THE GOVERNMENT OF THE REPUBLIC OF TRINIDAD AND TOBAGO

The Ministry of Energy and Energy Industries

Trinidad Joint Study Team – Phase 2 Report

Basin to Leads-Risks and Reserves: Exploration Potential of the Trinidad and Tobago Deep Atlantic Area

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II. TERMS OF REFERENCE

A. Objectives

The objective of this exercise is to increase the MEEI's understanding of the petroleum potential of the TTDAA for use in upcoming bid rounds.

B. Scope of Services

- Provide an integrated petroleum system view of deepwater Trinidad in terms of source(s), traps, reservoirs, seals, and timing. The goal of this work is to integrate the shelf and slope wells to explain the dry holes in the first deep water campaign, and discoveries in an integrated petroleum system study with emphasis on timing of the source rocks and trapping.
- Create basin models showing pressure, temperature, and porosity development through time in the deep-water area.
- Create geohistories for source rock maturation at the Middle Cretaceous, Top Cretaceous and Top Eocene. These will include sensitivity studies of the composition of the source rocks in order to better understand the expected hydrocarbons in reservoirs.
- Create geohistories for key reservoir intervals to address both sandstone compaction and diagenesis.
- Prospect-specific geohistories for source rock maturation at the Middle Cretaceous, Top Cretaceous, and Top Eocene. These will include sensitivity studies on the composition of the source rocks in order to better understand the expected hydrocarbon products in the traps. For each prospect, key reservoir intervals will be analyzed for sandstone compaction and diagenesis.
- Provide an analysis of 6 prospects of different ages – Pleistocene, Pliocene and Miocene. For each age, a three-way and four-way closure must be analyzed.
- Create isopach maps of each prospect.
- Provide prospect-specific models (for 6 prospects) showing pressure, temperature, and porosity development through time based on integrated models of two seismic lines. These results will include the model inputs (e.g. finite element meshes) and outputs, which are suitable for licensing or re-sale.
- Provide detailed risk and probabilistic reserve analyses for each objective at the prospect level and a prospect summary level.

C. Deliverables

- Basin models showing pressure, temperature, and porosity development through time
- Geohistories for source rock maturation at the Middle Cretaceous, Top Cretaceous, and Top Eocene. These include sensitivity studies on the composition of the source rocks.
- Geohistories for key reservoir intervals to address sandstone compaction and diagenesis
- Maps delineating the location of key plays for each of the source intervals
- Detailed understanding of the top leads/prospects with a range of ages and play types
- Geologic risking for each objective level
- Overall prospect geologic risking
- Input parameters for reserve calculations
- Probabilistic reserve estimates
- Well and completion design
- Estimated ultimate reserves per well
- Estimated rates vs. time per well
- Assessment of the need for the enhanced recovery efforts
- Documentation

III. DETAILED PROPOSAL

Robust Oligocene to Pleistocene sedimentation derived from the Orinoco river system developed broad outer neritic to mid-slope wedges that extend far into the present-day deepwater areas. A key analog for understanding the unsuccessful drilling in offshore eastern Trinidad is the similar drilling experience in the offshore Nigeria slope to deepwater area. This zone in offshore Nigeria shows a similar upper to mid-slope facies and yielded a number of marginal to unsuccessful wells. These facies are characterized by discontinuous, confined, low-energy sand systems.

The untested exploration play of eastern Trinidad is further outboard to the east and north and is the deeper Pliocene to Miocene, unconfined sheet-form, sand-prone basin floor fans. These fans bypass the slope at each lowstand and deposit good quality reservoir sand over large lateral extents, efficiently tapping the hydrocarbon migration system with large fetch areas, and usually forming multiple reservoir/seal targets that deliver large reserve potential and warrant further industry interest into this area. These units exhibit characteristic criteria, which are common in the seismic data area east and north of the current drilling limits.

However, further work is indicated to better define the petroleum system and understand the "prize" for the industry. This work builds on the recent DGA Phase 1 offshore Trinidad seismic interpretation. The base regional study for Phase 2 uses basin simulation models to integrate and expand on the risk elements critical to this play(s) including source rock maturation, reservoir seal, charge/migration timing, and estimated volume of hydrocarbon charge to the traps. Optional studies are proposed that address prospect-level petroleum systems analysis and detailed prospect characterization – via refined delineation of reservoirs, seals, and faults (inputs to the model), risk and reserve estimates, and reservoir and/or well deliverability estimates.

Dynamic Global Advisors (DGA) proposes a series of studies to assist the Ministry to better understand the petroleum potential of the deepwater area east of Trinidad. These four studies are focused on a regional petroleum systems analysis with optional studies to characterize selected prospects. These studies can greatly assist in planning for and estimating the value of these potential assets in future concession rounds.

