N333: Factors Affecting Rift-Basin and Passive-Margin Evolution: Examples from the Fundy and Orpheus Basins *(Nova Scotia, Canada)*

Instructor(s): Martha Oliver Withjack and Roy W. Schlische

Format and Duration

Field - 5 Days
Low Physical Demand

Summary

The course examines the factors that influence the types and evolution of rift basins and passive margins with field and seismic examples from the Fundy rift basin and the adjacent offshore Orpheus rift basin on the Atlantic continental margin of southeastern Canada.

Learning Outcomes

Participants will learn to:

1. Appraise the influence of pre-existing zones of weakness on rift-basin development and basin inversion.
2. Evaluate the influence of pre-rift and syn-rift salt on rift-basin development and basin inversion
3. Assess the influence of tectonics on the large-scale stratigraphic architecture of rifting.
4. Predict rift-basin evolution including the changing geometry of depocenters through time and the development of syn-rift and post-rift unconformities.
5. Understand the factors that influence the hydrocarbon potential of rift basins and passive margins.

Training Method

The five-day field course is based in the Bay of Fundy region, Nova Scotia, Canada. The proportion of field time to classroom time is approximately 50:50. Classroom exercises and lectures provide background information as well as reinforce field observations and place them into context.

Physical Demand

The physical demands for this class are LOW according to the Nautilus field course grading system. All sections are located along coastal outcrops, with no significant climbing. Maximum descent is approximately 50 m (150 ft) along good tracks to the beach. Walking (up to 6 km / 4 miles round-trip) is mainly on sandy beaches, with good walking conditions. However, some rocky beach sections are present, including a boulder field that is up to 0.75 km long (depending on tides). The climate is mild but variable; it may be hot (with little shade) during midday, and participants should be prepared for showers or rain on any day.

Who Should Attend

This course is ideally suited to more experienced geoscientists involved in exploring in rift-basin and passive-margin settings. The lectures and exercises, as well as field discussions, will integrate the various disciplines.

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Prerequisites and Linking Courses

A familiarity with the basic theory of clastic depositional systems, seismic interpretation and structural interpretation and validation would be useful. A variety of courses addressing these topics are available on the Nautilus portfolio and include N155 (Clastic Deposystems), N085 (Seismic Interpretation) and N016 (Structural Interpretation). N005 (Tectonic Controls on Basin Development and Petroleum Systems) would be an ideal course also to take as a primer.

The course links well with other Skilled Application Level classes on the Structure and Tectonics portfolio particularly those focusing on rifts and extensional tectonics, e.g., N380 (Seismic Interpretation Workshop: Play Recognition on Passive Margins), N144 (The Corinth Rift: Normal Faults, Tectonics and Stratigraphic Architecture (Gulf of Corinth, Greece)), N041 (Extensional Tectonics and Normal Fault Patterns (Utah, USA)) and N114 (Extensional Tectonics and Normal Faulting (Nevada and California, USA)).

Course Content

The world's major petroleum provinces include many rift basins and passive margins (e.g., the Grand Banks of southeastern Canada, the North Sea, offshore Norway, offshore Brazil, offshore West Africa, the Gulf of Suez). Thus, understanding the development of rift basins and passive margins is important to successfully explore and produce hydrocarbons in these tectonic settings.

In this course, we will examine the tectonic and structural processes associated with rifting, breakup, and post-rift deformation on the 'passive' margin of eastern North America using field and seismic-reflection data from the Fundy rift basin and the adjacent offshore Orpheus rift basin of southeastern Canada. We will also study seismic data from the Newark rift basin (eastern United States) and the results of scaled experimental models of extension-related and inversion-related deformation.

