbon play elements using sequence stratigraphic techniques is well-established. Our previous work demonstrated the veracity of a sequence stratigraphic model for the Arabian Plate identifying 63 major Maximum Flooding Surfaces (MFS) and Sequence Boundaries (SB). Ongoing work, incorporating nearly all of Earths sedimentary basins, now demonstrates the occurrence of 118 biostratigraphically constrained sequences that are global and observed independent of tectonics or sediment supply. The rapidity and magnitude of sea-level changes inferred from our model implicate eustatic forcing.

In Eastern Canada, recent exploration has shifted focus towards the deepwater of the Scotian Slope driven by successes in other circum-Atlantic deepwater basins. Despite a proven petroleum system, the slope remains underexplored. Sandy lowstand fans comprise the principal reservoir targets, but are risky, borne out by few commercial successes.

Biostratigraphically constrained sections from the Scotian Shelf provide a framework within which sequence stratigraphy can be applied. The recognition of large hiatus relating to second-order SB's allows prediction of viable lowstand reservoirs down systems-tract. For example, the absence of Early Paleocene in many shelf wells, relates to an important late Maastrichtian SB during which significant down-slope transport of sediment is predicted. Major transgressions are often associated with development of organic-rich facies. Such is the case for Naskapi Member source rocks which relate to a second-order intra-Aptian MFS.

Here, major second-order sea-level fluctuations are identified which are postulated to have exerted an important control on reservoir and source rock development on the Scotian Slope.

Thursday, August 14, 2008

Session 1C - Margin Evolution & Development

SLOPES, BASIN FLOORS, DIAPIRS, AND CANOPIES: REGIONAL-SCALE SALT-SEDIMENT INTERACTION IN THE NORTHERN GULF OF MEXICO AND THE SCOTIAN OFFSHORE

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Salt diapirs and allochthonous canopies are well known from the northern Gulf of Mexico and the Nova Scotian offshore. Canopies can be divided into two end-member styles: salt-stock canopies, in which the canopy is linked to the autochthonous salt layer by vertical feeder diapirs and intervening minibasins are characterized by turtle structures; and salt-tongue systems, where the canopies are connected to the deep layer by counterregional welds that have basinward-dipping expulsion-rollover structures in their hanging walls.

The fundamental difference between the two styles is the degree of asymmetry. In salt-stock canopies, diapirs grow vertically and spread radially before amalgamating, and sub-canopy withdrawal geometries tend to be symmetrical. In salt-tongue canopies, diapirs grow up and basinward and extrude basinward, and the withdrawal basins are correspondingly asymmetric. Because both diapirs and allochthonous bodies grow passively at the sea floor, the simplest explanation for the difference is the slope of the sea floor. If it is horizontal, there will be no preferred direction of growth and extrusion, resulting in vertical diapirs and salt-stock canopies. If the sea floor slopes, diapirs will lean basinward and extrude salt tongues basinward. Thus, the structural style is largely determined by the evolving bathymetric profile of the passive margin, which in turn is controlled by the history of sediment progradation.

In the northern Gulf of Mexico, a regional boundary between more proximal salt-tongue canopies and more distal salt-stock canopies roughly parallels the margin and probably represents a long-lived base of slope initially established during Paleogene Wilcox deposition. In the Scotian deepwater, a similar boundary is oriented highly oblique to the margin, with vertical diapirs to the southwest (Shelburne Subbasin) and salt-tongue canopies to the northeast (Sable Subbasin). The structural boundary is located along the southwestern edge of the Upper Jurassic to Lower Cretaceous Mic Mac and Missisauga progradational system, and thus represents a lateral boundary to a broad slope to the northeast, with a basin floor along strike to the southwest. One of the key applications of this model is that it can be used to estimate the paleo-toe of slope and thus regional turbidite facies distribution, with channelized slope facies dominant in areas of salt-tongue canopies and ponded basinal facies more likely in areas with vertical diapirs and salt-stock canopies.

SEISMIC STRATIGRAPHY, SALT STRUCTURES AND THERMAL AND PETROLEUM SYSTEMS MODELS ACROSS THE CENTRAL NOVA SCOTIA SLOPE BASIN

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Two regional deep seismic profiles, GXT NovaSpan 1400 and Lithoprobe 88-1A, are used to better characterize the sediment, salt and basement structures across the Central Nova Scotian Slope Province. Imaging of deeper structures is especially improved, using either pre-stack depth migration with the long offset streamer (NovaSpan 1400) or a combination of pre-stack time migration and wide-angle velocity models (Lithoprobe 88-1A). Seaward of the salt, basement morphology and crustal velocities suggest that highly-stretched and rotated continental crustal blocks extend further into the ultra-deep basin. Beneath the salt, basement is also well-defined except locally beneath major salt diapirs.

Petroleum systems models are derived along the two profiles for various potential source rocks and reservoirs. Along both profiles, salt flank and salt crest Late Jurassic and Early Cretaceous reservoirs form the primary exploration targets. However, significant differences also exist for the two profiles, primarily associated with variations in salt structures. Along NovaSpan 1400, the Jurassic Verrill Canyon Formation is the main source rock for both the Jurassic and Cretaceous reservoirs. For the Early Cretaceous reservoir, hydrocarbons may contain a major volume of liquids (>75%) with an API of 45-55^o and only mild overpressures. Along Lithoprobe 88-1A, Early Jurassic lacustrine and Late Jurassic salt-associated marine reservoirs are potential exploration targets, although these would lie within an over-pressured, dry-to-wet gas regime. Mass balance calculations for both seismic lines indicate that more preserved hydrocarbons are expected within the various reservoirs on NovaSpan 1400.

Model calculations of present-day sea-floor heat flow predict a gradual landward reduction from 55 mW/m^2 in the ultra deep-water basin, to 45 mW/m^2 on the upper slope. However, large variations are caused by high conductivity associated with salt diapirs, yielding values as high as 85 mW/m^2. In July 2008, we plan to take detailed measurements along both profiles in order to verify these predictions.

BASIN-SCALE SALT TECTONIC PROCESSES AND SEDIMENT PROGRADATION IN THE SLOPE AND DEEPWATER BASIN OF THE NORTH-CENTRAL SCOTIAN MARGIN

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The complex salt deformation styles characterizing the diverse Scotian Basin salt provinces are the result of complex basement topography in the narrow linked rift basins, variable salt thickness, and high clastic sediment input during the Jurassic and Cretaceous. Salt tectonics concepts developed in salt basins around the Atlantic margins cannot be adapted reliably to the Scotian margin. Consequently, the next generation of basin models must investigate the role of the unique basin characteristics including palaeogeography, sediment supply, and rift basin geometry.

Basin-scale seismic sections of the GXT NovaSpan data allow structural modelling and provide the parameter for scaled physical experiments of regional transects of the Laurentian, Abenaki, and Sable subbasins extending from the shelf to the deepwater basin. The Salt Dynamics Group utilizes physical experiments to analyze salt tectonic processes and their interaction with depositional systems. 4D strain data and experiment sections enable mechanical modelling of salt tectonic processes from early post-rift salt mobilization to late post-rift allochthonous salt complexes. Salt tectonic concepts derived from our experiments relate characteristic salt structures to the palaeo-depositional environment and kinematic stages of the basin evolution.

Our study demonstrates that the Scotian salt provinces differ strongly from the salt basins of the Gulf of Mexico and the younger South Atlantic salt basins. Low mechanical coupling of the sediment overburden due to thick original salt in narrow linked rift basins has favored rapid down-building and sediment aggradation rather than progradation in the early post-rift stage. Salt mobilization and basinward salt inflation started in the Laurentian Basin and propagated in southward direction along the margin due to shelf-parallel sediment transport sourced by the Laurentian Fan from the NE. This depositional pattern has led to diachronous salt extrusion shown by southward younging of allochthonous salt complexes in the North-Central Scotian Basin.

4D PHYSICAL MODELLING OF SALT TECTONICS IN SABLE SUB-BASIN, SCOTIAN MARGIN

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Salt tectonic structures of the interconnected Sable, Abenaki, and Laurentian sub-basins at the north-central Scotian margin indicate variable rift-basin geometries and tectono-sedimentary environments with high rates of sedimentation and progradation during the Jurassic and Early Cretaceous. The understanding of the deepwater tectono-stratigraphic framework in this area depends on our ability to accurately interpret the variable depositional systems and corresponding salt tectonic structures in these sub-basins.

This study integrates seismic interpretation with analogue experiments to gain insight into the mechanics of thin-skinned deformation and halokinetic sequence stratigraphy in the Sable sub-basin. The experimental setup including salt basin morphology, sedimentation patterns and rates, and initial salt thickness is determined using the GXT NovaSpan survey and other public domain seismic reflection and well data. The initial salt basin morphology is modeled as two rift half grabens. Variable original salt thickness combined with high, shelf-oblique, sediment input in landward salt-withdrawal basins during the Middle Jurassic to Early Cretaceous has caused major salt inflation in the mid to distal salt basin. This inflated salt complex had a positive, pronounced, and irregular topography which resulted in localized depocentres throughout the Early to Late Cretaceous. These localized depocentres of the deepwater slope and basin have led to the development of a confined mini-basin bounded by a salt wall or diapir and an extensive allochthonous salt tongue. A compressional phase is seen during the Late Cretaceous in features such as thrusted packages of rafted sediments over a salt pillow and squeezed diapirs.

The next phase of the study will focus on the 3D depositional patterns of the entire north-central Scotian margin to analyze the linked structural evolution of the Laurentian, Abenaki, and Sable sub-basins. Improved understanding of the structurally dynamic depositional system of the Scotian Basin will support future exploration activities in the slope and deepwater basin.

THERMAL EFFECTS OF SALT ON THE PETROLEUM SYSTEM: EVIDENCE FROM FISSION TRACK THERMOCHRONOLOGY, FLUID INCLUSIONS AND BASIN MODELLING

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The thermal conductivity of salt is up to four times greater than other sedimentary rocks, thus salt diapirs funnel geothermal heat and cause a high-temperature anomaly in the basinal sediments above. Depending on the shape of the salt body and its depth, the surface heat flow over the salt can be 2 to 3 times greater than away from the salt, and thus can have drastic effects on diagenesis and on hydrocarbon maturation: over mature above, under mature below salt. In addition to heat conduction, advection of warm fluids (brines, oil and gas) produces highly localized heat anomalies on top of diapirs, as proposed for Atlantic Canada offshore by C.E. Keen (1983, CSPG Bull. 31, 101-108).

In the Maritimes Basin, Lower Carboniferous salt of the Windsor Group has diapirically risen to the surface locally from a depth of ca. 8 km. Apatite fission track data indicate that the basin was inverted and rocks now at surface cooled below ca. 100°C during the Triassic-Jurassic Atlantic margin break-up, whereas apatite within siltstone in the salt dome yields Cretaceous apparent ages; the temperature-sensitive fission-track lengths have been significantly shortened (equivalent to what happens >3 km depth in a well). Time-temperature modelling of the data requires re-burial of the salt structure in post Early Cretaceous times and heating of the diapir to higher temperatures than the regional background, confirming the focused thermal effects of the salt diapir. We have demonstrated similar thermal effects from evaporite diapirs in the Sverdrup Basin in the Canadian Arctic.

We have studied fluid inclusions in autochthonous and allochthonous salt in Atlantic Canada. Supposedly-impermeable salt contains a variety of generations of fluid inclusions, some with brines, some with oil and gas. It is evident that salt has been permeable to various fluids. Entrapment temperatures of the fluids vary from 25°C to more than 100°C. For autochthonous Jurassic salt this implies a sub-salt source rock or an algal source within the salt. Modelling of Scotian Basin wells (e.g. Wyandot) using Petromod® shows that the presence of salt in the stratigraphic column imposes drastic changes in the thermal evolution of the petroleum system.

SEDIMENTARY BASINS IN THE CENTRAL AND SOUTH ATLANTIC CONJUGATE MARGINS: DEEP STRUCTURES AND SALT TECTONICS

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The tectonic evolution of Central and South Atlantic conjugate margins has recently been constrained by the integration of geological and geophysical data, including deep seismic reflection profiles extending from the coastline towards the oceanic crust. The syn-rift and halokinetic structures imaged in these profiles have fundamental impact on the petroleum exploration of deep water regions, allowing the identification of sedimentary depocentres with pre-salt and post-salt source rocks. Well and seismic data from conjugate basins along the Canadian (Nova Scotian) and Northwest African (Moroccan) margins indicate an initial phase of subsidence (Triassic rifting) followed by deposition of Late Triassic evaporites, which were coeval with a major magmatic event that is registered in the conjugate margins. Igneous intrusions within evaporite layers have also been recently recognized as part of the CAMP magmatism in the intra-cratonic Paleozoic basins in northern Brazil, with important effects on the petroleum systems.

The South Atlantic rifting in the Early Cretaceous formed conjugate basins along the Eastern Brazilian and West African margins. The new vintage of regional deep seismic profiles indicate that several segments of the incipient margin are characterized by the presence of seaward-dipping reflectors in the transition from continental to oceanic crust, which appear to be coeval with salt deposition. The pre-salt sedimentary package is characterized by a belt of proximal syn-rift tilted blocks which are overlain by an extremely thick sag basin in more distal areas. Several boreholes have drilled though the salt layer and resulted in important hydrocarbon discoveries in the South Atlantic. We discuss the analogies between structures imaged in the Central (Canada-Morocco) and South Atlantic (Eastern Brazil - West Africa), particularly in the ultra-deep water regions that are exploratory frontiers for petroleum exploration.

Session 2A - Petroleum Systems

PETROLEUM SYSTEMS OF THE U.S. CENTRAL ATLANTIC MARGIN

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From 1975–1988, a single stage of expensive, disappointing hydrocarbon exploration took place on the U.S. Atlantic margin (USAM). Fifty-one wells (5 COST – 46 industry) were drilled in the Georges Bank basin, Baltimore Canyon Trough (BCT), and Southeast Georgia Embayment: none were drilled in the Carolina Trough.

Tested play types included drape/compaction structures, amplitude anomalies, listric fault traps, a dyke-swarm cored uplift, various carbonate margin plays, and slope-apron siliciclastics. The only positive results in the USAM were the gas encountered and/or tested in the eight wells drilled in the four-block Hudson Canyon (HC) 598 area, a listric fault trap in the BCT.

Analogs previously applied to USAM basins are inappropriate. While the same geologic age, they differ in regional and local setting. Carbonate and clean/mature siliciclastic reservoir analogs in the Gulf of Mexico Mesozoic basins are located on salt rollers, or related to salt-cored or salt-withdrawal structures. Other than in the Carolina Trough, similar structures are not widely recognized in USAM basins. The productive Sable sub-basin siliciclastic depocentre is located basinward from the carbonate margin and reservoirs are often overpressured, preserving porosity and permeability. In USAM basins, siliciclastic depocentres are generally landward from the margin and reservoirs encountered to date are not overpressured.

Throughout the USAM, issues regarding petroleum system elements include: generally degrading siliciclastic reservoir quality with depth, poorly developed carbonate reservoir facies, identification and areal distribution of source rocks, and timing of seal deposition/lithification in carbonate margin tests drilled to date. Petroleum system processes; *i.e.*, timing of hydrocarbon generation–migration–accumulation are also poorly understood and appreciated.

Assessment of these basins using a forensic petroleum system approach may provide guidance for future exploration strategies.

UNUSUAL JURASSIC CONDENSATE OF THE HUDSON CANYON AREA, U.S. ATLANTIC

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Gas and minor condensate was discovered in Late Jurassic and Early Cretaceous reservoirs in the Hudson Canyon (HC) 598 area of the Baltimore Canyon Trough (BCT). The oldest sedimentary rocks in the BCT are interpreted to be Triassic syn-rift deposits. Predominantly carbonate Early to Middle Jurassic units overlie the Triassic and underlie the Late Jurassic-Early Cretaceous siliciclastic reservoirs.

Condensates from the Kimmeridgian (HC 598-1) and Albian (HC 642-2) reservoirs originate from the same source rock. While biomarkers are absent or in low relative abundance in the condensate, diamondoids, consisting primarily of adamantane and diamantane, along with their methyl and ethyl derivatives, are relatively abundant. The diamondoids have been concentrated during intense thermal cracking of an original oil. The carbon isotopic properties of the condensate are extremely enriched in ^{13}C (-23.7‰ to -24.6‰ PDB), consistent with a Jurassic marine kerogen source. Triassic source rocks appear unlikely to have sourced these condensates because Triassic-sourced oils in the Newark and Culpepper basins are strongly depleted in ^{13}C. The unusual geochemistry of the condensate is interpreted to be the result of extreme thermal cracking of oil sourced from the underlying Early to Middle Jurassic carbonate-rich source rocks. Diamondoid maturity indices suggest that the maturity of the condensate ranges from ~1.3% to ~1.6% vitrinite reflectance (R_o), significantly higher than the estimated ~0.9% R_o of the deepest Kimmeridgian reservoir. Vertical migration of deeper, more mature hydrocarbons into shallower reservoirs was facilitated by faults connecting the source and the reservoir.

The enrichment of diamondoids and ^{13}C are similar to condensates sourced by the Late Jurassic Smackover Formation of the U.S. Gulf Coast. The role of Jurassic oil-prone source rocks in the Central Atlantic is underappreciated.

BALTIMORE CANYON UNTESTED GAS POTENTIAL

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Hydrocarbon exploration in the Baltimore Canyon Trough (BCT) from the late-1970's through the mid-1980's targeted Middle Jurassic and younger siliciclastics and carbonates in structural and stratigraphic traps. Hydrocarbons were drillstem tested in five wells in the four-block Hudson Canyon (HC) 598 area with cumulative flow rates in excess of 90 MMCFG/D. Apparent discontinuity in reservoir extent resulted in project abandonment. A state-of-the-art geochemical interpretation of condensates from the HC 598 area suggests a deeper, Middle–Lower Jurassic source rock, which has similarities to the Late Jurassic Smackover Formation source rock encountered in the Gulf of Mexico.

Reprocessed seismic data analyzed using amplitude versus offset methods indicates reflectors typical of a single salt layer, which one-dimensional modeling suggests reaches a thickness in the range of ~200 feet in the center of its depositional extent, and which thins to less than ~70 feet in 2 km on either side. This interpreted autochthonous salt zone extends over an area ~15 miles wide and may cover ~2,900 mi^2. Because drilling has not penetrated this zone, its age is speculative and has been interpreted as being Early Jurassic. The presence of a salt bed suggests arid and restricted, and potentially anoxic, depositional climatic conditions during its time of deposition. Impermeable evaporites and shales, between the Early and Late Jurassic, may provide excellent seals explaining the lack of significant migrated hydrocarbons into porous reservoir rocks of the Late Jurassic and Cretaceous age.

An isopach map of the Triassic-Jurassic in the BCT suggests that a significant area of postulated Early Jurassic age rocks is buried to depths sufficient for gas generation. Reservoirs could be in carbonates and/or shelf siliciclastics. Future exploration in the BCT should consider focusing on deeper sections of the Early and Middle Jurassic, nearer to the BCT Jurassic depocentre, and at much greater depths than previously drilled.