The recently completed study (Phase 1) by DGA for the Ministry was a major reinterpretation and an updated exploration review of the eastern deepwater area of Trinidad. The study was sponsored by ION/GXT for the Ministry to better understand a large area covered by the ION/GXT CaribeSPAN™, PSDM/PSTM, long-offset 2D-seismic dataset. The Ministry contributed key well data and an additional 2D grid of PSTM 2D-seismic data shot and processed by Veritas. The report highlights a prime goal of the Ministry - to produce a new synthesis of the data using modern concepts of shelf-to-deepwater sequence stratigraphy and compressional structural style analysis to clarify the factors underlying the unsuccessful well drilling campaign of the first deep water block offerings. A second goal is to delineate new plays further to the east and north of this drilling and illustrate the criteria for these plays on the seismic data.

A key to advancing the interpretation is the recognition that the complex structures are the product of two major compressional systems that formed intersecting trends of contractional belts, deformed on a highly mobile, Lower Tertiary shale unit. The first system is compressive forces resulting from the eastward motion of the Caribbean Plate. This movement deformed the eastern deepwater area simultaneously as a second system developed; gravity acted on sediment loading coming from the southwest, sediments derived from the Oronoco drainage system. Gravity sliding and translation along a detachment surface within the mobile shale caused a linked extensional/compressional system that moved to the northeast. This contractional toe

A. PHASE 2 REGIONAL PETROLEUM SYSTEM STUDY

This study uses the structural and stratigraphic framework developed in Phase 1, leading to an integrated petroleum system view of deepwater Trinidad in terms of source, trap, reservoir, seal, and timing. The goal of this work is to integrate the shelf and slope wells to explain the dry holes and discoveries in an integrated petroleum system study with emphasis on timing of the source rocks and trapping. An integrated basin simulator is used to forward model the pressure, temperature, and porosity of a basin through geologic time. Subsidiary processes such as petroleum generation and migration are included to better understand key relationships in the basin (e.g., the relationships between source rock maturation, migration, and charge to a reservoir and seal). Several shallower horizons will be mapped to better define the Pleistocene deformation.

These studies are useful to locate and delineate plays as well as identifying the most prospective acreage in a basin. Matava (2006) presented results from a similar study in the northern Gulf of Mexico using the GulfSPAN™ data set, which resulted in a new view of the basin's petroleum systems.

Although individual and sparse 2D seismic lines are of limited utility for most E&P efforts, they provide a usable dataset for regional petroleum systems analysis. The basis for this study will be the existing 2D-seismic, well, and other data. We will use the seismic and structural interpretation (Phase 1) to create forward models for pressure, temperature, and porosity using IES's PetroMod™ 2D integrated basin simulator. We will model the following 13 lines from the CaribeSpan™ dataset (Figure 1): 3300, 3350, 3500, 4200, 4250, 4300, 4325, 4630, 4650, 4670, 4700, 4720, and 4750.

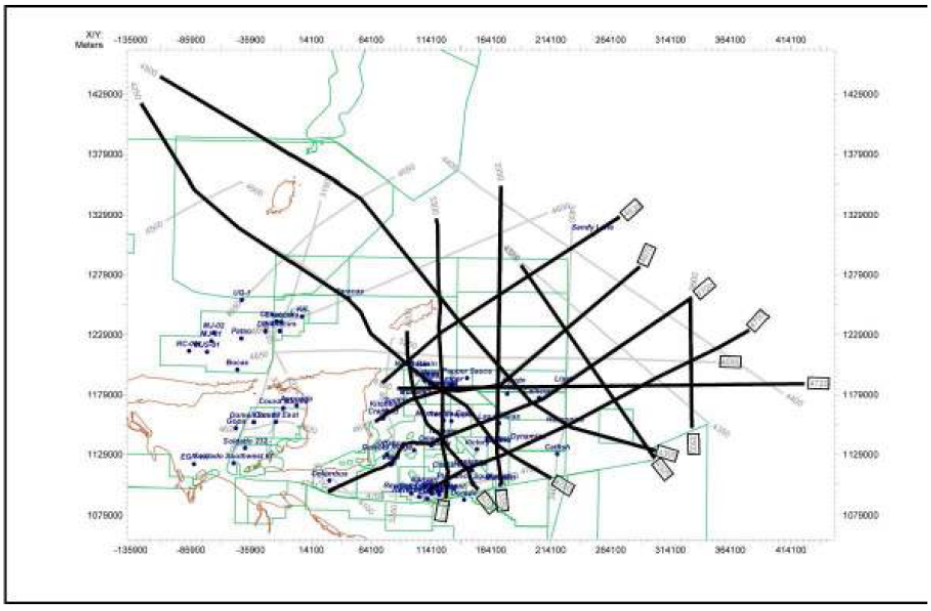

Figure 1: Base map showing the location of the CaribSPAN lines in relation to Trinidad and wells drilled in the area. The lines that are part of this petroleum system study are bold black lines and have the line name outlined with a rectangular box.

In order to develop this more complete view of the basin, we will integrate key wells in the basin to the basin petroleum systems. From such wells, we will use open-hole logging results and geochemical studies to understand accumulations, source rocks, and seeps. Additionally, we will require PVT information on produced hydrocarbons as well as measurements of reservoir temperature and pressure. The study requires a visit to Trinidad at initiation of the project to gather such data.