The Fundy and Orpheus rift basins are part of the Eastern North American (ENA) rift system that formed during the Mesozoic breakup of Pangaea. During the course, we will study the spectacular field exposures in the Fundy basin and interpret seismic-reflection data from both the Fundy and Orpheus basins. Our goal will be to define how variations in the attitude of the pre-existing zones of weakness and the thickness of the syn-rift salt influenced the structural and stratigraphic development of these basins during rifting and during subsequent episodes of post-rift deformation. Specifically, course participants will learn how: 1) the strike, dip, and slip on the border-fault system influenced deformation styles and depositional patterns during rifting and inversion, and 2) rift-related and inversion-related deformation differed in the Fundy basin, with limited syn-rift salt, from that in the Orpheus basin with widespread, substantial syn-rift salt deposition.

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Itinerary

Day 0:

Arrive at Halifax airport, Nova Scotia

Overnight at airport hotel

Day 1:

Classroom Lectures / Exercises

- Overview of continental rifting, breakup, and passive margins
- Overview of crustal extension, normal faulting, and rift basins; stratigraphic packaging; unconformities associated with rifting
- Overview and tectonic history of Eastern North American rift system and passive margin
- Interpretation of seismic-reflection profiles from Newark, Fundy, and Orpheus basins
- Overview of Fundy, Orpheus and Scotian basins
- Introduction to tectonic elements of Fundy basin
- Influence of pre-rift and syn-rift salt on rift-basin evolution

Transfer to Parrsboro, Nova Scotia

Day 2:

Classroom Lectures / Exercises

- Overview of basin inversion
- Interpretation and restoration of seismic-reflection profiles from Fundy rift basin
- Stratigraphy of Fundy rift basin: formations and depositional environments, paleogeographic framework, basin-filling models
- Overview of field sites

Carrs Brook field site –3D views of the pre-rift strata and oldest syn-rift rocks

- Early syn-rift stratigraphy reflects changes in tectonics, transport distances, and climate through time.
- Deformation is complex near faulted boundary of basin; many faults have steep dips.
- Fault activity shifted through time, leading to erosion / uplift of early syn-rift strata and formation of major syn-rift unconformity.
- Fault-related folding produced steep dips of syn-rift strata near faults.

Day 3:

Classroom Lecture / Exercises

- Basin inversion: interpretation of onshore seismic-reflection profile
- Map-view faults patterns and their kinematic significance
- Oblique-slip faulting and oblique extension

Five Islands field site – Spectacular 3D views of the syn-rift strata and rift-and inversion-related structures

- Syn-rift strata include shallow-water lacustrine, fluvial, and eolian deposits indicative of an arid climate during the later stages of rifting; lava flows are part of a large-igneous province.
- Rift-related deformation includes outcrop-scale normal faults, the geometry of which indicate oblique extension on border-fault zone.
- Inversion-related deformation includes folded strata, locally very steeply dipping, and high-angle faults with left-lateral strike-slip.

Day 4:

Classroom Lectures / Exercises

- Synthesis of post-rift deformation in Fundy rift basin
- Timing of post-rift deformation in the Scotian post-rift basin

Wasson Bluff field site – 3D views of syn-depositional border-fault zone

- Syn-rift strata are highly variable within a fault zone that was active during and after rifting; depositional environments include eolian, lacustrine, talus-slope, and fluvial/alluvial.
- Evidence for growth includes talus-slope deposits, wedge-shaped micro-basin fill, large changes in thickness and facies of syn-rift units across segments of border-fault zone, and sediment-filled fissures.
- Inversion structures include fault-parallel folds, some with vertical to overturned limbs, bounded by high-angle strike-slip faults, a product of deformation partitioning.

Day 5:

Classroom Lectures / Exercises

- Summary: types of rift basins and passive margins
- Factors affecting hydrocarbon potential of rift basins and passive margins, including Jeanne d'Arc rift basin of ENAM margin

Blue Sac field site – Views of youngest syn-rift strata and inversion-related structures

- Syn-rift units include shales, sandstones, and breccias of Early Jurassic age.
- Rift-related deformation consists of basalt-clast, talus-slope deposits that likely accumulated adjacent to a fault scarp.
- Inversion-related deformation consists of folded beds, locally very steeply dipping to overturned, and high-angle faults with left-lateral strike-slip.
- Inversion-related deformation was partitioned into two components: strike-slip faulting and folding.

Transfer to Halifax airport for departure