PALEOCEANOGRAPHIC AND PALEOENVIRONMENTAL IMPLICATIONS FOR HYDROCARBON EXPLORATION OF THE CONTINENTAL SLOPE OFF NOVA SCOTIA

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The continental slope off Nova Scotia has recently become of interest for oil exploration as a potentially new gas province, under the assumption that past success in exploration on the shelf can be extended onto the continental slope. Is such an assumption supported by the sediment depositional history on the shelf and by the general paleoceanography of the Central Atlantic Ocean during the late Mesozoic?

Of all elements of the Petroleum System, only the source rock and presence of reservoir rocks will be discussed. Source rock occurrences depend on marine organic matter generation and preservation. The former are controlled by the availability of nutrients supplied either by continental runoff (therefore controlled by climate), or as a result of coastal upwelling, surface water mixing, and open ocean divergence. Could such conditions have developed during the Mesozoic on the Scotian Slope? An additional constraint to be considered is ocean bottom water oxygenation, as such conditions changed dramatically during Mesozoic-Cenozoic time in the Central Atlantic. During the Late Jurassic, Late Cretaceous and early Cenozoic, oceanic bottom waters in this region were highly oxygenated, resulting in the destruction of organic matter deposited in ocean bottom sediments. In contrast, the middle Cretaceous was a period of organic matter preservation in deep sea and marginal basin sediments, either due to changes in deep water circulation, climate and/or increases in depositional rates.

Occurrence of reservoir rocks is another important parameter to be considered. The existence of both sandstone and carbonate reservoirs was proven by drilling on the shelf. For continental slope exploration, the petroleum industry applied known models of turbidite fans, apparently without giving sufficient consideration to the sediment supply and sea level changes affecting development of the shelf area during the Cretaceous. This may prove to be the major factor in a lack of commercial hydrocarbon discoveries in exploration wells drilled on the Scotian Slope. Deeper understanding of the geologic evolution of the continental margin and paleoceanographic conditions affecting it, together with a modification of exploration strategy are needed to improve the success of hydrocarbon exploration in the Scotian upper slope domain.

THE PENICHE BASIN: TECNO-SEDIMENTATION AND EXPLORATORY ASPECTS

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Petrobras in partnership with Galp and Partex, has acquired a total of 12,000 km^2 in the Peniche basin, offshore Portugal - a counterpart to some northeast North American basins. The main subject of the present work is to show some geological aspects of the Peniche basin, based mostly on seismic data and a few wells drilled nearby. No wells have been drilled in the whole concession area.

The Jurassic Peniche basin is bounded by SW-NE lineaments, which subdivide the basin into horst and grabens, and by NW-SE lineaments, which are most likely transfer faults. From the end of the Jurassic to the present-day, compressional stress seems to have predominated in the basin, reactivating old lineaments, and creating thrust faults and a series of flower structures. Normal faulting associated with sediment deposition related to middle to late Jurassic salt movement is also a common features on seismic lines. Uplifting in the shallow portion of the Peniche basin brought about slumping and rotation of huge blocks in the deep water realm.

Three major unconformities are easily mapped on seismic, and corroborated by well data: 1) base of lower Cretaceous; 2) pre upper Jurassic sequence (strongly erosive), and 3) Cretaceous-Tertiary boundary. The erosive phases associated with these unconformities have great potential to provide sediment that can be transported deep into the basin, suggesting the possibility of sandstones reservoirs, either as channelized or unconfined lobe deposits. Channelized, coarse-grained Cretaceous sandstones are well exposed along the coast in Santa Cruz, Portugal. The wells drilled in the shallow part of the basin have shown porosity ranging from 15% to 30% (Cretaceous) and 15% in deeper sandstones (Jurassic).

Carbonates are another possibility as reservoir rocks, with porosity ranging from 15% to 20% based on bioconstruction, probably rudist reefs such as the ones exposed in several onshore locations and along the coast, such as Praia do Guincho, near Estoril.

The potential source rocks (Pliensbachian and Kimmeridgian), present in outcrops and wells in the Lusitanian basin, have been traced to deep horizons in the Peniche basin, where the sedimentary section is thicker, suggesting greater potential source rock thickness than in the shallow-water areas.

GEOLOGICAL EVOLUTION AND HYDROCARBON POTENTIAL OF THE HATTON BASIN (UK SECTOR), NE ATLANTIC OCEAN

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The deep-water Hatton Basin (flanked by the Hatton and Rockall Highs) is located 600km west of Scotland (NE Atlantic Ocean) on the western margin of the Eurasian continental plate. Prior to Atlantic opening, the area was adjacent to SE Greenland. The basin straddles the UK/Irish median line. Water depths increase southwards from 1000m to over 1300m.

The basin has never been licensed for hydrocarbon exploration and is currently the subject of ownership negotiations related to the UN Convention on Law of the Sea. Consequently it is under-explored. The deepest borehole penetration is by DSDP borehole 116 which terminated at 854m below sea bed in the Upper Eocene.

The Pre-Cambrian metamorphic basement only crops out on Rockall Bank where high-grade gneiss and granulite have been sampled and dated at c. 1900 to 1700 Ma. This is a different terrane from that which underlies most of Scotland. Palaeozoic rocks have not been proved in the area but may provide some of the pre-rift basin infill. The Hatton Basin probably opened during the Cretaceous. Recent (2007) seismic data suggest the presence of tilted fault blocks on the basin margins. Mid Cretaceous (Albian) sandstones and mudstones have been proved (by what? – be specific) at shallow depth on the Hatton High. The area was affected by massive Late Paleocene to earliest Eocene volcanism which emplaced several large central igneous complexes and caused widespread lavas which degrade the seismic data from the deeper geology. Atlantic rifting commenced west of the Hatton High at about 56 Ma. During the Cenozoic the Hatton Basin was affected by differential subsidence and several unconformity-forming compressional events.

Numerous potential hydrocarbon trap styles have been identified including syn-rift tilted fault blocks, folds, truncations, prograding fans, pinch-outs, scarp fans and traps related to sill intrusions. Reservoir intervals are likely to be present in the Cretaceous, Paleocene and Eocene. The overlying Oligocene to Recent sediments are mudstones and oozes and may provide a seal. The main risks for an accumulation are the presence of a source rock and the shallow occurrence of some of the potential traps.

REVISITING THE EAST GEORGES BANK BASIN, OFFSHORE NOVA SCOTIA - WHAT THE EXPLORATIONISTS SAW TWO DECADES AGO

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The East Georges Bank basin is located offshore Nova Scotia on the southeastern Canadian continental shelf. The basin covers 10,000 km^2 (~2.5 million acres) and is one of the last undrilled basins in North America.

The geological understanding of this basin is based on 16,000 km of seismic data which was studied and interpreted in the 1980's by Texaco Canada's geoscientists. The first public presentation of the interpreted data was at a CSPG-GAC-MAC conference in 1988 in St. John's, Newfoundland. Subsequently, the geological and geophysical interpretations were presented at a number of oil industry conferences worldwide (San Diego, Calgary, Lagos, Rio de Janeiro). This presentation is a re-presentation of the 1988 and subsequent papers.

In 1988, the Canadian government placed an oil activity moratorium on Georges Bank. Consequently, no activity such as modern seismic surveying has taken place since that time. Therefore, although this presentation is based on vintage seismic data, it must be viewed as up-to-date since no new data has been acquired on the bank for over twenty years.

The Georges Bank basin formed during the Triassic when the landmass of Pangea began separating along rift zones. A prominent Paleozoic basement high, the Yarmouth Arch, separated the East Georges Bank Basin from the West Georges Bank Basin, and had a dominant influence on sedimentation until Middle Jurassic. During the Middle Jurassic, major growth faulting and halokinesis commenced in the basin.

The structural and stratigraphic evolution of the East Georges Bank basin has resulted in the development of a number of economically attractive seismically-defined prospects. The Geological Survey of Canada (GSC) in 1983 estimated that the average hydrocarbon expectation of the basin was 168 x $10^6 m^3$ barrels oil (1.0 billion barrels) and 150 x $10^9 m^3$ natural gas (5.3 TCFG). The GSC's speculative (higher) estimate for the basin was 350 x $10^6 m^3$ barrels of oil (2.1 billion barrels) and 307 x $10^9 m^3$ gas (10.8 TCFG).

NOTES

Friday, August 15, 2008

Session 2B - Petroleum Systems

GEOLOGY AND HYDROCARBON POTENTIAL OF THE NW AFRICAN ATLANTIC MARGIN

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The NW African Atlantic Rift System began to open in Carnian times (ca. 235 Ma) and produced a series of half graben with red-bed clastic fill in Morocco. Near the end of rifting, a 1-2 km thick salt was deposited, and is interpreted to be the same age as the CAMP volcanic rocks (200±1 Ma). Farther south, the deep Triassic rifts have not been drilled, but they could contain good oil prone source rocks similar to the southern USA basins. New evidence is presented that salt is present along the Cap Boujdour area of Aaiun Basin 450 km farther to the south of present mapped salt limit. The salt on the North American margin may also extend farther south, linking the South Georges Basin with the Baltimore Canyon Stone Dome occurrence. The northern limit of the Moroccan salt basin is currently mapped to terminate at the overthrusted southern edge of the Rif Thrust Belt, but the salt must continue northward below the Rif. A sub-thrust play exists in Northern Morocco, which has never been tested due to the lack of good imaging below the thrust belt. The Cenomanian-Turonian source rock may be mature in this area, due to the tectonic loading in the Oligo-Miocene. The overlying Jurassic sequence is mainly a carbonate slope facies, but occasionally a rimmed platform edge developed (Senegal, Gambia and Mauritania). The carbonate play has still to be fully tested, because the wells drilled on the USA margin appear to miss the rimmed carbonate edge, and very few wells have drilled the carbonates in NW Africa. The carbonate platform eventually became drowned in the Early Cretaceous, when clastic deltas were deposited. The increased clastic sediment input may be due to the internal rifting and flank uplift occurring throughout North Africa. Cretaceous -Cenozoic clastic sediments constitute the main deepwater target reservoirs. Recent wells in Morocco appear to have failed due to lack of reservoir.

MID TO LATE CRETACEOUS STRUCTURAL AND SEDIMENTARY ARCHITECTURE AT THE TERRA NOVA OILFIELD, OFFSHORE NEWFOUNDLAND - IMPLICATIONS FOR TECTONIC HISTORY OF THE NORTH ATLANTIC

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Multiple exploration, delineation, and development wells, in association with a high-quality 3D seismic survey over the Terra Nova oilfield, provide a detailed data set for the analysis of the mid to Late Cretaceous structural and stratigraphic development of the Jeanne d'Arc basin on the Grand Banks of Newfoundland. Closely spaced wells allow for recognition of multiple parasequences of shoreface to shelf siliciclastic sediments deposited during falling relative sea level in Hauterivian through Barremian time. The northward translation of the coastline with progressive truncation of the parasequences to the south demonstrates that regional uplift of the southern margin of the Jeanne d'Arc basin occurred during and immediately following deposition of these progradational parasequences. The upper bounding surface, defined by an angular unconformity with widespread evidence of valley incision, is dated as mid-Aptian. Highly variable thicknesses of back-stepping coastal plain, shoreface and marine shelf strata document a long-term increase in relative sea level accompanied by abrupt changes in subsidence rates occurring across W- to NW-striking, syn-depositional normal faults active during the mid-Aptian through Middle or Late Albian.

What do these patterns of uplift, subsidence, and faulting reveal about the tectonics of the Jeanne d'Arc

basin during the mid-Cretaceous? Specifically, are the W- to NW-striking normal faults related to gravity-driven processes or plate-tectonic processes? Although the basin tilting and the presence of Triassic/Jurassic salt would support gravity-driven processes, erosion in the south and deposition in the north would inhibit the northward flow of salt. Additionally, evidence of synchronous detached shortening is lacking. Basement-involved extension would produce W- to NW-striking subsalt and suprasalt normal faults. These decoupled faults occur exclusively to the east of the border fault of the Jeanne d'Arc basin (*i.e.,* the Murre fault).Thus, the Murre fault would have had both normal and strike-slip components of displacement during the mid-Cretaceous extension.

RESERVOIR CONNECTIVITY ANALYSIS, HYDROCARBON DISTRIBUTION, RESOURCE POTENTIAL & PRODUCTION PERFORMANCE IN THE CLASTIC PLAYS OF THE SABLE SUBBASIN, SCOTIAN SHELF

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Reservoir Connectivity Analysis is a systematic approach to understanding reservoir "plumbing". It is central to understanding fluids, pressures and field/pool size distribution in the clastic reservoirs of the Sable Subbasin. We will illustrate this approach with examples from the five producing Sable gas fields, other significant discoveries, and, the recent, third tranche of exploration and delineation drilling.

Hydrocarbon traps in the clastic system at Sable vary progressively from linear, low relief, extensional fault bend folds (which have small scale internal faulting), to high relief, heavily faulted domes where salt movement is involved in addition to listric faulting. It was recognized pre-production that despite complex overpressure distribution (attributed to recent charge) hydrocarbon accumulations are dominantly controlled geometrically, by "fill & spill" mechanisms: spill and breakovers at structural saddles, and critically, juxtapositional connections at internal and bounding faults. Because the Sable Subbasin is predominantly a high net-to-gross, marginal marine system with limited thick topseals there is - with a few very important exceptions - a propensity for "leaky traps", short hydrocarbon columns, and numerous small hydrocarbon pools.

In the absence of direct seismic indications of hydrocarbons, RCA has been the most effective technique for fluid prediction ahead of the drill. Previous speculation that fault processes and ensuing "fault rocks" would provide lateral seals, with longer gas columns and a larger resource is inconsistent with drilling results and production history.

REGIONAL SETTING OF THE LATE JURASSIC DEEP PANUKE FIELD, OFFSHORE NOVA SCOTIA, CANADA - CUTTINGS-BASED SEQUENCE STRATIGRAPHY AND DEPOSITIONAL FACIES ASSOCIATIONS ABENAKI FORMATION CARBONATE MARGIN

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Deep Panuke, discovered in 1998, is the only carbonate gas field in the eastern North America continental shelf. Several recently published studies (Weissenberger et al., 2006; Wierzbicki et al., 2005, 2006; EnCana 2006) give details on the hydrothermally-dolomitized reef margin gas field itself. Expanding on those studies using mainly cuttings and core data, Panuke is placed in a larger context between the northeast contemporaneous major Sable Island paleodelta prograding ramp shelf and the southwest thicker cleaner carbonate platform.

Wells can be grouped based on geometry and position relative to the shelf margin as follows: prograding ramp margin (only a few of the numerous wells in the Sable Island paleodelta are included), margin slope, margin with full shoaling sequence, margin with paleohighs and encased pinnacles (typical of Deep Panuke area), margin inboard flexure with shoals, interior platform oolitic shoals, interior platform shaly lagoon and 'moat' and near-shore ridge/siliciclastic-rich. The large-scale (second order?) vertical full-shoaling stratigraphic sequence is seen in nearly all margin wells. It comprises a basal transgressive oolite usually, then forereef with microbial mud mounds, then shallow coral-coralline sponge reefs, then oolites and two types of capping beds - either oolites (with or without sandstone interbeds) or lithistid sponge-rich beds. Only Deep Panuke does not show this pattern.

Laterally there is a curious pattern to the argillaceous sponge-rich cap beds in being flanked by wells with oolite caps both nearer the delta and southwestward of the Panuke area wells. There is also a regional trend in the color from darker to lighter (and finally even red in the slope beds) away from the Sable Island paleodelta. These facies trends relative to the Sable Island delta and the associated early, deep prodeltaic burial are key factors that contributed to Deep Panuke's reservoir, trap, seal and charge properties.

NOTE: This talk will be supplemented by a series of posters illustrating the facies associations mentioned briefly in this presentation.

LITHOLOGY-BASED, HIGH-RESOLUTION SEQUENCE STRATIGRAPHIC FRAMEWORK OF LOWER CRETACEOUS, MIXED CARBONATE-SILICICLASTIC SEDIMENTS, ATLANTIC COASTAL PLAIN, EASTERN UNITED STATES

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A lithology-based sequence stratigraphic framework for the Lower Cretaceous mixed carbonate-siliciclastic sediments of the subsurface Albemarle Basin of eastern North Carolina was developed using thin sectioned well cuttings, wireline logs, and 2D seismic. Thin sections were analyzed to characterize lithology, fossil components, depositional facies, and diagenetic events, because the study interval is confined to the deep subsurface in a basin lacking core control. Integration of lithologic data with 2D seismic data and biostratigraphic control allowed regional correlation of major transgressive-regressive events between wells, resulting in the generation of a sequence stratigraphic framework for the onshore basin. Dominant lithofacies include: (shallow to deep): sandstone, skeletal sandstone, variably sandy mollusk packstone/grainstone, siltstone to shale, skeletal wackestone, variably sandy (quartz and glaucony) lime mudstone, and marl.

Comparison of observed facies with cores and wireline logs from the Baltimore Canyon and Southeast Georgia Embayment confirms that many updip sequences consist of upward-shoaling siliciclastic shoreface successions, with basal open shelf mollusk-rich carbonates often marking transgressive events. Basin-scale depositional trends indicate greater accumulation of the carbonate facies in the southern portion of the basin, with increased fine siliciclastic material to the north. This trend may reflect a major siliciclastic point-source in the vicinity of the ancestral Chesapeake region. The depositional and diagenetic models generated provide insight into the facies and reservoir properties in coeval offshore units comprising frontier exploration targets along the Western Atlantic margin of the U.S. and Canada.

DISTRIBUTION OF DIAGENETIC MINERALS IN LOWER CRETACEOUS SANDSTONES WITHIN A DEPOSITIONAL FACIES AND SEQUENCE STRATIGRAPHIC FRAMEWORK: GLENELG, THEBAUD, AND CHEBUCTO FIELDS, OFFSHORE SCOTIAN BASIN

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The spatial and temporal distribution of diagenetic cements has been constrained in relationship to lithofacies and sequence stratigraphy of the Lower Cretaceous sandstones from the Glenelg, Chebucto, and Thebaud fields in the Sable sub-basin. Quartz and lithic grains coated with illite and chlorite occur in transgressive systems tracts (TST) in Glenelg N-49 and Thebaud I-93, and are cemented by Fe-calcite. Early kaolinite occurs as booklets and vermicular stacking textures principally in sandstones immediately beneath the TSTs, particularly in cross-bedded, coarse-grained, channel sandstones. Illite occurs as fibrous crystals, which in the Chebucto K-90 are included by ankerite. Fe-rich chlorite rims, found only in the Thebaud samples, have developed from earlier Fe-rich clay.