1. Deliverables

Deliverables for this study include:

- Basin models showing pressure, temperature, and porosity development through time for each of the 13 CaribeSPAN lines. These results will include both the model inputs (e.g., finite element meshes), and outputs, which are suitable for licensing or re-sale.
- Geohistories for source rock maturation at the Middle Cretaceous, Top Cretaceous, and Top Eocene. These include sensitivity studies on the composition of the source rocks in order to better understand the expected hydrocarbon products in traps.
- Geohistories for key reservoir intervals to address both sandstone compaction and diagenesis.
- A report of the results and maps delineating the location of key plays for each of the source intervals.

2. Value

Proving that a viable petroleum system is present and identifying the most favorable portions of the basin.

3. Completion

Delivery date will be 3.5 months from the date that the project is sanctioned by the Trinidad Petroleum Directorate.

4. Team

The team will be lead by Dr. Barbara Radovich and include Dr. Tim Matava, Dr. Chris Connors, Dr. Martin Traugott, Dr. Lesli Wood, Dr. Dan Hsu, Scott Sechrist, Carl Marrullier, and Tim Kiley. Joe Studlick will be the project manager.

B. PHASE 2A PROSPECT PETROLEUM SYSTEMS

This study builds on the petroleum systems concepts developed in Phase 2 to risk individual prospects in the play(s). We propose to build models over each prospect using a strike line and a dip line. In addition to these models at the prospect, the 3-phase flow simulator in PetroMod™ will be used to better risk fluid types in each trap.

2A is an analysis of 6 prospects of different ages – Pleistocene, Pliocene, and Miocene; for each age, a three-way and a four-way closure will be analyzed.

1. Deliverables

Deliverables include:

- More detailed interpretation of reservoir, seal, and fault elements as well as structure and isopachs maps.
- Prospect-specific models showing pressure, temperature, and porosity development through time based on integrated models of two seismic lines at each prospect. These results will include both the model inputs (e.g., finite element meshes) and outputs, which are suitable for licensing or re-sale.
- Prospect-specific geohistories at each prospect for source rock maturation at the Middle Cretaceous, Top Cretaceous, and Top Eocene. These will include sensitivity studies on the composition of the source rocks in order to better understand the expected hydrocarbon products in the traps. For each prospect, key reservoir intervals will be analyzed for sandstone compaction and diagenesis.
- A report of the results including maps, models, and geohistories

2. Value

Detailed understanding of top prospects with a range of ages and play types.

3. Completion

Study 2A would be initiated near the completion of Project 2. Study 2A will require 10 weeks.

4. Team

The team will be lead by Dr. Barbara Radovich and include Dr. Tim Matava, Dr. Lesli Wood, Dr. Chris Connors, Scott Sechrist, and Tim Kiley. Joe Studlick will be the project manager.

C. PHASE 2B PROSPECT CHARACTERIZATION – RISK AND RESERVE ESTIMATION

This study is an in-depth analysis at the level of detail that an industry operator would complete prior to bidding. It will be done on all prospects studied in 2A.

Each study includes detailed risk and probabilistic reserves analyses for each objective level at the prospect and a prospect summary level. Variables studied will be net: gross, rock and fluid properties, pressure, temperature, and recovery efficiencies. Global deepwater analogs will be used to supplement the study.

1. Deliverables

Deliverables for each prospect studied include:

- Geologic risking for each objective level
- Overall prospect geologic risking
- Input parameters for reserve calculations
- Probabilistic reserve estimates
- Report

2. Value

Understanding the reserve estimates of key prospects should allow the Ministry to better assess the potential value of these assets and construct the most favorable bidding terms.

3. Completion

Study 2B would be initiated near the completion of Project 2. Study 2B will require 3 weeks *per prospect*.

4. Team

The team will be lead by Joe Studlick who will also be the project manager. Team members will be Dr. Tim Matava, Dr. Barbara Radovich, Dr. Chris Connors, Tim Kiley, Rick Richardson, and Kurt Mire.

D. PHASE 2C PROSPECT DELIVERABILITY

This study is an add-on to 2B, which is an analysis of producability (MBOPD and MMCFPD) on a reservoir and well basis.

Petrophysical and engineering studies will be conducted to determine how a typical well will produce over its lifetime (production rates of oil and gas, cumulative production of oil and gas, and pressures) from the subject prospect and reservoir. Such results (per well rates and ultimate reserves) are the building block of a development model and economics as done by most E&P companies prior to bidding.

1. Deliverables

Deliverables for each prospect studied include:

- Well and completion design
- Estimated ultimate reserves per well
- Estimated rates vs. time per well
- Assessment of the need for enhanced recovery efforts
- Report

2. Value

Documenting "world class" production rates should make these concessions much more attractive to industry bidders.

3. Completion

Study 2C would be initiated near the completion of Project 2B. Study 2C would require 2 weeks *per prospect.*

4. Team

The team will be lead by Joe Studlick who will also be the project manager. Team members will be Rick Richardson and Kurt Mire.