Pore-filling chlorite occurs in contact with detrital quartz grains on which diagenetic quartz cement has not developed. This chlorite is commonly associated with illite. Quartz cement, well developed in medium- and coarse-grained sandstones, postdates kaolinite and predates most other cements. Calcite, Fe-calcite, Mg-calcite, ankerite and siderite are the major cementing minerals in the studied wells. In Glenelg H-59, two siderite cements were defined; the earlier one occurs in TSTs as large, corroded crystals and is low in Mg. The late microcrystalline siderite (< 10 μm) is Mg-rich (~ 9 wt.%). It forms the tiny crystals that fringe detrital grains and fill intercrystalline micropores. Early calcite cement is found principally in bioturbated sandstones and mudstones with bioclasts, typical of the highstand systems tract (HST). In samples from the Glenelg field, perthite is replaced by Fe-calcite. Late framboidal pyrite in carbonate cement indicates burial under both reducing and alkaline conditions. Rare traces of francolite (1 to 6 wt.% P_2O_5) are found in the Glenelg wells associated with illite and calcite cements.

This study demonstrates that the distribution of diagenetic minerals and their impact on reservoir-quality evolution can be better elucidated when linked to a sequence stratigraphic framework.

HYPERPYCNAL RIVER FLOODS AND THE DEPOSITION OF LOWER CRETACEOUS SANDS, SCOTIAN BASIN

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The large supply of sand that reached the Scotian basin in the latest Jurassic and early Cretaceous resulted from tectonic reactivation and erosion of the Appalachian hinterland. The rivers that transported this sediment were steep and braided, based on sediment calibre and sedimentary structures preserved in the Chaswood Formation. Such rivers have the propensity to discharge hyperpycnally during floods. The importance of such hyperpycnal flows can be evaluated from sedimentological criteria in conventional core.

Thick-bedded reservoir sandstones from fields such as Thebaud and Venture appear to be inner shelf hyperpycnal deposits (facies 9), forming graded sandstone beds decimetres to metres thick, with Bouma Ta-Tc sequences, abundant phytodetritus, detrital intraclasts of mudstone and siderite, and minor bioturbation at the top of beds. This facies passes stratigraphically upward into tidally influenced river-mouth and river-channel sandstones (facies 4) and downward into thinner, graded sandstone beds with interbedded mudstone (facies 0). Highly bioturbated thin-bedded sandstones (facies 2) in places show hummocky cross-stratification, concentration of shells at the base of beds, and wave-ripples, suggestive of storm reworking. In the Glenelg field, tidally-influenced hypopyncal silts interbed with hyperpycnal sands and both change character distally. Turbidites in the middle Missisauga Formation in the Tantallon M-41 well show petrography and sedimentary structures that indicate deposition from overbank hyperpycnal flows.

Exploration models for the Scotian basin must take account of this reinterpretation of the major sandstone facies. The presence of widespread hyperpycnal flows means that there may have been a major transfer of sand to deep water. The rapid deposition of hyperpycnal flow sands, overlain by slowly sedimenting transgression surfaces, may have strongly influenced the style of early diagenesis and the neoformation of iron-rich clays that transformed on burial to chlorite rims.

RIVER SOURCE AND DISPERSION OF LOWER CRETACEOUS SANDS, SCOTIAN BASIN

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Understanding the source and dispersion of Lower Cretaceous deltaic sandstones is important for predicting (1) the distribution of sandstone; (2) the availability of quartz; and (3) regional variation in diagenesis. Many analytical techniques to identify sediment provenance have been applied to samples from conventional cores from the offshore Naskapi N-30 well in the west to the Dauntless D-45 well in the east. The results were compared with similar analyses of onshore Chaswood Formation samples.

Geochronology of detrital monazite shows several modes: ~330 and ~400 Ma at the Naskapi N-30 well; ~400 Ma in wells from the Alma field to the Venture field, with minor ~1.0 and ~1.65 Ga modes; and predominant ~1.0 and ~1.8 Ga modes at the Peskowesk A-99 well, with a minor ~380 Ma mode. Detrital zircons show similar modes. However, the ~1.0 Ga mode predominates from the Alma field to the Venture field, and an additional ~650 Ma mode is present. Morphology and texture show that 45-80% of detrital zircon is of first cycle igneous origin, with the proportion of polycyclic zircon decreasing stratigraphically upward. Sources of monazite and zircon are further constrained by mineral chemistry. Variation in abundance and chemical composition of heavy minerals, notably chromite, tourmaline and garnet, has been determined.

Bulk-rock geochemistry provides information on the total source area, whereas mineralogical studies emphasize source rocks containing heavy minerals. The Ti content of Scotian basin shales is almost double the world average due to detrital ilmenite. Fe is also abundant and Ca very low. Sandstones show geochemical variability within the basin; however, shales are more uniform geographically.

The integration of this data suggests that the Naskapi N-30 well was supplied by a river that also furnished sediment to the Chaswood Formation in central Nova Scotia. The sands in the area from the Alma field to the Venture field were sourced from a major river draining Newfoundland. Sandstones on the eastern Scotian Shelf were sourced by one or more separate rivers, also draining Newfoundland.

Session 2C - Petroleum Systems

PETROLEUM SYSTEMS DEVELOPED ALONG THE NW AFRICA OFFSHORE MARGIN: CHALLENGES FACING EXPLORATION & PRODUCTION COMPANIES

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The offshore NW African Atlantic margin extends from northern Morocco to the Guinea Fracture Zone in the south and comprises up to 6km of Mesozoic and Cenozoic siliciclastics and carbonates overlying Triassic salt.

The primary source rocks are Albian, Cenomanian and Turonian mudrocks, with lesser contributions from Palaeocene intervals that are thought to have reached marginal maturity in some areas, and restricted Liassic shelfal carbonates. Deep water gravity deposits provide the main reservoirs and include confined canyon systems and unconfined turbidite lobes. Less well explored plays include carbonate reefs and deltaic topsets further up-dip. The most prominent trapping mechanism along the length of the NW African margin is related to halokinesis. Allochthonous salt diapirs and canopies (largely absent from offshore Western Sahara, Senegal, Gambia and Guinea Bissau) have generated proven and unproven traps including sub-salt, salt stock, and supra salt closures. Other trapping mechanisms include tilted fault blocks (some are counter regional faults), stratigraphic pinch-out (Banda gas discovery), extensional roll-over folds, and toe trust compressional folding.

The under explored nature of the NW African Atlantic margin provides E&P companies with numerous challenges. The lack of detailed well control makes prediction of sandstone problematic, particularly as many of the canyons appear to be by-pass systems. Where geobodies have been mapped, lack of seismic imaging makes it difficult to differentiate with confidence between prospective sheet turbidite sandstones and reservoir-poor debrites, particularly in the deeper Cretaceous section. Other pitfalls have recently come to light after drilling. These include reef-like morphologies along the carbonate platform break of slope that are possibly contourites of siliceous ooze, and bright seismic amplitude anomalies that are not hydrocarbon filled sands, but low velocity shales.

These challenges are generally prospect specific, but there are further difficulties which relate to the cost of exploration in immature basins. Increasing water depth places restrictions on rig availability, and requires increasingly larger prospects to be considered commercially viable. As the restrictions imposed by the water depth drive companies to explore deeper in the basin it becomes more likely that prospects will be overpressured as they are in other deep passive margins (e.g. Nigeria, Borneo). This will only increase well costs, placing greater pressures on commerciality.

CONTROLS ON FACIES DISTRIBUTION AND RESERVOIR DEVELOPMENT OF UPPER TRIASSIC RIFT CONTINENTAL SYSTEMS IN INTERMONTANE RIFT SETTINGS: A COMPARATIVE STUDY OF EXTENSIVE OUTCROPS IN SW MOROCCO

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Upper Triassic (Carnian) sediments in SW Morocco comprise a continental red bed sequence deposited in discrete rifted basins following the break up of Pangea and opening of the Atlantic. This comparative study examines extensive outcrops of the Oukaimeden Sandstones Formation (F5) in the High Atlas and Unit T6 in the Argana Basin, SW Morocco, deposited within a series of narrow fault bounded intermontane basins. Both contain a variety of braided fluvial, overbank, shallow ephemeral lacustrine, alluvial fan and aeolian facies.

Traditional sedimentological data (sedimentary facies logs, palaeocurrent information, gamma ray logs etc) has been combined with high resolution 3D laser (LIDAR) and Differential Global Positioning System (DGPS) to map these outcrops and provide a detailed dataset.

On a basin scale, the often complex facies distribution evident in the Argana Basin suggests a highly variable fill within these basin types. Correlation of individual facies elements is often difficult and relies on identification of key stratal surfaces. Local tectonics controls accommodation and influences facies patterns, such as the development of alluvial fans and entry points of major drainage systems. Significant changes in fluvial style, from ephemeral to perennial, are recognized in both basins within this interval, which suggests rejuvenation of the source areas and a potential interplay of climatic and tectonic control. An overall drying upward pattern is observed, with increasing influence of aeolian processes towards the top of both the Oukaimeden sandstone (F5) and T6 of Argana. This supports previous work that has demonstrated a change from humid to increasingly arid conditions during the Upper Triassic, recognized both throughout SW Morocco and in the Fundy Basin, Canada, and highlights the climatic control on the depositional system.

These studied sections offer potential analogues for subsurface Triassic hydrocarbon systems in similar settings, and provide valuable information on the tectonic and climatic control on depositional facies and architecture. Analysis of basin-wide facies variation, provenance and sediment pathways provide regional scale analogue data. More detailed field scale reservoir models have also been developed for the high net: gross intervals in the Oukaimeden sandstone.

FUTURE PROSPECTS OF OIL AND GAS WITHIN SELECTED TARGET AREAS OF SCOTIAN SHELF AND SLOPE, OFFSHORE NOVA SCOTIA, EASTERN CANADA: EVALUATION BASED ON PETROLEUM SYSTEMS RISK ASSESSMENT

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Recent deepwater drilling surrounding the Sable Subbasin within the Scotian Slope, Eastern Canada has indicated that the successes/failures in finding economic hydrocarbon discoveries are closely related to complex petroleum systems and mobilization of Jurassic salts compared to deepwater basins of both the Gulf of Mexico and Angola. New comprehensive research combining seismic stratigraphy, heat flow assessment, geochemical fingerprinting, and petroleum system modeling of the Triassic-Tertiary sediments from the Scotian Slope reveals that the formation, timing, and fluidity of several large allochthonous salt canopies (Sable Subbasin) or autochthonous salt diapers (area between Sable and

Shelburne Subbasins) are closely connected to source rock anoxia, bypassing of turbidite sands (in early Tertiary and late and middle Cretaceous), and the survival of hydrocarbons within various play types. Early mobilization of Jurassic salt forming large canopies (especially within the Tertiary sediments of the Sable Slope) possibly originated from enhanced heat flow and three-phase fluid flow in the late Jurassic-early Cretaceous. Our study indicates that the various play types (especially the salt flank and salt top reservoirs) in the late Jurassic and early Cretaceous may possibly be charged with three petroleum system hydrocarbons (gas-condensate, light oil-gas and heavy oil-gas) within the Sable (beyond 2500m water depth) and Shubenacadie-Shelburne Slopes (beyond 1500m). The late Triassic/Early Jurassic lacustrine and Jurassic/Cretaceous Verrill Canyon marine source rocks are the most significant components within various petroleum system hydrocarbons although the timing of hydrocarbon charge could be significantly different in various parts of the Scotian Basin.

EARLY INFILL OF THE TRIASSIC FUNDY BASIN: ARCHITECTURE OF THE WOLFVILLE FORMATION AND FLUVIAL EVOLUTION

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The Fundy Basin forms one of a series of early Mesozoic rift basins developed along the north-western Atlantic margin. Syn-rift continental sediments were deposited during Late Triassic times within the basin. The sedimentary succession comprises the lower fluvio-aeolian Wolfville Fm, the overlying ephemeral fluvial/playa Blomidon Fm capped by basaltic lava (Olsen et al., 1989; Wade et al., 1996). Three sub-basins are present in the Fundy Basin: the Fundy sub-basin, the Minas sub-basin to the east and the Chignecto sub-basin to the north.

The Wolfville Fm displays a complex interplay of coarse and fine-grained fluvial sandstones, aeolian dune deposits and alluvial fan sediments. This study focuses on the Wolfville Fm stratigraphy and correlation within the gravely- and younger sandy-dominated fluvial deposits of the Minas sub-basin. This contribution will present a detailed analysis of the large scale architecture (27 km) of a gravely braided river system deposited within this endorheic basin, and will discuss the major changes in fluvial style within the basin. The palaeogeography of the Wolfville Fm is analyzed by determining the size of the braided river system and by taking an allostratigraphic approach to the recognition and correlation of extensive bounding surfaces.

The bounding surfaces and cycles within both coarse and fine-grained fluvial units allow correlation across the basin. Together with a palynological analysis, the stratigraphy of the Wolfville Fm is assessed in the Minas sub-basin. This new scheme of the Wolfville Fm architecture in a better constrained timescale has the potential to help predict sand-fairways and reservoir architecture within similar coarse grained alluvial deposits.

RESERVOIR QUALITY, DIAGENETIC HISTORY AND PROVENANCE OF THE LATE TRIASSIC SANDSTONES OF THE WOLFVILLE FORMATION, BAY OF FUNDY, NOVA SCOTIA, CANADA

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The provenance of Triassic Wolfville Formation sandstones at Cambridge Cove, Bay of Fundy were investigated using petrography, heavy minerals, and microprobe analysis of tourmalines and garnets as provenance indicators. The study included grain size analysis, diagenesis, porosity, heavy mineral analysis and possible reservoir characteristics dependent on these properties.

These fluvial sandstones are calcite cement-supported feldspathic litharenites to lithic felsarenites. The sandstones have a recycled orogenic provenance derived from metasedimentary and granitic rocks postdating collision and from the early stages of rifting.

The Meguma, Horton and Windsor Groups, and the South Mountain Batholith, which were and still are, the dominant rock units in the area, are the main provenance of Wolfville Formation sediments. Minor contribution from Appalachian exposures north of the Bay of Fundy in New Brunswick, cannot be excluded. However, the absence of volcanics in the studied sediments minimizes that possibility.

The Wolfville Formation, which is overlain by the Blomidon Formation, has a limited exposure area relative to its wide subsurface extension beneath the Bay of Fundy. In this area, it is underlain by the Horton Bluff Formation in the Minas Basin area, and by the Meguma and/or Avalon Terranes in the southwestern parts of the region.

Wolfville sandstones have porosities ranging from 2.6 to 16.6% (averaging 6%). Consequently, in the subsurface (beneath the Bay of Fundy), the sandstones are potentially moderately good reservoir rocks. Hydrocarbon charge could occur where these sandstones overlie potential source rocks; *e.g.*, the organic-rich shales of Horton Bluff Formation, or where overlain by or laterally equivalent to Mesozoic lacustrine shales.

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4D RIFT ANALYSIS FOR THE JEANNE D'ARC BASIN

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The study provides for the first time a full 4D (space and time) analysis of heat flow-, subsidence-, maturation- and compaction history for the Jeanne d' Arc basin, located offshore Newfoundland. The Jeanne d'Arc basin is a typical failed rift basin, whose development and burial history is based on crustal thinning processes. Therefore, the basin is an ideal place to quantify and verify rift-related processes such as heat flow history depending on the magnitude of the stretching of the crust and other factors.

The study compares the results of simulated geological and geophysical processes and their mutual effects for variations of the McKenzie approach, mostly related to the stretching behavior of the upper mantle. These assumptions have been applied to a 4D numerical basin model extending from the Port au Port area in the south to the Adolphus area in the north in the Jeanne d'Arc basin. The model was simulated with a software package PetroMod®, developed by Integrated Exploration Systems. Additionally, a special workaround has been applied to simulate not only single rift events but also multiple-sequence rift events.

The simulation technique uses an inverse approach with respect to the traditional McKenzie approach and is called advanced McKenzie approach. Based on the known burial history, the tectonic subsidence is calculated by back-stripping and decompaction. In a second step, the stretching factors can be determined by adjusting them to fit the tectonic subsidence. Lastly, the heat flow history can be calculated based on the calculated stretching factors. The 4D regional Jeanne d'Arc basin model uses the results of over 45 individual 1D models (well locations) and calibration data from 61 wells. Thus, the study of the Jeanne d'Arc basin quantifies the impacts of diverse rift- and heat flow scenarios on the basin based on a non-steady-state finite-element simulation.

BASIN, PETROLEUM SYSTEM AND PLAY ANALYSIS IN THE WEST AFRICAN ATLANTIC BASINS

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We report on a study of the relationship between tectono-stratigraphic basin evolution and petroleum system development in West African marginal basins between Angola and Cameroon. For this analysis, a novel framework model has been created.

The basins have evolved since the Early Cretaceous from a lacustrine synrift, through a transitional hypersaline stage into a post-rift succession, characterized initially by a shallow marine carbonate, followed by a deep marine and finally a deltaic depositional environment. This history reflects intra-cratonic rifting followed by the creation of the South Atlantic passive margin: all basins considered have experienced a similar tectonic and sedimentary basin evolution. The petroleum systems identified in these basins can be related to common source facies and may be grouped into families or Petroleum System Types (PSTs). Two proven regionally extensive PSTs and two probably local PSTs have been identified. The regionally extensive PSTs are the lacustrine synrift PST and the marine post-rift PST. The probably local PSTs are the restricted marine hypersaline transitional PST and the deltaic/deep marine post-rift PST. Families of petroleum accumulations (or plays) that characterize these petroleum systems, and which are defined by their reservoir lithofacies and trap type, are also similar in each of these basins.

This group of similar basins therefore demonstrates the close link between tectonic- and sedimentary basin evolution on the one hand, and petroleum system and play development on the other. We call such a group of basins a basin family; one which can be used for analogue purposes in basin studies.

PREDICTIVE TRENDS IN SALT MORPHOLOGY DERIVED FROM SYSTEMATIC ASSESSMENT OF MERGED 3D SEISMIC COVERAGE OVER ENTIRE BASINS

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3D seismic data is acknowledged to have significantly increased both drilling success rate and our understanding of the subsurface geology within localised areas of a basin by revealing detailed 3D relationships between structural geometries and stratigraphy which could not be discerned from a grid of 2D cross-sections. In recent years, the computational power and expertise have developed to merge discrete interlacing and overlapping 3D surveys into a single 'MegaSurvey' of normalized, contiguous 3D seismic data covering entire basin systems. No such projects yet exist in the Central Atlantic Margin Province. However, we have examined such 'MegaSurveys' over basins on both margins of the South Atlantic and from the North Sea with particular reference to the geometries of salt structures developed and their influence over sag-phase sediment deposition. By systematically measuring the spatial distribution and dimensions of all the halokinetic features within the entirety of each basin, we are able to identify general patterns in, for example, wavelength and amplitude, and the ranges and statistical distribution of these parameters. The trends in these attributes appear to be consistent and independent of the tectono-stratigraphic history of the various salt basins, as a result of which each basin exhibits differences in the age and thickness of the salt, along with variations in the age and character of the overlying sediments. The spatial distribution and aspect ratio of salt walls and diapirs are therefore interpreted to result from the inherent physical properties of the salt itself.

The importance of salt movement for hydrocarbon trap formation and as a control on reservoir distribution is well documented, yet drilling results frequently indicate that the dimensions; *i.e.*, the thickness, height and lateral extent of the salt, is often over- or under-estimated. These parameters from several independent and widely distributed basins, give a valuable calibration for examining salt features in other basins.

VARIATION IN CRUSTAL EXTENSION AND ITS IMPLICATION FOR HYDROCARBON HABITAT IN THE DAKAR - RUFISQUE AREA, OFFSHORE SENEGAL

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It is postulated that during Triassic – Lower Jurassic rifting, the Senegal margin between the Rufisque and Cayar Fracture Zones (Dakar Compartment) suffered a higher degree of crustal extension than adjacent north and south sections. Rapid Albian–Upper Cretaceous post-rift sedimentation created a thick, regional depocentre containing some basic intrusions intruded locally exposed onshore. In Santonian times, north-south directed compression caused major uplift of the rigid, less extended Rufisque High to the south of the Rufisque transform. This feature was generally stable during Senonian–Palaeogene times in contrast to the Dakar Compartment to the north. The Dakar-Cayar-Rufisque suffered a regional hypabyssal–volcanic igneous event in the Oligo–Miocene with far more pronounced intrusion into the shallow section in the Dakar-Cayar area (thinner crust / leaky transforms) than over the Rufisque High. This resulted in a thermally driven inversion of the pre-existing Late Cretaceous and Paleogene basins, which has resulted in the present topographic expression of the Dakar Peninsular.

Several basin-scale observations are postulated to be directly related to the compartmentalization of the margin and the more highly extended crust in the Dakar Compartment:-

- Post-rift passive continental margin depositional systems and facies reflect the additional accommodation space. This is most spectacularly demonstrated by the lateral offset, across the Rufisque Lineament, of the Late Jurassic-Early Cretaceous carbonate bank sequence, coeval to that of the Scotian Shelf
- Upper Cretaceous source rock bearing sequences are thicker within the Dakar Compartment as a result of the greater accommodation space created over the thinned crust at the time of deposition.
- Outboard of the carbonate margin, source rocks are thermally over-mature (within the gas generation window) due to their greater depth of burial and higher heat flow over the extended crust. The same source rocks in the compartments north and south of the Dakar compartment are thinner and geochemical modeling suggests they are marginally mature.
- The present Dakar Peninsula is a topographic expression of an east-west, thermally driven, Neogene inversion of the Dakar Compartment. The inversion is clearly expressed on offshore seismic data and is accomplished through the contrast in rigidity between the thinned crust under the Dakar Compartment and the adjacent more rigid (thicker) crustal compartments.
- The Cayar Dome, an igneous edifice of presumed Tertiary age, is located on the northern accommodation zone of the Dakar Compartment, illustrating its importance as a crustal scale detachment.
- Neogene inversion of the Dakar Compartment may have resulted in avulsion of drainage of the Senegal River Basin from the Dakar area southward to its present position, and rejuvenation of the Banjul River.

Syn-rift compartmentalisation of the shelf to deep water sectors of the Senegal margin is postulated to have a profound effect on the petroleum geology by influencing; reservoir fairways and facies distribution, destruction (or preservation) of reservoirs, heat flow, and maturity of source sequences. Recognition of these factors can enable the prediction of optimal areas for hydrocarbon exploration through an integrated model of source rock distribution, timing of maturation, expulsion pathways and accumulation in favourable reservoir facies, and improve the prediction of hydrocarbon phase.

TECTONO-STRATIGRAPHIC EVOLUTION OF SALT STRUCTURES AND DEPO-CENTER MIGRATION IN THE ABENAKI SUB-BASIN AND ITS DEEPWATER EXTENSION, OFFSHORE NOVA SCOTIA

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Despite extensive exploration activity on the Scotian Margin, the latest round of drilling has yielded disappointing results. An in-depth analysis of the interplay between salt tectonic processes and sediment input is required to better understand the regional tectono-stratigraphic framework of the Scotian Basin and its individual sub-basins.

We are using scaled analogue experiments to simulate coupled salt tectonic processes and depocentre migration in the Abenaki sub-basin and its deepwater extension. Experiments simulate the salt tectonics history from the early post-rift stage to the allochthonous salt nappe formation on the modern margin. The experiments are constrained by sedimentation patterns and rates, original salt basin thickness, and basement morphology deduced from the GXT NovaSPAN survey and public-domain 2D seismic reflection data.

Seismic interpretation results of the Abenaki sub-basin show a complex salt basement morphology, which includes a mid-basin high implying variable salt thickness in the early post-rift salt basin. Experiment results suggest that the complex basement morphology and variable salt thickness had a strong effect on the initial salt mobilization and early post-rift depocentres, and that it controlled the pattern of sediment transport from the Jurassic to the Cretaceous. During the Cretaceous, seaward salt extrusion in the deepwater slope of the Abenaki sub-basin created an allochthonous salt nappe system with new mini-basins developing on this secondary source level. Mechanically constrained salt tectonic concepts and seismic interpretation templates deduced from the experiments will aid further seismic interpretation of the Abenaki sub-basin.

These concepts will also give insight into how basement morphology influenced salt structure development, and how sedimentation rates and patterns affect depositional styles. This integrated approach will contribute to our understanding on the evolution of the Abenaki sub-basin and how its evolution relates to the timing of adjacent sub-basins on the Scotian Margin.

ANALOGUE MODELLING OF SALT TECTONIC PROCESSES AND DEPOCENTER MIGRATION ON THE SHELF AND DEEPWATER SLOPE, WESTERN LAURENTIAN SUB-BASIN

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The Scotian Basin is situated on the Atlantic continental margin offshore Nova Scotia and is composed of a series of interconnected Mesozoic-Cenozoic sub-basins resulting from the rifting of North America from Africa. Thick deposits of late syn-rift Argo Salt coupled with complex basement morphologies and varied sedimentation patterns along the margin have resulted in a complex and laterally variable basin evolution. Unsatisfactory results from the recent round of hydrocarbon exploration in the deepwater slope demonstrate that a better understanding is required about the link between early post-rift salt mobilization and late post-rift formation of canopies and allochthonous salt nappes, and their relation to depocentre migration. We are using scaled analogue experiments comprised of sand and silicone putty to gain such an understanding by simulating basin evolution and salt tectonic processes constrained by seismic data. First-order model parameters of the western Laurentian sub-basin analogue experiment including sedimentation rates and patterns, basement morphologies, and initial salt thickness were constrained by GXT NovaSpan and public-domain seismic data. Experiment results confirmed appropriate timing and speculation of the evolution of this region with diverse structural processes including; (1) numerous passive downbuilding events throughout basin evolution, (2) extension focused in the Cretaceous forming a ramp flat geometry, and (3) minimal contraction in the upper Cretaceous. The next phase of this project includes modeling the interaction of sediment progradation and salt tectonics between the inter-connected Laurentian, Abenaki and Sable sub-basins. This experiment will evaluate the role of margin parallel sediment transport from the northeast via the Laurentian Channel during the early post rift stage of basin evolution and salt tectonics in the NE Scotian Margin. Insight from both models, when compared to regional seismic data, will contribute to our understanding of the structural evolution of the western Laurentian Sub-basin and determine the influence of margin parallel sedimentation.

MAPPING POST RIFT SILLS ALONG THE NEWFOUNDLAND PASSIVE MARGIN

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A high amplitude reflector package at the base of the sedimentary sequence in the Newfoundland Basin sampled during ODP Leg 210 results from thin diabase sills. Chemical analyses and dating suggest that the sills were emplaced in two separate post-rift thermal events, probably related to hot spot activity. Seismic data tied to the borehole reveal that the sills are widespread and continuous over hundreds of square kilometers. Spectral decomposition is used here on high quality seismic profiles (migrated near trace gathers) in order to map the peak energy frequency variation of the U reflections throughout the basin which is then related to thickness of sills.

The analysis is complicated due to limited signal bandwidth and the complexity of the sill geometries but trends are apparent throughout the basin. The lowest frequencies (thickest sills) are associated with the central basin, particularly towards the south. Higher frequencies (thinner sill) are associated with the upper sill in the north but the upper sill in the south central basin is low frequency. Based on sill thickness variations, the source of magma is proposed to be in the south central basin close to the present day Newfoundland Seamounts.

A REGIONAL TRANSECT ACROSS THE SOUTH NEWFOUNDLAND BASIN, A NONVOLCANIC MARGIN

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New seismic reflection data from the Grand Banks of Newfoundland and the Newfoundland Basin add to the knowledge of composition, structure and history of this nonvolcanic margin. Two parallel profiles over the shelf platform image deep crustal fabric representing Precambrian or possibly Appalachian deformation as well as Mesozoic extension. Progressively more intense extension of continental crust is imaged oceanward below the continental slope without the highly reflective detachments frequently seen on profiles off Galicia.

A landward-dipping event 'L' is imaged sporadically and appears to be analogous to a similar event on the approximately conjugate Iberian IAM9 profile. The transition zone is probably unroofed serpentinized mantle as interpreted off the Iberian margin although there appears to be a difference in the character of ridge development and reflectivity. The distinctive 'U' reflection in the Newfoundland Basin is highly regular and continuous except where interrupted by basement highs. 'U' is also seen to have a major impact on the ability to image underlying basement. A full transect from completely unextended continental crust to oceanic crust has provided two estimates of extension and the pre-rifting location of the present continental edge; 85 km based on faulting and 120 km based on crustal thickness.

U.S. EAST COAST: CONTINENTAL MARGIN EVALUATION WITH NEW TOOLS, DATA AND TECHNIQUES

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Exploration discussions of the Central Atlantic margins typically omit the U.S. East Coast Continental Margin (ECUS) which has been dormant, without drilling since 1984, despite on-going E&P activities to the north (offshore Nova Scotia), south (offshore northern Cuba), and on the conjugate African margin (Morocco to Mauritania). Shell has documented its exploration success with new ideas and new technology. After a more than twenty year hiatus, we too have new data, technology and ideas along the ECUS, suggesting that timing is favourable for a thorough review.

Our data compilation began with advanced coverage of public domain bathymetry, gravity and magnetic data, all re-levelled, cross-correlated and merged. Our Central Atlantic data set includes five million-odd line-kms each of gravity and magnetic profiles plus a half-million data points. Each data set was carefully merged to regional backgrounds derived from multiple satellites. Stunning imagery of bathymetry, gravity, magnetic and auxiliary data were generated from the final 4 km (super-regional) and 1 km (basin-level) grids. Including multiple data attributes that are somewhat area-dependent, we generated about 40 images, each with specific and general interpretation value.

Evolution of passive margins and adjacent oceanic crust has been studied extensively since the mid-1980's, with continued academic work along the ECUS. The Minerals Management Service is conducting a re-analysis of pre-1985 drilling and seismic data augmenting the older ECUS literature. We make initial comparisons between published interpretations and our new imagery, presenting adjustments, revisions, extrapolations and some speculation. While the dominant structural features are largely unchanged, they are better delineated. This includes evidence of more subtle correlations with published depictions of play-defining features such as areas of salt tectonics and carbonate bank edges. The interaction of these features with plate tectonic elements is also better defined. Each of these observations is illustrated with specific imagery on which feature changes and extensions are highlighted.

THE NOVASPAN PROJECT: DEEP IMAGING OF AN ENIGMATIC CONTINENTAL MARGIN

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The 2003 NovaSPAN data set comprises over 3400 km of 2-D regional reconnaissance seismic data designed to image down to the base of the crust using large guns (>4200 in^3) with a 9 km long cable and 18-second record lengths. The data has undergone Prestack Time Migration (PSTM) as well as Prestack Depth Migration (PSDM - to 40 km).

The primary objective of the NovaSPAN survey was to deliver critical insight into the geologic evolution and basin architecture of the Scotian Margin, and the resultant temporal and spatial history of regional petroleum systems.

The NovaSPAN survey provides a useful regional structural and stratigraphic framework. An initial fast-track seismic stratigraphic interpretation, largely on the PSTM data, has yielded the following preliminary results:

- The discovery of rotated crustal blocks in front of the margin provides evidence of significant changes across this zone along the margin, suggestive of transtension along a transform fault zone. If true, there may be important relationships within a zone of comparatively high basement underlying the slope to shifts of major basin elements such as the basement hinge zone and the position of allochthonous salt basins.
- The geometry and nature of syn-rift basins along portions of the LaHave Platform may prove important for understanding how the rifting occurred, while the presence of salt within some of the basins might affect evaluation of overlying prospects in the Abenaki carbonate bank.
- The long transects across the upper rise and lower slope allow for detailed subdivision of the seismic stratigraphy which in turn aids correlation of units through areas of complex deformation.
- A remarkably high rate of sedimentation during the Late Jurassic is manifested by an extensive synkinematic wedge occurring above a salt detachment system in the eastern part of the survey area toward the Laurentian Channel. The implication of this feature is that the southern limit of allochthonous salt deposition lies roughly 100 km further north than previous workers have assumed.

More recent work underscores the enigmatic nature of the deeply buried basement structure and crustal nature.

The GXT SPAN™ surveys provide sufficient aperture and illumination, when combined with the right imaging tools, to reveal how complex basin structuring is controlled by Tertiary, Mesozoic and older deformational events and early basin tectonics. We suggest that these data sets, in conjunction with other detailed "prospect-level" surveys, will aid industry in defining petroleum systems and new plays, especially at great depth and in deeper off the shelf waters and can considerably reduce basin exploration risk.
The NovaSPAN data set is now at the core of a regional re-interpretation effort of the Scotian Margin by the Nova Scotia Department of Energy in conjunction with the GSC and the Departments of Geology of Dalhousie and St Mary's universities to build a new tectono-stratigraphic framework and a post-mortem of recent deep water drilling failures.

LOW-T THERMOCHRONOLOGY PROVIDES NEW INSIGHTS IN THE MESOZOIC TO PRESENT

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To constrain upward and downward vertical movements in NW Africa we have sampled for low-T thermochronology a 500km long transect from the Mediterranean coast to the Anti Atlas of Morocco. The analysis of this large data set has provided major surprises requiring a reconsideration of generally accepted ideas.

The data we have produced document an Early to Middle Jurassic stage of subsidence and of Late Jurassic to Early Cretaceous exhumation affecting a large elongated region stretching from the Moroccan Meseta to the Anti Atlas. These domains are typically considered as stable during the same time span. Late Jurassic to Early Cretaceous exhumation caused the erosion of a large amount of terrigenous sediments transported offshore and deposited in the otherwise monotonous and fine-grained succession of the Moroccan Atlantic passive continental margin.

Alpine deformations began in the Late Cretaceous and continue until present. They were initially associated with the development of large scale, WNW-ESE trending folds and then with localization of shortening and exhumation in the Atlas system.

SEQUENCE STRATIGRAPHIC EVOLUTION OF THE DEMERARA RISE, SURINAME, SOUTH AMERICA- TRANSITION FROM A RIFTED TO PASSIVE MARGIN; POSSIBLE ANALOGUE TO THE SCOTIAN SLOPE

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The Demerara Rise is a deep water extension of the continental margin north of Suriname and French Guyana; conjugate to the Guinea Plateau of West Africa. Late-stage Atlantic rifting began in the Mid to Late Cretaceous, resulting in opening of the Atlantic gateway between the North and South Atlantic Oceans. The margin is highly prospective in light of hydrocarbon exploration and production successes to the south, off Brazil. Regional 2D seismic data and a few offshore wells set the stage for the latest phase of exploration activity. RepsolYPF acquired a 3D volume on the inboard margin of the Demerara Rise in 2006, bridging the shelf to slope transition region. These data allow for detailed investigation of the Cenozoic stratigraphy on this portion of the Suriname margin in order to understand shelf to slope linked deposition systems of a relatively recently rifted margin. The Suriname margin, representing the last vestige of the proto-Atlantic, is a possible modern analog to the Jurassic Scotian margin. Understanding forcing functions, sedimentary pathways and depositional patterns are expected to provide insights into exploration models for passive clastic margins.

Exploration seismic data off Suriname show a passive rifted margin reflecting sedimentary sequences of subsidence infill and overall progradation. Early post-rifting, the region was anoxic, resulting in a thick (~90 m) interval of Cretaceous organic black shales outboard of the rise; excellent hydrocarbon source rock. Several significant regional unconformities indicate episodes of extensive erosion, such as during the Mid-Miocene and Oligocene. Offshore, the Cenozoic section is thin, but inboard in the position of the 3D seismic volume, the section is expanded and remarkably complete with classic shelf-to-slope progradational bedding structures. Tracing the shelf-to-slope hinge line, it is apparent that progradation slowed during the Paleogene relative to earlier. In the Neogene, a regional Pliocene unconformity marks the return to rapid progradation that continued into the Quaternary. Interpretation of seismic facies indicates turbidites and mass-failure deposits dominate the sedimentary section on the upper slope.

A number of features were identified from the shallow, near surface section that represents potential geohazards or constraints to offshore hydrocarbon development. Faulting is perhaps the most prevalent. Extensive faults with seafloor offsets, in some cases paralleling the shelf edge, are readily apparent. These faults may be involved in seafloor instability, providing a mechanism for shelf to slope sediment transport and deposition.

QUANTITATIVE KINEMATIC AND THERMOMECHANICAL ANALYSIS OF THE EVOLUTION OF THE MOROCCAN RIFTED CONTINENTAL MARGIN

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The Atlantic passive margin of Morocco developed during Mesozoic times in association with the opening of the Central Atlantic. Extension caused the development of extensional basins along the future continental margin and, further to the E, the Atlas rift system. Therefore, this must be considered as part of the rift system, which led to the formation of the passive continental margin of Morocco. It was inverted in Alpine times to form the present-day High and Middle Atlas Mountains.

To provide a first quantitative analysis of the evolution of the rifted margin, we have constructed a crustal section from the Anti-Atlas (the plate interior) to the Atlantic Ocean crossing the Atlas system, the Meseta and the Atlantic continental margin in the Doukkala Basin segment. We applied numerical models to test quantitative relations between amounts and distribution of extension and isostasy-related vertical movements. A region of particular interest is the Moroccan Meseta, which is generally considered as a stable region separating the subsiding Atlas and Atlantic margin system. This picture is incompatible with the recent findings, which, on the basis of low-thermochronology, have demonstrated the existence of a Late Triassic to Middle Jurassic stage of subsidence followed by a Late Jurassic to Early Cretaceous exhumation.

We use the results of the quantitative analysis presented above to address the importance and regional tectonics of these syn-rift and post rift vertical movements.