Results

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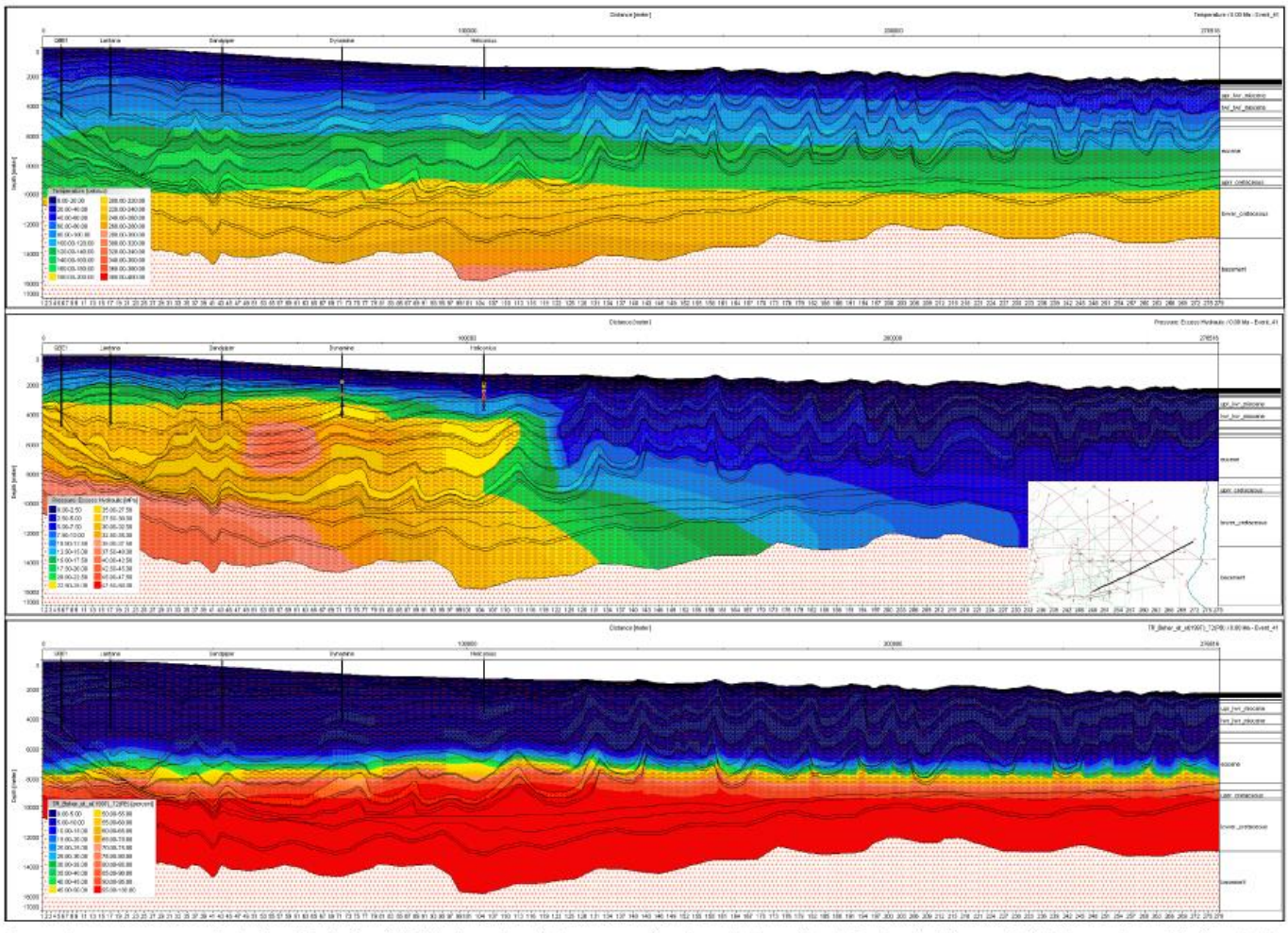
Part 1
Chapter 1 – Basin Models



Temperature, overpressure and maturity profiles generated for each seismic line.

Results were compiled to assess maturity across the basin.