THE EVOLUTION OF THE PERDIDO FOLD BELT IN THE CONTEXT OF SALT TECTONICS OF THE NORTHWESTERN MARGIN OF THE GULF OF MEXICO – INSIGHTS FROM NUMERICAL MODELING

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The Perdido Fold Belt (PFB) is a prominent salt-cored deep-water structure in the northwestern Gulf of Mexico. In the last decade it has become a major target for exploration. It is characterized by a 4.5 km thick pre-kinematic, folded section, symmetric kink folds, a short duration of folding and associated lack of significant syn-kinematic sedimentation, and a seaward tilt of the fold envelope. The fold belt is located above the pinch-out of the autochthonous salt adjacent to and below the extensive Sigsbee Salt Canopy. This study investigates the previously unresolved temporal and spatial relationship of the folding across the area, the tilting of the fold belt, and the formation of the Sigsbee Canopy.

We use 2D finite-element models in which frictional-plastic sediments overlie a viscous salt layer. The models comprise a passive margin sedimentary sequence from shelf to deep water to account for the dynamical interaction of gravity spreading caused by shelf progradation. Model experiments include sediment compaction, flexural isostasy, and loading by the overlying water column. Parametric calculations include the effects of pore fluid pressures in the frictional-plastic sediments.

Analytical calculations of the stability of a salt-bearing margin reveal that a 4.5 km thick fold belt can have formed by gravity spreading across the passive margin alone. No crustal tectonics was necessarily involved and only moderately high pore-fluid pressures ratios of approx. 0.8 were required.

The model fold belt shows good correlation with the kink-type folds, geometry and dimensions of the PFB. Timing and extent of the folding of the model fold belt are controlled by system parameters such as overburden strength, margin width, salt thickness and salt viscosity. Variability in the latter two can generate two end-member types of fold belts: the fold belt either evolves above the distal section of the salt with folding occurring synchronously or it initiates at the toe of the slope from where it progressively propagates seaward. Although previous studies proposed that an evolving canopy buffered earlier compression and allowed the distal sediments to be deposited undisturbed, the numerical models suggest that the configuration of the system limited early compression to the toe-of-slope region. This deformation then led to localization of diapirs and canopies, which evolved mostly coevally with the fold belt.

SEISMIC STRATIGRAPHY, SALT STRUCTURES AND THERMAL AND PETROLEUM SYSTEMS MODELS ACROSS THE CENTRAL NOVA SCOTIA SLOPE BASIN

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Two regional deep seismic profiles, GXT NovaSpan 1400 and Lithoprobe 88-1A, are used to better characterize the sediment, salt and basement structures across the Central Nova Scotian Slope Province. Imaging of deeper structures is especially improved, using either pre-stack depth migration with the long offset streamer (NovaSpan 1400) or a combination of pre-stack time migration and wide-angle velocity models (Lithoprobe 88-1A). Seaward of the salt, basement morphology and crustal velocities suggest that highly-stretched and rotated continental crustal blocks extend further into the ultra-deep basin. Beneath the salt, basement is also well-defined except locally beneath major salt diapirs.

Petroleum systems models are derived along the two profiles for various potential source rocks and reservoirs. Along both profiles, salt flank and salt crest Late Jurassic and Early Cretaceous reservoirs form the primary exploration targets. However, significant differences also exist for the two profiles, primarily associated with variations in salt structures. Along NovaSpan 1400, the Jurassic Verrill Canyon Formation is the main source rock for both the Jurassic and Cretaceous reservoirs. For the Early Cretaceous reservoir, hydrocarbons may contain a major volume of liquids (>75%) with an API of 45-55^{o} and only mild overpressures. Along Lithoprobe 88-1A, Early Jurassic lacustrine and Late Jurassic salt-associated marine reservoirs are potential exploration targets, although these would lie within an over-pressured, dry-to-wet gas regime. Mass balance calculations for both seismic lines indicate that more preserved hydrocarbons are expected within the various reservoirs on NovaSpan 1400.

Model calculations of present-day sea-floor heat flow predict a gradual landward reduction from 55 mW/m^2 in the ultra deep-water basin to 45 mW/m^2 on the upper slope. However, large variations are caused by high conductivity associated with salt diapirs, yielding values as high as 85 mW/m^2. In July 2008, we plan to take detailed measurements along both profiles in order to verify these predictions.

THE LAST 100 MILLION YEARS ON THE SCOTIAN MARGIN, OFFSHORE EASTERN CANADA: AN EVENT STRATIGRAPHIC SCHEME EMPHASIZING BIOSTRATIGRAPHY

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In the 1970s and 1980s, the principle biostratigraphic groups used for dating the Late Cretaceous-Cenozoic interval were foraminifera, nannofossils and dinoflagellate cysts (dinocysts), although in recent years the last-named group has been the most intensively used. No concerted efforts were made in the early days to marry results from the different microfossil groups, and this was sometimes reflected in diverse age schemes for individual exploration wells. The present study is based mainly on studies of material from seven exploration wells, selected to provide a composite section: Demascota G-32, Hesper I-52, Onondaga E-84, Sauk A-57 and Shelburne G-29 (all on the shallow water shelf), and Shubenacadie H-100 and Wenonah J-75 on the deep water slope. The Late Cretaceous-Cenozoic interval from each of these wells was analyzed for dinocysts and pollen and spores and, in some of the wells, for calcareous

nannofossils and planktonic and benthic foraminifera. The integration of data from different sub-disciplines, especially the calibration of dinocyst events with nannofossil events and thus indirectly with the largely deep-sea-based magnetostratigraphic timescale, has made possible for the first time a detailed sequence of biostratigraphic events.

INTEGRATED LATE SANTONIAN-EARLY CAMPANIAN SEQUENCE STRATIGRAPHY, NEW JERSEY COASTAL PLAIN: IMPLICATIONS TO GLOBAL SEA-LEVEL STUDIES

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Our studies on New Jersey Coastal Plain indicate existence of the Santonian-early Campanian (Merchantville Formation) unconformity-bounded sequences that originated from sea-level changes. The ages of the Merchantville sequence boundaries are similar to those of Russian platform and northwestern Europe implicating a global cause of their origin. The ages of the Santonian-early Campanian sequences boundaries appear to match the ages of deep-sea benthic foraminiferal δ^{18} increases from ODP 511 site (Franklin plateau), implying that the Santonian-Campanian δ^{18} signature was, at least in part, due to development of ice sheets. Miller et al. (2003) explained the presence of ice sheets in the greenhouse world of the Late Cretaceous by proposing that the ice sheets were restricted to Antarctica and paced by Milankovitch forcing. Modeling of Milankovitch forces suggests that about 1/3 of the δ^{18} increase is attributed to ice and the 2/3 to deep-water cooling. The eustatic falls calculated from Milankovitch orbital solutions are similar to those obtained from the New Jersey margin backstripping analysis. The match of calculated results with our experimental sea-level estimates suggests that the Merchantville sequences on the New Jersey Coastal Plain are connected to the upper Santonian-lower Campanian global climatic variations and provides evidence for existence of small, ephemeral size ice sheets in Antarctica in the greenhouse world.

NEW PROFILE MODELS OVER THE U.S. EAST COAST CONTINENTAL MARGIN

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Profile-based models are excellent for incorporating multiple data sets to illustrate basin architecture. New models across the U.S. East Coast Continental Margin incorporate reprocessed seismic lines, depth-stretched with projected well data, stacking functions and published refraction velocities. Four dip profiles (ranging from 220-480 km each) were tied to a composite (~2,300 km) strike profile; then extended landward and seaward to model long-wavelength crustal variations (from unthinned continental to fully oceanic regimes) defined by our latest gravity and magnetic data.

The seismic interpretation constrains shallower horizons while deep crustal structure derives largely from potential field and published refraction data. Intermediate levels, especially acoustic basement, are revealed as other layers are defined. Models frequently constrain the nature and volume of intrusives such as the lamprophyre dike swarm cored Great Stone Dome (Schlee Dome), and allochthonous salt diapirs, as targeted in the profile model. The feature extents were then interpreted areally, away from seismic coverage, based on gravity and magnetic imagery.

Comparing our profiles with published interpreted and modeled seismic lines; *i.e.*, DNAG volumes, the authors note significant differences. Previously interpreted “salt structures” in the Georges Bank Basin

(GBB) do not exist. Salt structures in the Baltimore Canyon Trough (BCT) appear limited to a small, seismically defined diapir and the salt penetrated in the Hudson Canyon 676-1 well on the flank of Schlee Dome. We validated salt structures in the Carolina Trough (CT), although the CT appears to be more complex and separate from the Blake Plateau Basin and BCT. Sediment thickness maxima in the GBB were confirmed on one model and matched to gravity data that improves the definition of previously indicated sub-basins with some exploration potential. Ongoing work is extending the interpretation of the models across the entire margin and will no doubt reveal further interpretation changes.

THE LUSITANIAN BASIN (PORTUGAL) STRATIGRAPHIC AND GEODYNAMIC CORRELATION WITH OTHER PORTUGUESE AND MOROCCAN BASINS

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The Lusitanian Basin is located on the western Atlantic side of Iberia, corresponding to a passive margin of the North-Atlantic Cretaceous opening, conjugate with basins of the eastern North America. However, its Late Triassic - Early Cretaceous evolution indicates relationship with the Central Atlantic and the Alpine Tethys. This fact can be better understood by looking at other nearby basins, such as the *Algarve* basin (200 km S), and the Moroccan basins of the *Atlas* (700 km SE) and *Essaouira* basin (800 km S).

The Lusitanian Basin presents a 1st late Triassic intra-continental rifting, with siliciclastics, evaporites and carbonates. The 2nd rifting starts in the Oxfordian, marked by a regional unconformity and thick marine and continental siliciclastics. The opening of the North-Atlantic, with a 3-stepped diachronous (Berriasian-Aptian) break-up unconformity, is marked by prograding fluvial and coastal mixed deposits.

The same broad evolution may be identified at the Algarve basin, with small differences: Sinemurian volcanics, an Aalenian gap and depositional hiatuses coeval with three Cretaceous Atlantic break-up steps, migrating north.

The complex Atlas basins are closely related to the Tethys evolution, with important subsidence during the 1st rifting phase: Triassic red-beds and Liassic carbonates give place to deltaic and continental red-beds (or even depositional gaps) with a generalized upper Jurassic unconformity. Opening to the Tethys marine influences and carbonates became definitive since the Cenomanian.

The Essaouira basin, closely related with the Central Atlantic opening, presents a more complete stratigraphic record, with abundant Sinemurian volcanics (CAMP) and post-break-up Jurassic marine and Cretaceous continental deposits. As in the Lusitanian basin, the subsidence is mainly upper Jurassic, but without an unconformity.

A comparative approach to these basins supports strong geodynamic correlations, related with the opening of the Central and North Atlantic, as well as the spreading of the Alpine Tethys and detachment of the Iberian plate.

CONTROLS ON FACIES DISTRIBUTION AND RESERVOIR DEVELOPMENT OF UPPER TRIASSIC RIFT CONTINENTAL SYSTEMS IN INTERMONTANE RIFT SETTINGS: A COMPARATIVE STUDY OF EXTENSIVE OUTCROPS IN SW MOROCCO

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Upper Triassic (Carnian) sediments in SW Morocco comprise a continental red bed sequence deposited in discrete rifted basins following the break up of Pangea and opening of the Atlantic. This comparative study examines extensive outcrops of the Oukaimeden Sandstones Formation (F5) in the High Atlas and Unit T6 in the Argana Basin, SW Morocco, deposited within a series of narrow fault bounded intermontane basins. Both contain a variety of braided fluvial, overbank, shallow ephemeral lacustrine, alluvial fan and aeolian facies.

Traditional sedimentological data (sedimentary facies logs, palaeocurrent information, gamma ray logs etc) has been combined with high resolution 3D laser (LIDAR) and Differential Global Positioning System (DGPS) to map these outcrops and provide a detailed dataset.

On a basin scale, the often complex facies distribution evident in the Argana Basin suggests a highly variable fill within these basin types. Correlation of individual facies elements is often difficult and relies on identification of key stratal surfaces. Local tectonics controls accommodation and influence facies patterns, such as development of alluvial fans and entry points of major drainage systems. Significant changes in fluvial style, from ephemeral to perennial, are recognized in both basins within this interval, which suggests rejuvenation of the source areas and a potential interplay of climatic and tectonic control. An overall drying upward pattern is observed, with increasing influence of aeolian processes towards the top of both the Oukaimeden sandstone (F5) and T6 of Argana. This supports previous work that has demonstrated a change from humid to increasingly arid conditions during the Upper Triassic, recognized both throughout SW Morocco and in the Fundy Basin, Canada, and highlights the climatic control on the depositional system.

These studied sections offer potential analogues for subsurface Triassic hydrocarbon systems in similar settings, and provide valuable information on the tectonic and climatic control on depositional facies and architecture. Analysis of basin-wide facies variation, provenance and sediment pathways provide regional scale analogue data. More detailed field scale reservoir models have also been developed for the high net: gross intervals in the Oukaimeden sandstone.

LITHOSPHERIC DENSITY VARIATIONS AND MOHO STRUCTURE OF THE IRISH RIFTED CONTINENTAL MARGIN FROM CONSTRAINED 3-D GRAVITY INVERSION

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The structurally complex Irish margin was separated from its conjugate pair, the northern Flemish Cap/Orphan Basin region, during Late Cretaceous rifting of the North Atlantic. While crustal-scale 2-D seismic surveys have been collected across many parts of the margin, the results generated from these surveys cannot easily be interpreted in a regional sense due to their sparse sampling.

We have undertaken a 3-D gravity inversion of the free air data over the Irish margin in order to generate a 3-D density anomaly model that can be compared with the seismic results and used to gain insight into regions lacking seismic coverage. We use the GRAV3D inversion algorithm and constrain our inverted model with bathymetric and sediment thickness information. We are able to closely reproduce the observed gravity anomalies over the margin and use the resultant density anomaly model to interpret the regional Moho structure by identifying a density isosurface appropriate for the crust-mantle transition. Our interpreted Moho shows good correspondence with Moho depths from seismic results while providing a more detailed Moho depth map over the region. This map allows the lateral extent of crustal thinning beneath the Rockall Trough, the Porcupine Seabight Basin and south of Goban Spur to be investigated.

We present regional cross-sections through the 3-D model to highlight lateral variations in Moho structure and lithospheric densities. We also compare sediment and crustal thickness across the margin to show deviations from local isostatic compensation. These deviations correlate with faults and rifting trends along the boundaries of most of the main structural features. Ultimately, the insights provided by our results must act as constraints for future paleo-reconstructions of North Atlantic rifting.

STRUCTURE AND RIFTING EVOLUTION OF THE NORTHERN NEWFOUNDLAND BASIN FROM ERABLE MULTICHANNEL SEISMIC REFLECTION PROFILES ACROSS THE SOUTHERN MARGIN OF FLEMISH CAP

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We present four multichannel seismic reflection profiles from the 1992 ERABLE experiment collected over the southern margin of Flemish Cap and extending into the Newfoundland Basin. These profiles are between and sub-parallel to lines 1 and 2 from the 2000 SCREECH seismic experiment and provide more comprehensive data coverage over the region.

Combining these data with the SCREECH seismic profiles, two ODP drill sites, and other geophysical data has allowed the mapping of distinct zones of continental, transitional, and oceanic crust in this region. Comparisons with mapped crustal boundaries on the Iberian margin from detailed seismic surveys and drilling show asymmetry in the conjugate pair, with the zone of extended continental crust and transitional crust being much wider on the Iberian margin compared to the Newfoundland margin. Furthermore, while detachment faulting is evidenced on both margins, it is less widespread on the Newfoundland margin.

We propose either a simple shear model, or, a simple shear/pure shear combination model involving a westward dipping detachment fault with the Newfoundland margin acting as the upper plate. Along-margin variations in the present-day structure, which deviate from the simple 2-D rifting model, are explained within the context of Late Jurassic to Early Cretaceous rifting and break-up.

THERMOCHRONOLOGY EVIDENCE FOR MESOZOIC AND CENOZOIC INVERSIONS OF THE CONTINENTAL MARGIN OF NOVA SCOTIA, CANADA

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Considerable erosion followed the folding, metamorphism and grainotoid intrusion (ca. 380 Ma) of the Devonian Acadian Orogeny. By the Early Carboniferous (ca. 350 Ma) coarse clastics - followed by extensive marine carbonates and evaporites - were deposited non-conformably on exhumed granitoids and metamorphic rocks. The Carboniferous-to-Permian Maritimes Basin developed, accumulating clastic sediments in excess of 12 km in its depocentre further north. Maximum burial of the basin was attained in the Late Carboniferous (ca. 300 Ma), and the youngest sediments preserved in this basin are Lower Permian in age.

Apatite fission track thermochronology studies have shown that basin inversion led to erosion of ca. 5 km of strata in the Late Triassic, coinciding with the Atlantic break-up unconformity, and preceding extensive but short-lived basaltic magmatism (ca. 200 Ma). The traditional view of gradual exhumation and peneplanation of the Nova Scotia margin since the Triassic-Jurassic is untenable. During the Aptian-Albian, continental sediments were deposited throughout Atlantic Canada over a weathered surface that included karst and has wide expression along the margin. The exhumation of the land went hand in hand with deposition in the adjacent Scotian Basin, part of the present Atlantic passive margin, an active depositional basin from the Late Triassic-Early Jurassic to the present. In such a passive margin it was expected that rocks deep in offshore wells would be at their maximum temperature today. However, our apatite fission track thermochronology data indicates that rocks in offshore wells were once tens of degrees hotter (e.g. within the oil window) than at present, and that substantial post-Paleocene cooling has occurred.

Although higher paleo-mean annual surface temperatures in the Late Cretaceous may account for some of the thermal anomaly detected, the most probable cause for this cooling is inversion of the margin and erosion of ca. 1 km of post-Albian cover from onshore and offshore, probably in the Eocene - Oligocene. This Tertiary inversion may have important implications for hydrocarbon maturation, the distribution of deep-water sand bodies, overpressures, and post-Paleocene canyons and unconformities.

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VARIATION IN PORE CONNECTIVITY WITHIN ABENAKI FORMATION CARBONATE LITHOFACIES, OFFSHORE NOVA SCOTIA.

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Three-dimensional MicroCT imaging, together with reflected, transmitted and epifluorescence microscopy of samples from the Abenaki Formation (Jurassic), Scotian Shelf, offshore Nova Scotia, have been used to identify different carbonate phases and assess their roles in affecting pore distribution, geometry and connectivity for different carbonate lithofacies.

A total of twenty-two core chip samples from the Panuke H-08, Demascota G-32, Acadia K-62, Margaree F-70, Albatross B-13 and Panuke IA/1 wells were examined. With the exception of K-62 and B-13 wells, the remainders are located within the Deep Panuke field. Sampled textures include: biosparite-biopelmictrite with irregular-shaped vugs and micro fractures; sparse to packed biomicrite and biopelmicrite with microstylolites; drusy dolostone-bioclastic dolostone, drusy dolostone with zoned dolomite crystals, calcitic dolomite, sparry calcite; and fractured oolitic grainstone. The samples are assigned to various lithofacies namely skeletal-rich forereef rubble, proximal forereef slope, oolitic grainstone shoals/intershoals and oncolitic backreef.