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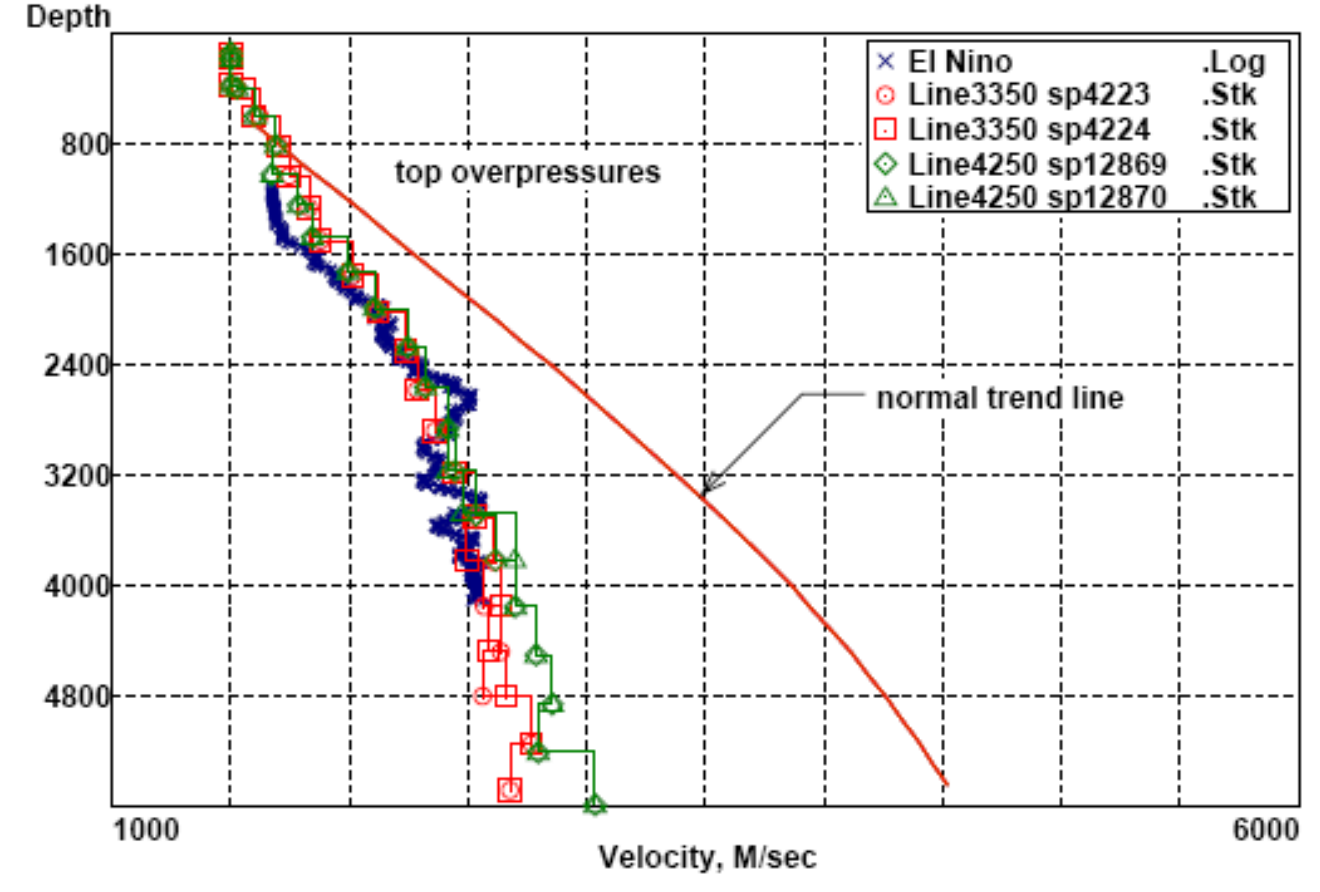
Part 1
Chapter 2 – Pore Pressure Study



Seismic data, wellbore data from twenty wells, and basin models were integrated to establish a framework for predicting pore pressures, assessing seal risks, deliverability and potential drilling hazards.