Our analyses show that calcification and dolomitization processes contribute to the development of pore spaces in various ways, notably whether or not they are fabric selective, the degree of connectivity and the variations between their preservation and or destruction of their original fabrics. These observations support previous work undertaken using enhanced light petrography, fracture and geochemical analyses which showed that porosity of the Abenaki reservoir is mainly controlled by burial dolomitization and dissolution and that fractures are important components of the permeability network for this reservoir.

OLIGOCENE CANYON AND FAN DEVELOPMENT: THE RESPECTIVE ROLES OF SEA LEVEL AND SEDIMENT DELIVERY IN EVOLUTION OF THE EASTERN SCOTIAN MARGIN

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The Cenozoic sedimentary section of the eastern Scotian margin is characterized as a progradational sequence incised by canyons, valleys and gullies. These features provide conduits for offshelf sediment transport, slope by-pass and deposition on the continental rise and abyssal plain during periods of low relative sea level. The Stonehouse 3D seismic volume, spanning outer shelf and upper slope terrain of a portion of the modern eastern Scotian Slope, provides an opportunity to study the detailed Cenozoic stratigraphy and modern and buried seafloor morphologies in this critical shelf to slope transition zone. Sequence stratigraphic concepts were applied to the Neogene section of this depth-migrated 3D data set to map the distribution of seismic facies and their bounding unconformities. Several widespread unconformity surfaces were identified and compared to the present-day seafloor. Canyon incision appears to be episodic throughout the Cenozoic section. As with the modern seafloor, ancient canyon systems are fundamental to slope sedimentary processes and sediment delivery mechanisms. Canyon formation requires significant removal of slope material to the deep ocean floor, following which these canyons act as sediment pathways. A particularly widespread Oligocene (?) erosive surface has a complex morphology that is potentially analogous to the modern Sable Gully canyon system that “drains” much of the central and eastern Scotian Shelf through a system of feeder channels and valleys. The implications of repeated canyon formation on the Scotian Slope imply that the residence period of sediments on the slope is geologically short and that preservation potential is confined to periods of canyon fill or local reductions in gradient. Canyon formation on the slope presumably requires significant sea level lowering, so repeated canyon formation raises the question of eustatic versus tectonic controls on sedimentary processes. Given the extent of the Oligocene (?) erosional unconformity, it is suggested that eustatic change alone cannot explain this consequence, thus tectonic inversion on this passive margin may have contributed to sea level lowering.

MIDDLE CENOZOIC DEPOSITIONAL PROCESSES ALONG THE WESTERN SCOTIAN MARGIN

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Extensive 2D and 3D seismic exploration data on the deep water margin off Nova Scotia reveals prospective hydrocarbon bearing structures, yet seven recent exploration wells met with only moderate success. The difficulties encountered in finding quality reservoirs reveal that geologic models successfully applied in other parts of the world need to be refined for the Scotian margin. It is the purpose of this study to develop an understanding of margin-scale geologic process relevant to the middle Cenozoic section of the Scotian margin in order to develop appropriate exploration models.

Published studies of the Oligocene to Pliocene geological history of the outer Scotian margin show that canyon incision on the slope and local depositional lobe progradation dominates sedimentation during periods of relative sea-level lowstands. During this same period, development of Antarctic glaciation and opening of Arctic Ocean circulation established North Atlantic oceanic currents that influenced sedimentation on the lower slope and rise. There is also evidence for occasional tectonic activity, presumably due to changes in intra-crustal stress, salt migration, and movement along ancient faults. Throughout the Cenozoic, large scale sediment mass-wasting events wield considerable influence over the evolution of depositional systems along parts of the margin.

Preliminary analysis of 2D and 3D seismic reflection data from the western Scotian margin reveals evidence of widespread erosion and associated depositional elements, which, through correlation with biostratigraphic data at the Shubenacadie H-100 and Shelburne G-29 wells, are of Oligocene to Miocene age. Here, the geological history of the outer margin records a complex interplay of down-slope and along-slope processes. The relationship of these various processes; sea level change, canyon cutting, contour current intensification, tectonics, sediment slope by-pass and sediment instability, for example, is unknown at this time but is critical, both for understanding the geology of the Scotian margin and how continental margins evolve in general.

LITHOLOGY-BASED, HIGH-RESOLUTION SEQUENCE STRATIGRAPHIC FRAMEWORK OF LOWER CRETACEOUS, MIXED CARBONATE-SILICICLASTIC SEDIMENTS, ATLANTIC COASTAL PLAIN, EASTERN UNITED STATES

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A lithology-based sequence stratigraphic framework for the Lower Cretaceous mixed carbonate-siliciclastic sediments of the subsurface Albemarle Basin of eastern North Carolina was developed using thin sectioned well cuttings, wireline logs, and 2D seismic. Thin sections were analyzed to characterize lithology, fossil components, depositional facies, and diagenetic events, because the study interval is

confined to the deep subsurface in a basin lacking core control. Integration of lithologic data with 2D seismic data and biostratigraphic control allowed regional correlation of major transgressive-regressive events between wells, resulting in the generation of a sequence stratigraphic framework for the onshore basin. Dominant lithofacies include: (shallow to deep): sandstone, skeletal sandstone, variably sandy mollusk packstone/grainstone, siltstone to shale, skeletal wackestone, variably sandy (quartz and glauconite) lime mudstone, and marl.

Comparison of observed facies with cores and wireline logs from the Baltimore Canyon and Southeast Georgia Embayment confirms that many updip sequences consist of upward-shoaling siliciclastic shoreface successions, with basal open shelf mollusk-rich carbonates often marking transgressive events. Basin-scale depositional trends indicate greater accumulation of the carbonate facies in the southern portion of the basin, with increased fine siliciclastic material to the north. This trend may reflect a major siliciclastic point-source in the vicinity of the ancestral Chesapeake region. The depositional and diagenetic models generated provide insight into the facies and reservoir properties in coeval offshore units comprising frontier exploration targets along the Western Atlantic margin of the U.S. and Canada.

INTEGRATED RESERVOIR CHARACTERISATION, DEEP PANUKE GAS POOL, OFFSHORE NOVA SCOTIA

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The Deep Panuke gas pool is the first, significant carbonate reservoir gas discovery on the Scotian Shelf. Development of the pool is currently proceeding. The Jurassic Abenaki Formation-hosted, lean, slightly-sour gas accumulation was delineated in two rounds of drilling involving seven wells resulting in five successes. Well test rates exceed 50 million cubic feet per day per well.

Diagenesis controls secondary porosity development in the Deep Panuke fractured dolostone and associated leached vuggy limestone reservoir. Three litho-types were defined in the reservoir characterisation process: non-reservoir unleached limestone, porous vuggy limestone and dolostone. Petrophysical analysis of the wells defines relationships between lithology, porosity, Sw and fracturing for each litho-type. In particular, it has been important to recognize the presence of a bimodal porosity distribution in the High Permeability Reef Front (HPRF) region of the pool which contains 80% of the gas resource. The bimodality is a consequence of the presence of both dolostone and unleached limestone litho-types. Similar reservoir characteristics have been documented at Simonette, Alberta (Duggan, 2004). Neural Net methods were used to integrate the petrophysical results with 3D seismic-derived rock properties, resulting in bimodal low/mid/high case porosity predictions for the HPRF. This multi litho-type approach and aquifer modeling has led to significant improvements in the integrated reservoir characterisation, well test matches and in the static and dynamic reservoir simulation models.

The approved development plan (EnCana, 2006; CNSOPB, 2007) involves subsea tie-back of wells to a new jack-up production field centre and new export pipeline to shore.

THE MOHICAN CHANNEL GAS HYDRATE ZONE, SCOTIAN SLOPE: GEOPHYSICAL STRUCTURE

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The Cenozoic section of the Scotian margin largely consists of turbidity current, mass transport and glacial sediments, with related canyon and valley formation. A significant portion of the continental slope of this margin falls within the methane gas hydrate stability zone (GHSZ), yet a prominent bottom simulating reflector (BSR) was identified at only one location. 3D seismic reflection, ocean bottom seismometer (OBS) and long offset (9 km) pre-stack 2D multichannel seismic data were used to study the velocity structure, geophysical characteristics and volume of this Mohican Channel gas hydrate zone. The Mohican Channel area shows a double BSR 0.35 to 0.45 s below the seafloor within channel levee deposits in water depths of 1,200 to 1,500 m. Primary and secondary BSRs are ~280 km^2 and 50 km^2 in area. A system of polygonal faults extends from an apparent gas-charged zone at ~1.2 s subbottom (Miocene-Eocene Unconformity) to ~0.3 s subbottom. Some faults form vertical chimneys and appear as conduits for gas leakage into the GHSZ. Some chimneys reach the seafloor producing positive-relief gas-charged mounds. A total of 39 OBSs were deployed along 3 profiles; one strike line and 2 dip lines. A few of the P and S-wave velocity profiles derived from these data over the BSR show anomalies consistent with the presence of hydrate and free gas, but others are ambiguous. Dissimilarities within the low velocity zone (LVZ) and amplitude variations suggest hydrate is laterally inhomogeneous. Shear-wave anisotropy appears related to changes in density of polygonal faults. As in any petroleum system, source, pathway, reservoir and trapping mechanisms are necessary for hydrate occurrence. Rare appearance of BSRs on the Scotian margin with low gas and hydrate concentrations imply that gas hydrates are in far less abundance than theoretical calculations suggest.

ABENAKI CARBONATE MARGIN FACIES ASSOCIATIONS - POSTER 1: UPDATED DEPOSITIONAL FACIES TEMPLATE AND VERTICAL-LATERAL MARGIN VARIATIONS AS PIE DIAGRAM SECTIONS-MAPS

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Although artificially static, a carbonate facies template and schematic carbonate facies model are useful for high-lighting the general relationship of facies in a dip transect of a carbonate platform from shore to basin. The biological-sedimentological criteria in cuttings and core for facies association identification are thus tabulated. However contemporaneous local variability such as channels versus reef buildups versus skeletal shoals at the margin are more difficult to show sometimes even on 3D models. And in some cases facies many not be contemporaneous locally such as argillaceous sponge reef beds versus clear-water deeper coral or microbialite reefs or mounds. While perhaps in the same depositional depth and relative position, they are widely separated in space and/or time, but are shown on a single facies template or model for practical presentation and simplification. Modified from Wilson (1975) template by Eliuk (1978), Eliuk and Levesque (1988) then Wierzbicki, Harland and Eliuk (2002), the Abenaki facies associations are as follows: 1) Open marine shale – bathyal/deep, 2) open marine shale – neritic/shallow, 3A) foreslope channel, 3B) proximal foreslope (forereef), 3C) distal foreslope including microbial mounds (see 5C), 4A) ‘deep’ siliceous sponge reef mound & intermound, 4B) ‘shallow’ siliceous/lithistid sponge mound, 4C) ‘shallow’ lithistid-stromatoporoid/coral sponge reef, 5A) skeletal rich, 5B) shallow coralgal reef (coral-coralline sponge), 5C) pelleted ‘mud’ (see 3C), 5D) oolitic, 5E) oncolitic, 5F) thin bypass

sandstones, 6) 'moat' open inner shelf (deep lagoon), 7) mixed carbonate-siliciclastic platform interior (nearshore ridge), 8) coastal deltaic-interdeltaic-restricted lagoon (loferite)-continental (coals). As discussed in the accompanying talk, geometry and position relative to the shelf margin (see seismic in Kidston et al. 2005) is another way of subdividing the well 'magnafacies' especially when they have a particular vertical depofacies pattern. Yet another method of viewing relative changes is showing percentage lithofacies-essential biotic-sedimentological components on pie diagrams placed vertically on sections or areally on maps by stratigraphic sequences.

ABENAKI CARBONATE MARGIN FACIES ASSOCIATIONS - POSTER 2: SLOPE-FOREREEF SETTINGS AND SPECTRUM OF MICROBIAL MUD/REEF MOUNDS

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With the exception of M-79 in Deep Panuke and Cohasset D-42 that is a bit back of the margin flexure, all thick shelf margin wells (Marquis L-35 & L-35A, Cohasset L-97, Dominion J-14, Musquodoboit E-23, Demascota G-32, Acadia K-62, Albatross B-13) have a significant portion of their lower and middle sections (lower Baccaro Member or EnCana's Sequences 2 and 3) in a microbial-hard peloid-carbonate mudstone lithofacies rich in calcite cements. These lithofacies are interpreted as distal carbonate slope with microbial mud/reef mounds. This is strongly supported by core (G-32, K-62, sidewall cores in B-13 and core at the base of the Baltimore Canyon Trough 'Civet' OCS-0337 well) which show isopachous submarine cements, marine geopetals, microbial thrombolitic-stromatolitic and even stromatactis textures. The amount and variety of associated biota, degree and openness of submarine cavity systems and presence of debris flows varies, possibly systematically with distance from the Sable Island delta. Color changes show this with B-13 most distal and white and red. In contrast, two wells with core (Penobscot L-30, West Venture C-62) in the Sable Island paleodelta with prograding ramp geometries have microbial mud mound facies that are considerably darker with a less varied biota compared to those of cores in wells to their southwest. Queensland M-88 is the only well drilled completely on the Abenaki carbonate slope to test possible bypass sandstone reservoirs immediately basinward of the Deep Panuke field. Cuttings, strongly supported by drilled sidewall cores, indicate a distal slope setting with abundant microbial mud/reef mound facies. An exception is thin sponge or stromatoporoid-rich limestone beds that define the sequence boundaries with overlying often-black shales. Proximal slope or forereef facies are fairly common in most margin wells especially in Deep Panuke. There, these generally sandier carbonates are often 'leached' limestones or dolomites forming much of the porous reservoir. Even in core distinguishing forereef from reef flat sands can be a difficult interpretive problem. However in the Margaree F-70 core, the inclined dips and interbedding of thin *in situ* relatively low-energy hence deeper-water microbial-sponge-microsolenid coral reeflets support a proximal forereef interpretation for the dolomites and graded echinodermal grainstone interbeds.

ABENAKI CARBONATE MARGIN FACIES ASSOCIATIONS - POSTER 3: VARIETIES OF REEFS AND REEF MOUNDS OF THE OUTER MARGIN

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Worldwide, the Late Jurassic is noted for great quantities of varied reefs and of hydrocarbons in carbonates. Surprisingly, with just a handful of exceptions, it is not the Jurassic reefs that contain the hydrocarbons but rather platform interior carbonates in structural traps. Deep Panuke is one of those exceptions. The gas is in the reef complex and the trap is partially stratigraphic with even the structural component mainly due to reefal growth. And in the Abenaki margin, all three Jurassic reef-reef mound end-members (Leinfelder's, 1994) are present: coral reefs, siliceous sponge and microbial (mud) reef mounds. These end-members have intermediate transitional forms but only the shallow-water coral-coralline sponge (stromatoporoids and chaetetids) reef complexes are significant reservoirs. Microbial mud/reef mounds (see poster 2) are well-cemented limestones and occur in slope facies below the reservoir levels. (As a caution against generalizations, some Jurassic Gulf of Mexico microbialite reefs occur in restricted shallow settings and are hydrocarbon reservoirs.) Siliceous (lithistid) sponge reefs (see poster 5) generally occur above the porosity-reservoir levels and actually contribute to the trap seal by their argillaceous content. These three reef type end-members can be distinguished even in cuttings. But only in core can one appreciate and possibly subdivide the shallow-water reef complex into reef flat, core (typically rubbly from bioerosion then storm and wave action) and proximal forereef (cores in Cohasset L-97, Margaree F-70, Panuke H-08, Demascota G-32, Acadia K-62). And in most cases the common presence of carbonate mud in the matrix, crinoidal debris and encrusting microbialites indicate that, unlike many modern *Acropora*-dominated reefs, these Late Jurassic hexacoral-rich reefs probably grew in slightly deeper margin water not at the crest. Probably particularly true when large phaceloid corals are seen still standing (L-97 core and on FMI in Panuke M-79). Seismic and dip-meter data clearly show that the reef-prone outer margin slope, between the updip oolitic inner flexure and the distally steepened downdip flexure, has considerable local topography. Some forereef beds on local pinnacle-like buildups even dip landward (F-70, MarCoh D-41). Usually that topography is encased by carbonates but Dominion J-14 shows that rarely shale can be trapped between individual buildups. In Baltimore Canyon Trough, the southward extension of the Jurassic gigaplatform, margin pinnacle reefs keep growing as the shelf interior is drowned and buried in shale.

ABENAKI CARBONATE MARGIN FACIES ASSOCIATIONS - POSTER 4: SHELF EDGE OOLITIC SHOALS OF THE INNER MARGIN AND ONCOLITE, BYPASS SAND, UNCONFORMITY THOUGHTS

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Worldwide, Jurassic carbonates are also noted for oolites. The Abenaki too has oolite nearly everywhere and in many cases it allows cyclic and sequence subdivision to be made. But rarely are these grainy rocks an important contributor to reservoir porosity at least in the deeply buried Panuke trend, in the carbonate ramp shelf associated with the Sable Island paleodelta, in the basal transgressive beds of the platform, or in the very oolitic Scatarie Member at the base of the Abenaki Formation. Seismically at the inboard margin flexure and sedimentologically, oolites occur in the shallowest carbonate settings and should be subject to effective winnowing and subaerial exposure. Both should create porosity but likely Late Jurassic calcitic seas may have made for less soluble ooids. And most oolites are completely occluded by burial cement except on the Western Shelf where they occur less deeply buried beneath the present-day deep-water slope. At Deep Panuke the oolitic grainstones are impermeable enough to form part of the seal for stratigraphic trapping as opposed to their usual role as platform reservoir rock. A very thick oncolitic facies was defined using core in Acadia K-62 where the common presence of ooids, megalodont clams and coral fragments with the large oncoids suggested a reef flat interpretation. Since the oncolite facies is not obvious in other wells, speculatively it may reflect a more local or special event - possibly nutrient enrichment corresponding to the influx of deltaic clays and siliceous sponge reefing closer to the Sable Island delta. Another facies definitely related to siliciclastic influx is thin bypass sands. These are widespread at particular levels and have been interpreted to represent unconformity related low-stand periods with sand influx. As well the sand may overlie unconformities when reworked during the next transgression. In bracketing the inferred unconformities they represent maximum regression surfaces. Thus they are a key to establishing a sequence stratigraphic framework on the platform whether that is based on transgression-regression or more elaborately on relative sea-level stands of transgressive, high, forced regression and low.