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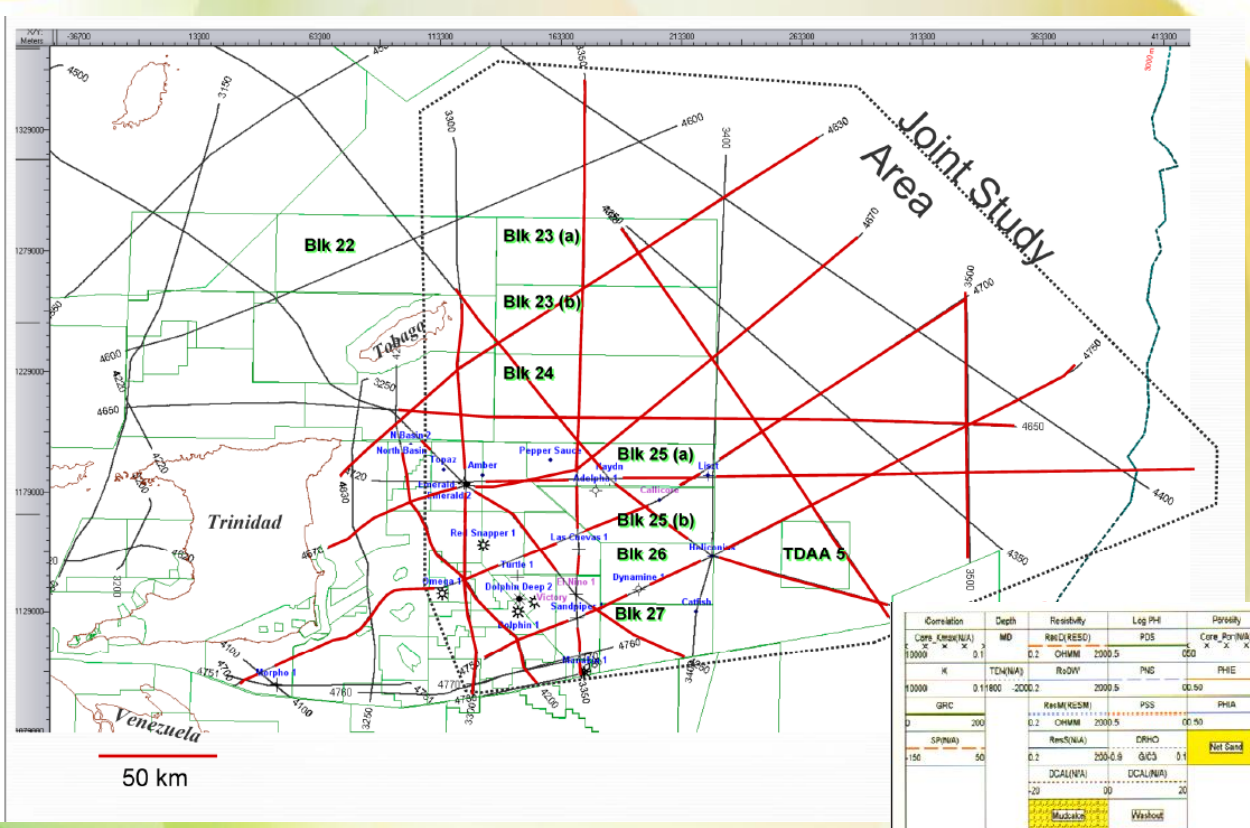
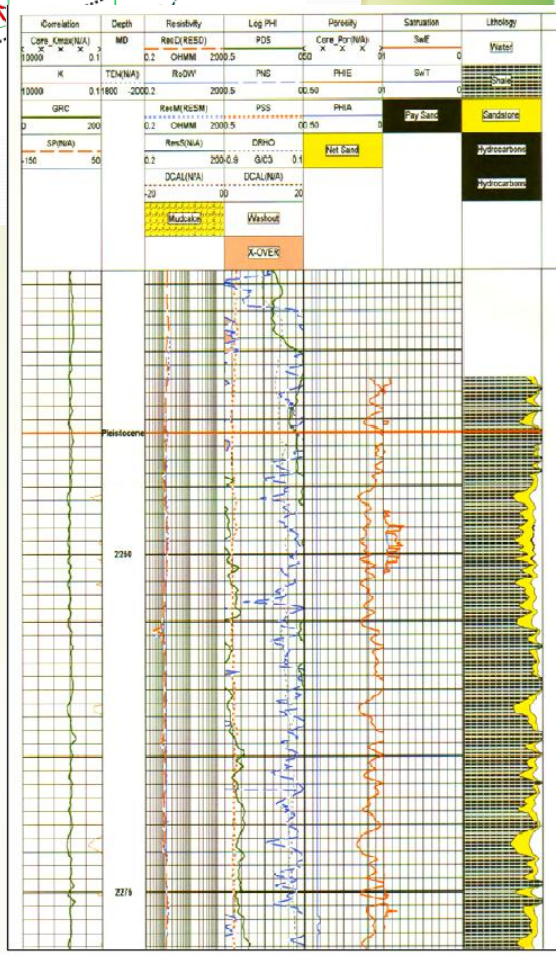
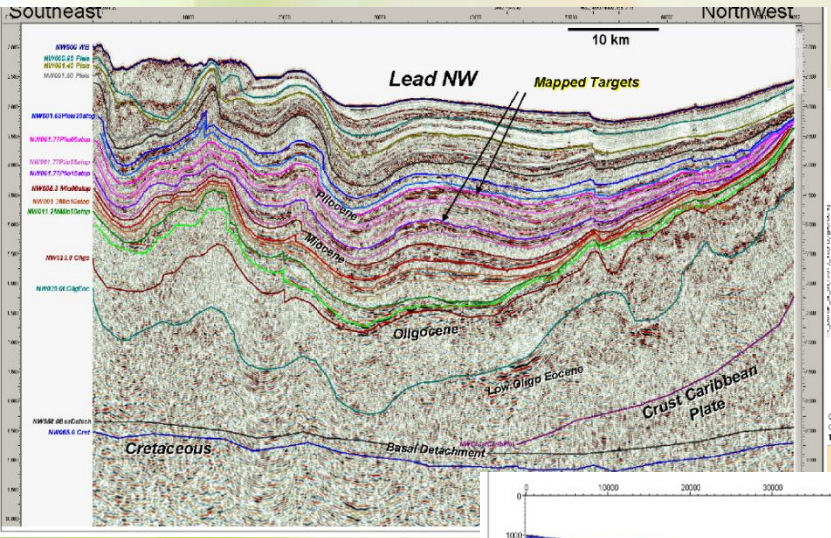
Part 1
Chapter 3 – Rock Properties

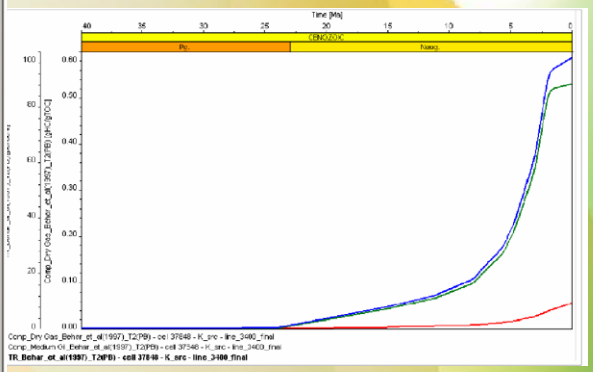


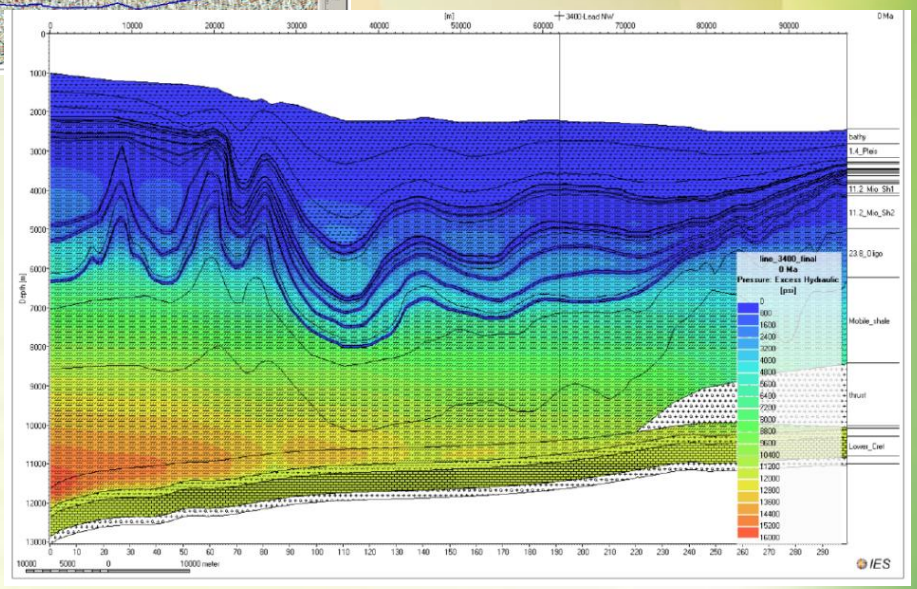


Regional petrophysical analysis using all deepwater exploration wells and some that tied to the shelf, was the basis used to establish reservoir parameters and evaluate potential reserves and producibility in deepwater leads.

Part 2
Chapter 1 – Leads Models







This section reviews the basin modelling results for six leads in the deepwater eastern Trinidad area to refine the understanding of the petroleum systems for these areas and provide key parameters for geologic risking. These models show that the timing and migration can be favourable for accumulations of oil, gas, and liquids in the deepwater area given certain parameters for a Cretaceous source rock, and a Pliocene and younger timing of the mobile shale movement.

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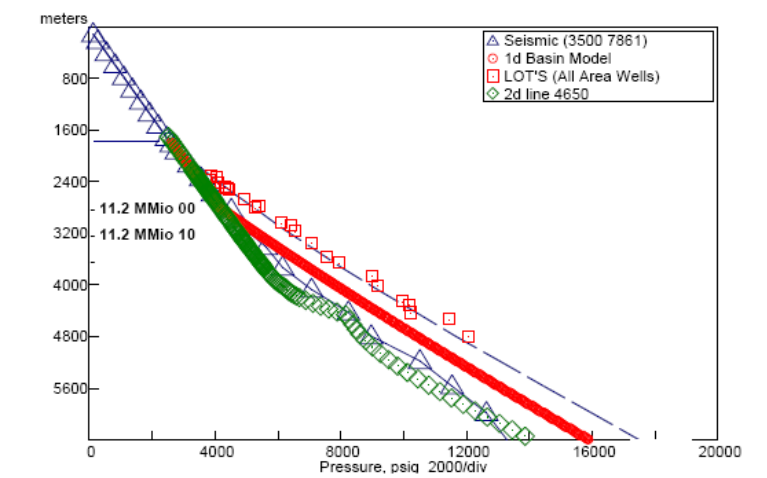
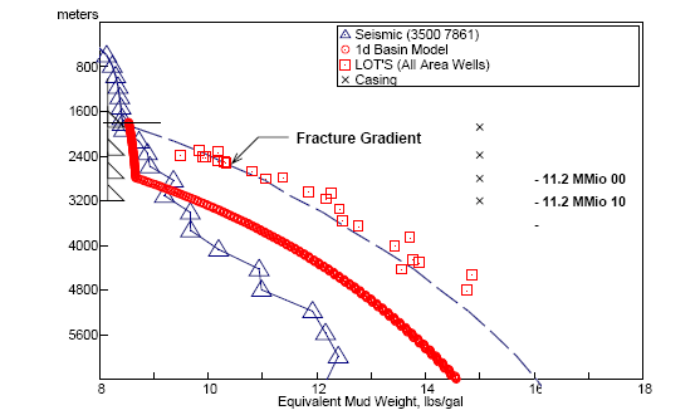
Part 2
Chapter 2 – Seal Evaluation