ABENAKI CARBONATE MARGIN FACIES ASSOCIATIONS - POSTER 5: SPONGE REEFS AND ARGILLACEOUS SPONGE-RICH CARBONATES RELATED TO DELTAS: THE JURASSIC-CRETACEOUS BALTIMORE CANYON-NOVA SCOTIA ABENAKI EXAMPLES COMPARED TO THE MODERN FRASER PRODELTA EXAMPLE

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Of the three Jurassic reef-reef mound end-members (see poster 3), the siliceous sponge reef mounds occur uniquely at the top of the Abenaki and at the top of equivalent carbonates in the Baltimore Canyon Trough (BCT). Then shales overlie both. A major oceanographic or relative sea-level carbonate drowning event or series of events affecting both areas seemed like an obvious explanation. However a limestone core just below the Venture Field shelf margin delta, diachronous age dating of sponge-rich beds and their limited distribution on the Nova Scotia shelf (NSS), and the discovery of siliceous sponge reefs adjacent to prodeltaic shales of the Fraser River delta, British Columbia (Conway, Barrie and Krautter 2004), may give an alternative explanation with a modern analogue. Seismic and Ringer's Valanginian model (in Eliuk and Prather 2005, repeated at this conference) in BCT show that after and perhaps even contemporaneously with the shelf margin pinnacle reefs, sponge mounds formed in nearby deeper water (several 100 feet or ~50-100m) below the pinnacle reef and in front of small deltas prograding over drowned inner platform carbonate. In the NSS, argillaceous sponge-rich beds at the top of the Abenaki are younger in wells further southwest of the large Sable Island delta. Even further away from the delta on the Western Shelf the Abenaki (Roseway unit) carbonates no longer have a sponge facies but continue in typical shallow platform facies and are younger yet. In the bottom of West Venture C-62 the older thin Late Jurassic #9 Limestone has a few metre thick sponge-stromatoporoid-microbial reef mound capping a pure microbialite reef mound of similar thinness. Laminated black prodeltaic shales at the base of a 50 m thick shelf margin deltaic sequence (Cummings and Arnott 2005) abruptly overlie the limestone. This is like a miniature version of the Abenaki carbonate platform terminations to the southwest and ignoring subsidence indicates an initial water depth around 50m. The change from microbialite up to sponge reef with possible red algae in a total of less than 5m indicates a relative sea-level fall and supports an interpreted forced regression. Like the modern Fraser delta sponge reefs, these more calcareous Jurassic sponge reefs were in deep quiet nutrient-rich waters but not yet engulfed and buried by clay sediment of an encroaching delta. Such a setting was environmentally untenable for shallow-water carbonate sedimentation that had therefore already "drowned".

CONTINENTAL SLOPE SEDIMENTATION MODELS: LAURENTIAN CHANNEL AND HALIBUT CHANNEL REGIONS, EASTERN CANADA

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Recently acquired seafloor multibeam, and 2D and 3D seismic reflection data of the St. Pierre and Halibut Slope regions provide evidence for successive mass failures at a variety of scales. The occurrence of stacked and regionally extensive mass failures suggests that this is a fundamental process for slope sedimentation in this area; the most recent mass-transport event was in 1929.

There are a variety of factors that explain the significance of mass failures in this area: 1) Drainage of the Great Lakes, which are the largest inland bodies of water in North America, cause the St. Lawrence River and Laurentian Channel to act as major fluvial and sediment transport conduits for most of eastern North America. It was also a major ice-outlet corridor during numerous Quaternary glaciations. As a result,

sedimentation rates at the mouth of Laurentian Channel and on Laurentian Fan have been periodically high, leading to potential generation of high pore pressures and a thick column of underconsolidated sediment. 2) Sediment sampling in the region has shown the presence of intra-formational methane gas within the shallow portion of the sediment column. Generation of gas within sediment reduces its strength properties. 3) Gas hydrates, which may be indicated by bottom-simulating reflectors, are interpreted to occur in the region. Their dissociation may provide another potential source for shallow gas. 4) Recognition of buried sedimentary bedforms suggests sandy intervals underlying St. Pierre and Halibut Slope areas. Listric faults extending from surface escarpments into this interval suggests that possible detachment surfaces, perhaps in response to generation of overpressures occur within them. 5) The area overlies the Cobequid-Chedabucto fault, a paleo-transform margin, which appears to have a higher level of seismicity than most of the Canadian east coast margin. Ground accelerations due to earthquakes plays a critical role in initiating sediment failure, as in the 1929 Grand Banks submarine landslide during a M7.2 earthquake.

Mass transport processes are clearly a significant mechanism of sediment delivery in the shelf to slope setting of the greater Laurentian Channel region. These processes are dependent upon a variety of pre-conditioning factors, both lithologic and structural, yet likely initiated by seismicity. The ubiquitous nature of such processes in the Quaternary section is a critical component to understanding reservoir potential of underlying rocks that reside in the same geologic setting.

SEAFLOOR DIAGENESIS OF THE SCOTIAN BASIN: THE ROLE OF FE, TI AND P

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Diagenesis in Lower Cretaceous sandstones of the Scotian basin is an important reservoir quality. Diagenetic processes include the effects of seafloor redox-controlled changes in pore water and the re-mineralization of organic matter; as well as later cementation and secondary porosity resulting from increases in the temperature and pressure with burial and the flux of formation waters and hydrocarbon expelled from compacting shales. Lower Cretaceous rocks of the Scotian basin are deltaic, with cycles of delta progradation characterized by high sedimentation rates capped by transgressive systems tracts typified by low sedimentation rates.

Transgressive systems tracts (TST) in one well (Peskowesk A-99 with 7 conventional cores) from the Scotian basin were identified in conventional cores with the support of available wireline logs, and core photographs (CNSOPB Geoscience Research Laboratory). The TST sediment facies include bioturbated medium- to coarse-grained sandstones with patchy siderite cementation and some bioclasts, grading upward into bioturbated mudstones. Geochemically, the Lower Cretaceous sedimentary rocks of the Scotian basin are unusual in having high titanium (Ti) and iron (Fe) and very low calcium (Ca). As a result, the early diagenetic system is dominated by Fe minerals and locally by phosphorus (P) minerals.

Samples have been collected from conventional cores through representative TSTs and underlying high-sedimentation rate deltaic sandstones in the Peskowesk A-99 well for whole-rock geochemical analysis. The vertical variation in particular Fe, Ti and P can be used to understand the seafloor diagenetic system and its relationship to abrupt changes in sedimentation rates in the TST.

CHARACTERIZATION OF PARALIC PALEOENVIRONMENTS USING BENTHIC FORAMINIFERA AND THECAMOEBIANS FROM EARLY CRETACEOUS SEDIMENTS (SCOTIAN SHELF)

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The benthic foraminifera and thecamoebians from an early Cretaceous cored interval of Cohasset A-52 well (located on the Scotian Shelf- North Atlantic), were used to interpret the depositional environments of these sediments. Paleoenvironmental interpretation was based on the analysis of samples from four cored intervals of A-52 corresponding to 25 m of interbedded, gray-black shale, mudstone and sandstone belonging to the Cree Member of the Logan Canyon Formation (Aptian –Albian). The foraminiferal association recovered from the samples is comprised mainly of agglutinated species of Trochammina, Haplophragmoides, Ammobaculites and Verneulinoides which are comparable at the generic level with the microfauna that live in modern marshes. A scattered occurrence of calcareous benthic foraminifera (typical of marginal marine environment) and thecamoebians (freshwater to brackish environment) is also recorded. The comparison of these microfauna with modern and fossil foraminiferal associations from paralic environment suggests that the sediments in the Cretaceous of A-52 were deposited in a marsh-estuarine environment. Additionally the species from A-52 were identical to those found in the Cretaceous of Alberta's Bearpaw Fm.

BIOSTRATIGRAPHIC STUDY OF CENOZOIC STRATA OF THE GRAND BANKS, NEWFOUNDLAND

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The only extensively cored Cenozoic sections from offshore eastern Canada were recovered from a series of core holes drilled in 1965 by Pan American Petroleum Corporation (now part of BP P.L.C.) and Imperial Oil Canada. The core holes are from several basins, including the Scotian, Horseshoe, South Whale and Jeanne d'Arc. Previously, only preliminary palynological studies have been made on materials from the core holes. The current study focuses on Core Hole 16 from the southern Jeanne d'Arc Basin and Core hole 2 from Bear Ridge. Core hole 16 penetrates a broadly fining-upwards section through the Banquereau Formation, with excellent dinocyst recovery, spanning the middle Eocene through the middle Miocene. Preliminary results indicate that Core Hole 2 represents a similar sequence through broadly fining-upwards strata in the Banquereau Formation, spanning the Late Eocene to Pleistocene. By incorporating pollen and spores with dinocysts, we plan to consolidate the taxonomy, develop detailed event biostratigraphy, interpret local paleoenvironments, and determine the prevalence and age of offshore currents, particularly the Proto-Gulf Stream. The results will provide new insights into the Cenozoic history of offshore eastern Canada, including an awareness of climate change during this time.

LOWER TERTIARY MASS TRANSPORT SYSTEMS EXHIBITED IN UPPER CRETACEOUS WYANDOT CHALK

Smith, Brenton M.

Canada Nova Scotia Offshore Petroleum Board, 1791 Barrington St., Halifax, Nova Scotia, B3J 3K9, Canada

The Upper Cretaceous Wyandot formation is a thick, continuous package of limestones, marls and chalks representing deposition on a stable, shallow, open-marine continental shelf.

Extremely detailed mapping of this surface is made possible by the strong seismic signature at the top of the Wyandot limestone. Interpretation of 16 3-D surveys covering 12,000 km^2 has described a complicated surface with varying degrees of erosion and has detailed several erosional features. The mapping results are displayed as a 3-D surface from which the following can be observed.

- A polygonal pattern covering much of the original chalk surface, possibly caused by brittle deformation of the Wyandot, has widths of up to 150 m.
- Early tertiary deltas prograding onto the Wyandot surface formed a series of troughs and ridges along the toe of these deltas. This pattern may have been caused by ocean current scour or sediment loading. Most of these patterns were eroded by subsequent mass transport systems.
- Slope failure of the prograding Paleocene and Eocene deltas resulted in erosion of the upper Wyandot formation. A failure plane in the upper Wyandot detached creating a clearly defined head scarp of ~80m in height. This scarp is over 100 km in length. A 5 km wide mass transport corridor leading out to the shelf break is also clearly imaged. The fill within this corridor suggests multiple mass transport events.
- Large slide blocks over 1 km long within the mass transport systems can be observed. Numerous failure events have overprinted, resulting in a complicated pattern of mass transport systems and varying degrees of Wyandot erosion.

These observations indicate that large quantities of transported Wyandot chalks should have been re-deposited out to at least on the upper slope, although these chalks would be mixed with Tertiary deltaic sediments. Re-deposited chalks are a major reservoir in the North Sea. Demonstrating that Tertiary deltas transported sediments to the slope provides additional evidence that similarly situated, Early and Middle Cretaceous deltas may have also transported sediments to the slope. This process is essential for the development of deep water turbidite reservoirs.

Core Workshop

Both siliciclastic and carbonate cores will be on display. Nova Scotia has producing Cretaceous deltaic gas fields of the Sable Island delta and the recently discovered Deep Panuke carbonate margin reefal gas pool that was overlain by now-depleted clastic oil pools. Cores from some of these commercial fields will illustrate their facies variations and reservoir characteristics. Cores from the carbonate margin that stretched in a Mesozoic gigaplatform from the Grand Banks to Florida will be on display from Nova Scotia Shelf and Baltimore Canyon Trough off Delaware USA and show the various Jurassic reef types – coral reef, siliceous sponge and microbial mound. Now off limits in the Gully marine reserve, the Primrose salt dome has deep shelf chalk oil reservoirs of the Upper Cretaceous Wyandot Formation that will also be shown. Although not a reservoir here, the Scotian Shelf has one of the rare examples of an offshore meteorite impact at Montagnais with brecciated core from the Lower Paleozoic Meguma Group basement.

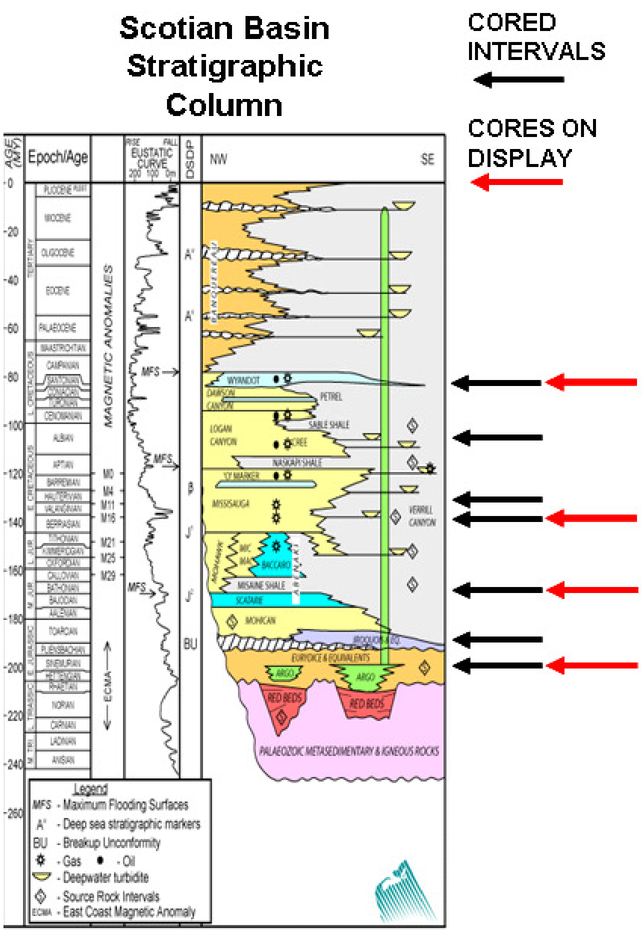

Figure 4: Generalized stratigraphic column for the Scotian Basin, offshore Nova Scotia (CNSOPB). Detailed columns can be found in Wade & MacLean, (1990). Sea level curve from Haq et al. (1987).

ORGANISERS

Leslie Eliuk (GeoTours, Dalhousie Univ.)
Andrew MacRae (Saint Mary's University)

WHEN

August 12, 2008, Tuesday 0900-1600 (Lunch included**)**

WHERE

Canada-Nova Scotia Offshore Petroleum Board's Geoscience Research Centre (GRC)
Suite 27, 201 Browlow Avenue, Dartmouth, Nova Scotia, B3W 1W2, (902) 468-3994. This recently renovated facility also houses CNSOPB other offshore data and will be the venue for Wednesday evening's CNSOPB-hosted Reception.

TRANSPORTATION

Bus departure time 0800 (in front of Dalhousie Student Union Building, University Avenue). Bus return time 1600 (to Dalhousie Student Union Building)

LUNCH

Free lunch is provided by the CNSOPB.

Core Display Presentations
By Stratigraphy

THE MONTAGNAIS METEORITE IMPACT STRUCTURE, WESTERN NOVA SCOTIAN SHELF
Lubomir Jansa and Georgia Pe-Piper

DEEP SHELFAL CHALK RESERVOIRS OF THE UPPER CRETACEOUS WYANDOT FORMATION, PRIMROSE SALT STRUCTURE AREA, OFFSHORE NOVA SCOTIA
Andrew MacRae

PRODELTAIC DEFORMATION FACIES FROM THE ALMA AND TANTALLON FIELDS
David Piper and Georgia Pe-Piper

HYPERPYCNAL FLOW DEPOSITS FROM THE THEBAUD FIELD
David Piper and Atika Karim

TIDALLY-INFLUENCED DELTAIC RESERVOIRS IN THE UPPER JURASSIC-LOWER CRETACEOUS MICMAC AND MISSISAUGA FORMATIONS (GLENELG AND ARCADIA FIELDS), OFFSHORE NOVA SCOTIA
Andrew MacRae

VARIED CARBONATE FACIES FROM THE JURASSIC-CRETACEOUS GIGAPLATFORM MARGIN OF BALTIMORE CANYON TROUGH OFF DELAWARE, USA.
Les Eliuk & Brad Prather

REEF MARGIN CARBONATE RESERVOIRS OF THE UPPER JURASSIC-LOWER CRETACEOUS ABENAKI FORMATION (DEEP PANUKE)
Les Eliuk *for* Rick Wierzbicki, Kevin Gillen, Rolf Ackermann, Nancy Harland, Leslie Eliuk, with a contribution by Jeff Dravis

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Core Display Abstracts

THE MONTAGNAIS METEORITE IMPACT STRUCTURE, WESTERN NOVA SCOTIAN SHELF

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The first of only three known offshore impact structures, Montagnais has a short core from fractured Meguma Group (Cambro-Ordovician) recovered in Union et al. Montagnais I-94. In 1987 a report in Nature (v.327, p. 612-614) was followed up by a 1989 larger article by Jansa, L.F., Pe-Piper, G. Robertson, P.B., and Friedenreich, O. in Geological Society of America, v. 101, p.450-463. Although the effects of meteorite impacts on land has been relatively well studied (including as significant hydrocarbon-bearing structures) those on the 70% of the water-covered earth are much less understood. An underwater extraterrestrial impact crater occurs on the North Atlantic continental shelf, 200 km southeast of Nova Scotia, Canada. The impact, in late early Eocene (51 Ma) produced a complex structure with a submarine crater, a central structural high and an inner topographic ring. The crater is filled with breccia, which exhibits shock deformation features. Lack of enrichment of the melt rocks in siderophile elements compared with basement rocks and a slight enrichment in iridium suggest that the impactor was either a stony meteorite or a cometary nucleus. The diameter of the impactor is estimated to be about 2-3 km.

The cored section is about 400 m below the top of basement in the central uplift of the crater. Megascopically, it resembles Meguma Group metagreywackes and phyllites exposed on land in southern Nova Scotia. The metagreywackes from the core have hairline microfractures and rare undecorated shock lamellae in quartz grains, visible in thin sections. Other evidence for the impact structure was based on petrographic examination of cuttings and included the recognition of thick breccias, melt zones of rhyolitic composition containing calcic plagioclase, and shock-induced features of minerals including isotropization and shock-induced lamellae.

DEEP SHELFAL CHALK RESERVOIRS OF THE UPPER CRETACEOUS WYANDOT FORMATION, PRIMROSE SALT STRUCTURE AREA, OFFSHORE NOVA SCOTIA

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Chalks of the Upper Cretaceous (Turonian-Maastrichtian) Wyandot Formation form an extensive stratigraphic marker on the Scotian Margin and parts of the Grand Banks. Although not commercial, significant discoveries of natural gas occur at two sites on the Scotian Margin, Eagle and Primrose, where the Wyandot Formation serves as the main reservoir. This core display will show selected examples of the reservoir intervals at the Primrose field.

At Primrose the Wyandot Formation is characterised by well-bioturbated chalk and minor marlstone with a diverse ichnofauna dominated by subhorizontal feeding and dwelling traces (e.g., *Thalassinoides*, *Zoophycos*, *Chondrites*), and body fossils of inoceramid clams. There are some subtle indications that firmground surfaces may occur within some intervals of the chalk. The nature of the ichnofauna and of published rock-eval data (Wielens et al. 2002) implies well-oxygenated bottom conditions at the time of deposition. These are clearly "autochthonous" chalks that have formed in-situ rather than being redeposited "allochthonous" chalks (Ings et al. 2005).

Stratigraphic relationships with the overlying Campanian-Neogene Banquereau Formation indicate these chalks were probably deposited in water depths in excess of 200-300m, and were located outboard of most of the clastic sedimentary input. Despite the significant water depths, they were still inboard of the main continental slope of the Upper Cretaceous, and are therefore described as forming in a "deep shelf" setting.

Porosity within the Wyandot Formation is as high as 20-30%, but, as for most chalks, it is extraordinarily fine-grained. Porosity declines significantly even within the approximately 200m thickness of the unit at Primrose, likely due to compaction-related cementation. It is probably the relatively shallow depths (<1600m) that have allowed the reservoirs to remain significant here (Ings et al. 2005). This issue probably precludes major reservoirs in this interval on the deeper parts of the Scotian Margin, however, were redeposited chalks and early hydrocarbon charge to occur as in the central North Sea, promoting porosity preservation, deeper reservoirs may still be possible.

PRODELTAIC DEFORMATION FACIES FROM THE ALMA AND TANTALLON FIELDS

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Conventional core through foresets of Lower Cretaceous deltas at the Alma field and in Tantallon M-41 show a wide range of sediment deformation facies. In particular, facies that have shallow-water sedimentological features (tidal-flat structures, wave ripples) occur in blocks of sizes ranging from centimeters to metres overlying a zone of sedimentary mylonite, with highly deformed sediments interpreted as the deforming base of a submarine landslide. Failure to recognise the allochthonous nature of these sediments has led to misinterpretation of the depositional environment and also has consequences for the connectivity of sandstone bodies. The range of observed allochthonous facies will be illustrated with core from Alma and Tantallon.

HYPERPYCNAL FLOW DEPOSITS FROM THE THEBAUD FIELD

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Hyperpycnal flow deposits, or "delta-front turbidites", are becoming increasingly recognised as important components of some deltaic systems. The presence of Bouma T_{abce} or T_{bce} sequences in sandstones, with unidirectional climbing current ripples and basal flute marks are the most diagnostic sedimentological evidence of prodeltaic hyperpycnal flows (Bhattacharya and Tye, 2004; Hampson and Howell, 2005; Myrow et al. 2006). Such beds may be capped by wave-generated oscillatory ripples and the tops are commonly strongly bioturbated. Laminae of phytodetritus are common in the sandstones and the T_e division commonly has a high organic content (Rice et al. 1986). Delta-front turbidites show distinctive ichnological suites (MacEachern et al. 2005) as a result of rapid event deposition and changes in oxygenation and salinity. Some coarse-grained cross-bedded sandstones have been interpreted as deposits of predominantly by-passing prodeltaic hyperpycnal flows (Edwards et al. 2005) and turbidite channels and lobes are interpreted as significant components of shelf facies models (Pattison, 2007). Hyperpycnal mud turbidites are also recognised in prodelta settings (Leithold and Dean, 1998), with sedimentological characteristics summarized by Piper and Stow (1991). Delta-front turbidites show many similarities to sandstone beds termed tempestites, which are interpreted to result from storm resuspension of littoral sand. Myrow et al. (2002) have demonstrated that well sorted sandstone beds showing Bouma sequences and basal unidirectional flute marks have climbing ripples with convex-up and sigmoidal foresets that are characteristic of mixed wave and current motion.

These concepts will be illustrated by selected core, principally from the Thebaud field. Thick bedded reservoir sandstones from fields such as Thebaud appear to be inner shelf hyperpycnal deposits (facies 9), forming graded sandstone beds decimeters to metres thick, with Bouma Ta-Tc sequences, abundant phytodetritus, detrital intraclasts of mudstone and siderite, and minor bioturbation at the top of beds. This facies passes stratigraphically upward into tidally influenced river-mouth and river-channel sandstones (facies 4) and downward into thinner graded sandstone beds with interbedded mudstone (facies 0). More highly bioturbated thin bedded sandstones (facies 2) in places show hummocky cross-stratification, concentration of shells at the base of beds, and wave-ripples, suggestive of storm reworking. In the Glenelg field, tidally-influenced hypopyncal silts interbed with hyperpycnal sands and both change character distally.

The recognition of hyperpycnal flow deposits has important implications for reservoir geometry and diagenesis**.**

BALTIMORE CANYON TROUGH MESOZOIC CARBONATE MARGIN CORES, OFFSHORE USA ATLANTIC

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In 1984 three wells operated by Shell tested various types of Jurassic-Cretaceous carbonate shelf and margin plays in deep water offshore New Jersey. Eleven cores were recovered: OCS-A 0336 cores R1-4, OCS-A 0337 cores C1-3 and OCS-A 0317 cores H1-4. Representative core intervals on display are keyed to seismic morphology and show litho-biofacies from three geometrically and stratigraphically separate shelf edges:

Oxfordian-Kimmeridgian prograded margin (R1+2) and slope (C3), Late Kimmeridgian-Berriasian aggraded margin capped by pinnacle reefs (C2, H3+4), then an extensive deeper-water mounded sponge-rich interval of Berriasian and Valanginian age (R2, C1, H2) and finally a back-stepped Barremian-Aptian reef margin (R1) on prodeltaic shales. Alternatively cores can be facies grouped into deeper-water upper slope microbial(?) mound (C3) and reef complex (R3–foreslope? + R4-reef framework & sands) of the prograded margin, shelf-edge shallow-water skeletal sands (H3+4, C2) in the aggraded margin, and deep-water carbonates capping a drowned shallow-water shelf (R2, C1, H2) then mid-Cretaceous shallow-water shelf-edge oolite (R1).

Previously unpublished paleoenvironmental models by Edwin Ringer and Harvey Patten illustrate the depositional facies relationships. No analogue is perfect, but older (and with the 1999 Panuke gas discovery many more recent) Nova Scotia (NS) shelf-edge wells also sample the Jurassic-Cretaceous gigaplatform margin. Though similar enough to apply the same formational terminology, and a very similar vertical depositional progression including ‘drowning’, the Baltimore Canyon wells in general sample much more carbonate-sand-rich beds. Whereas the NS margin wells sample muddier but much more reef framebuilder-rich beds. The basins have some major difference but these biofacies differences may indicate a “sampling” bias; possibly shallow-water J-K reefs simply grew in slightly deeper water. The best depositional model will integrate both data sets. Degree of dolomitization remains a significant difference.

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INTERPRETATION OF A FRACTURED DOLOMITE CORE: MARGAREE F-70, DEEP PANUKE, NOVA SCOTIA, CANADA

Leslie Eliuk for Rick Wierzbicki, Kevin Gillen, Rolf Ackermann, Nancy Harland, Leslie Eliuk, with a contribution by Jeff Dravis
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The purpose of this presentation is to show the facies, diagenesis, and fracture interpretation of the fractured and dolomitized margin of the Abenaki carbonate platform at Deep Panuke. Core from F-70, H-08, and PI-1B will be displayed.

The Deep Panuke gas reservoir was discovered in 1999, 250 km offshore of Halifax Nova Scotia. Gas is trapped in dolomite and limestone at the margin edge of the Jurassic aged Abenaki carbonate complex. Analysis of well test data had indicated that platform margin edge wells were connected to a highly permeable reservoir, assumed to be fractured or vuggy dolomite/limestone.

In 2004, data was obtained on the high permeability reservoir, when 24 meters of core was recovered from the F-70 well bore. The F-70 core encountered foreslope and reefal limestone and fractured vuggy dolomite in the upper portion of the reservoir. The core was examined and facies described in detail by Les Eliuk. Thin sections were examined and a diagenetic interpretation provided by Jeff Dravis.

The core and associated FMI image from F-70 was interpreted by Kevin Gillen. Data from his interpretation and interpretation of all of the FMI data by HEF Petrophysical were used by Rolf Ackerman (Beicip Inc.) to build a discrete fracture network model of the reservoir. The parameters and insights gained have been used to constrain the flow simulation model of the reservoir.

Repeated with only minor modification by permission from Canadian Society of Petroleum Geologists 2005 Core Conference in Calgary Alberta. Additions have been made to Eliuk's section on depositional setting and that will be the emphasis of the 2008 display. Also a brief appendix has been added with information on cores from Panuke PI-1A and H-08. Panuke M-79 has a 5m core in the basal Scatarie Member rich in quartz grains and ooids that will not be shown

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TIDALLY-INFLUENCED DELTAIC RESERVOIRS IN THE UPPER JURASSIC-LOWER CRETACEOUS MICMAC AND MISSISAUGA FORMATIONS (GLENELG AND ARCADIA FIELDS), OFFSHORE NOVA SCOTIA

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The sedimentary and ichnological signatures of tidal environments are well known from modern and ancient settings, but they are often tricky to recognize within core. This core display will demonstrate some of the diagnostic traits of tidal rhythmite deposits and associated trace fossils in a deltaic setting at the Arcadia (MicMac Formation) and Glenelg (Upper Missisauga Formation) fields. These two sites represent the approximate location of the front of the delta system in the Sable Subbasin in the Late Jurassic and Early Cretaceous, respectively.

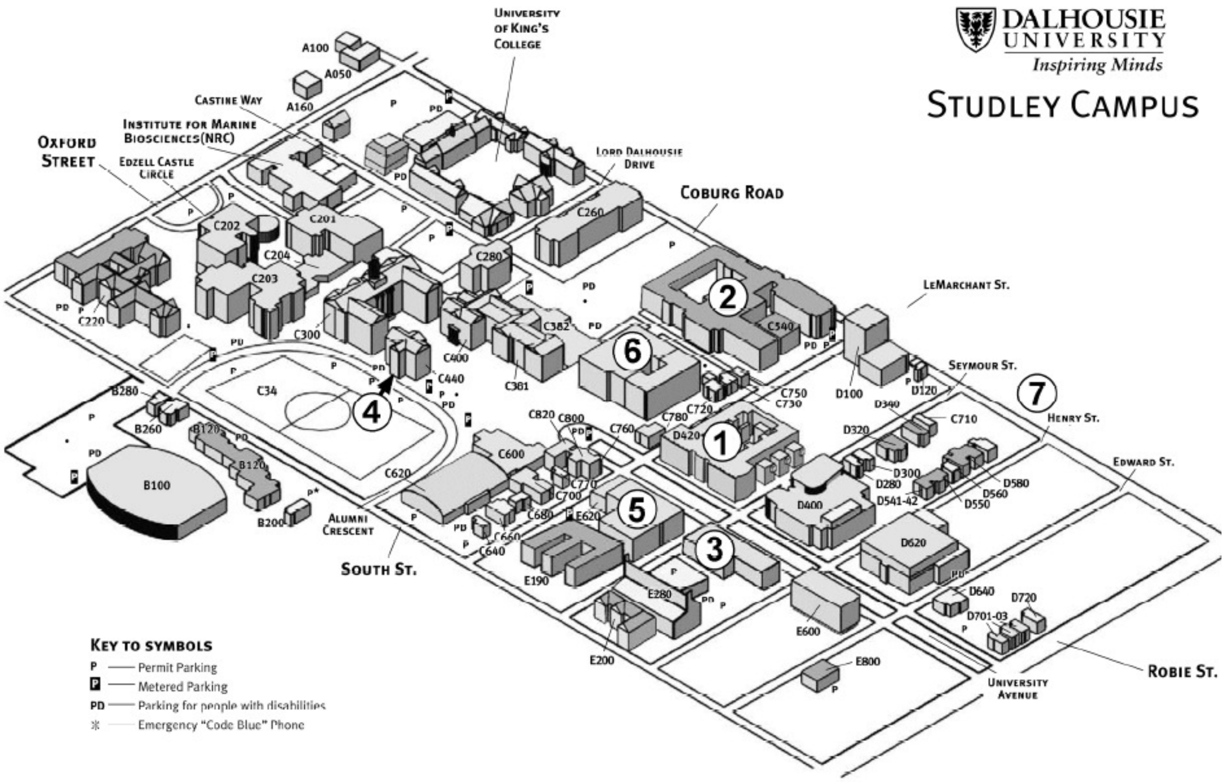
At Arcadia J-16, core 2 consists of a succession of "massive" and crossbedded medium sandstones interbedded at metre-decimetre scale with distinctly rhythmically-bedded (mm-cm scale) fine sandstone and mudstone. The rhythmites show varying degrees of overprinting by bioturbation, from none to moderate, showing how rapid deposition and/or exclusion of much of the biota is often a prerequisite for rhythmite preservation. The fauna is low diversity and dominated by simple vertical or horizontal burrows (mostly *Skolithos*, *Planolites*, and occasionally *Teichichnus*). The rhythmites show clear indications of diurnal inequality and spring-neap cycles, including "crossover", that unambiguously identify them as being produced by tidal processes. At the acme of some cycles the current became strong enough to generate current ripples.

At Glenelg N-49 the cored interval consists of medium-coarse dune-crossbedded or unstructured sands with coarse rip-ups and rare preserved mud drapes. These are interbedded at metre-decimetre scale with fine, occasionally-rippled sand-mud rhythmites. Unlike the rhythmites at Arcadia, diurnal inequality is not evident, and although there are thickness variations consistent with spring-neap cycles, the cycles are incomplete, suggesting that this site experienced a different current regime. The succession generally fines upwards, and is capped by bioturbated sands (*Diplocraterion* & *Skolithos*), rooted mudstones (tidal flat?) and coal, together interpreted as a channel fill. Below the channel is an interval of finer sand-mud rhythmites with rare bioturbation, reactivation surfaces, and current ripples that is interpreted as a more distal setting, perhaps in front of a distributary mouth, but still relatively sheltered from wave processes and influenced by tides.

Both of these sites demonstrate that throughout the long history of the succession of delta lobes referred to as the "Sable Delta", there were intermittent periods when tidal processes were locally significant, and these can be used to infer the proximity of the delta front at the time.

NOTES

Map – Dalhousie Campus



1 – Marion McCain Arts and Social Sciences Building
- Registration Desk (Atrium)
- Social Mixer (July 21st – Atrium)
- Most talks (Scotiabank Auditorium)
- Morning and Afternoon Coffee

2 – Howe Hall Residence (Dorms)

3 – Kenneth C. Rowe Management Building
- Some contributed talk sessions (Potter Auditorium – Rm 1028)

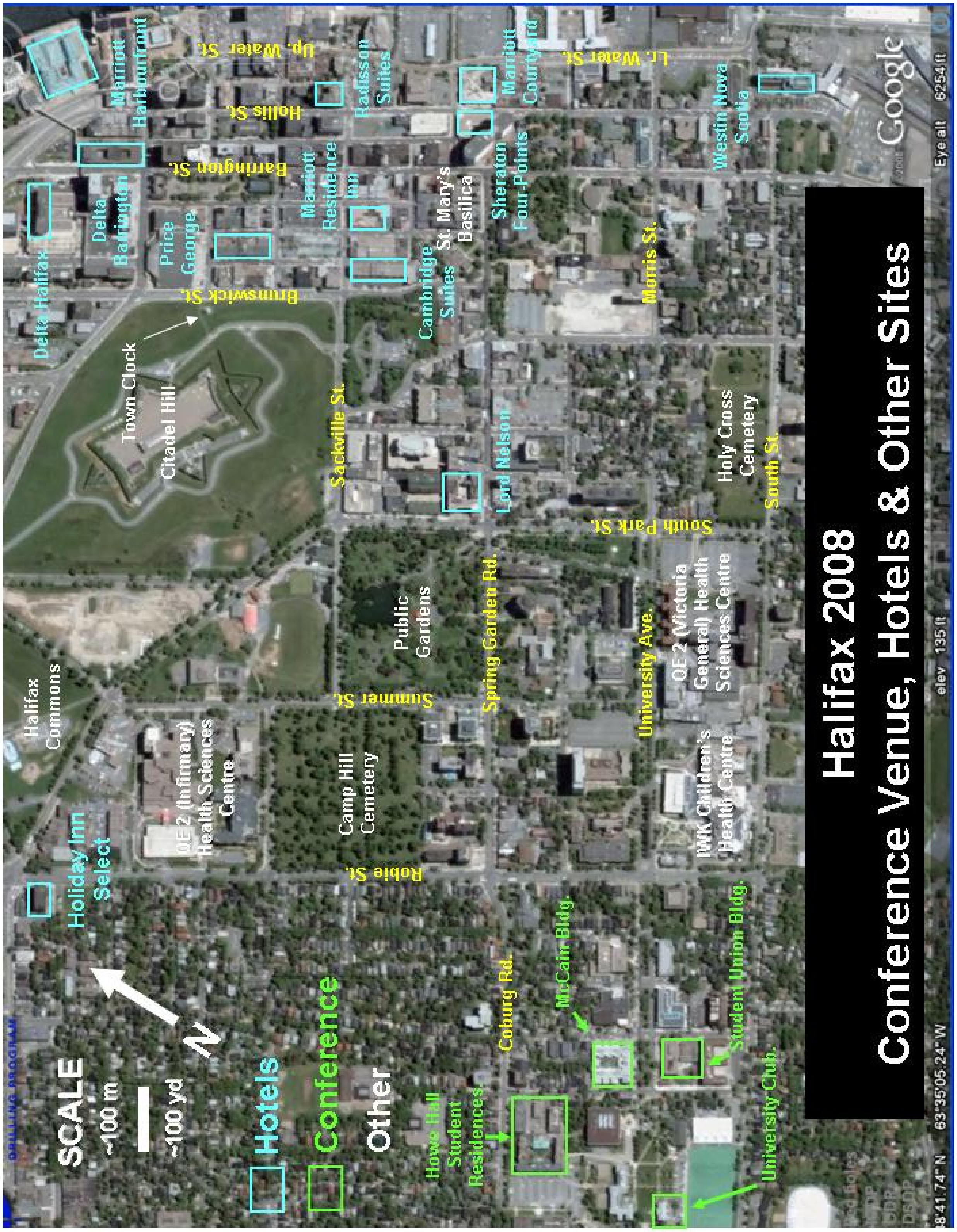
4 – University Club and Great Hall
- Lunch Pick-up
- Poster session (July 23rd – Great Hall)
- Banquet (July 24th - Great Hall)

5 – Student Union Building (SUB)
- Executive Committee Meetings (July 21st - Room 316)
- ISPN (July 21st -22nd – Room 224)
- Coffee shop (Tim Hortons)

6 – Killam Memorial Library
- Coffee shop (Second Cup)

7 – Coburg Coffee House (Closest independent coffee shop)

Buildings 1-6 all include accessible Dalhousie Wireless Internet Zones.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Camp Hill Cemetery
Robie St.
Summer St.
Public Gardens
Spring Garden Rd.
University Ave.
QE 2 (Victoria General) Health Sciences Centre
IWK Children's Health Centre
Town Clock
Citadel Hill
Sackville St.
Lord Nelson
South Park St.
Holy Cross Cemetery
South St.
Delta Halifax
Delta Barrington
Price George
Brunswick St.
Barrington St.
Hollis St.
Up. Water St.
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