This study was undertaken to predict the pore pressure conditions for the six leads in the eastern deepwater Trinidad area. The study used a calibration of pore pressures to seismic velocities determined from the 15-well dataset in the Columbus Basin. These calibrations were applied to the six leads and resulted in predictions of pore pressure, fracture gradient, and seal capacity for each.

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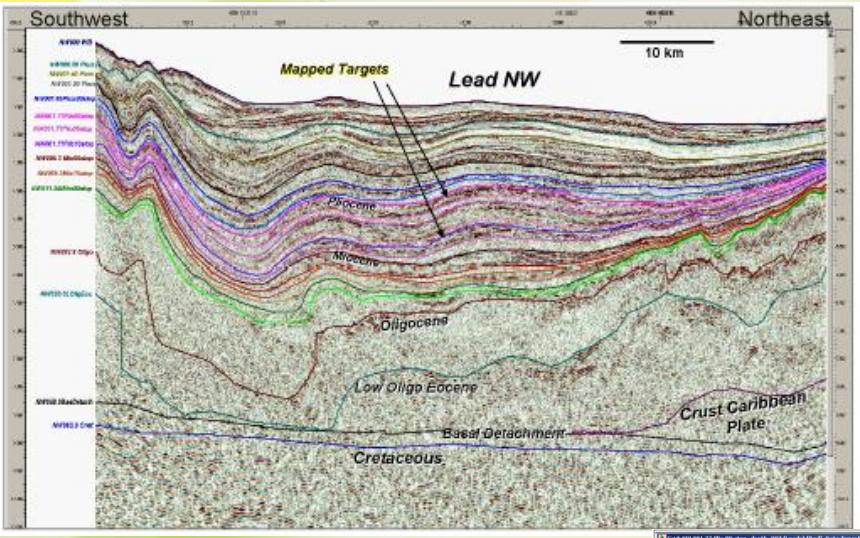
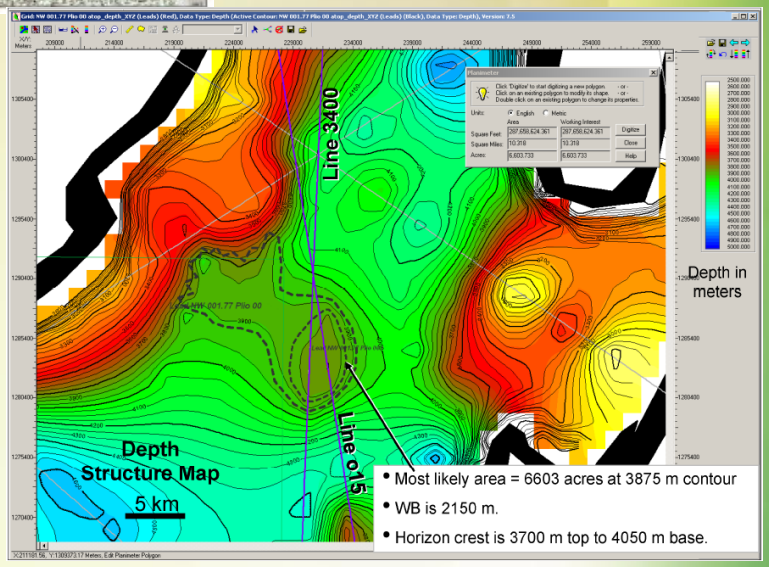
Part 2
Chapter 3 – Description of Leads





The seismic interpretation and mapping of the area was successfully refined in this part of the report which delineated individual lead-style anticlines and reservoir targets and set the stage for risks and reserve estimations. Six leads were selected and provide a representative sample of a variety of trap types, sizes, objective ages and depths, and different areas of the basin.

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Part 2
Chapter 4- Risks and Reserves

Modern risking methods and reserve estimation were applied to the six leads chosen to represent the offshore eastern Trinidad deepwater area. These results show that despite the high risks, the potential reserve sizes may be large enough to balance these risks and warrant further exploration interest. Much of this is due to the large size of the anticlinal structures and the potential for multiple-objective opportunities with good indications of recurrent, sheet-form, basin-floor fans that would sustain reservoir connectivity over the extent of the closures.

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Contact

Trinidad Joint Study Team – Phase 2 Report

Basin to Leads-Risks and Reserves: Exploration Potential of the Trinidad and Tobago Deep Atlantic Area

Available for sale from the Ministry of Energy and Energy Industries. For pricing and further information contact us at:

Phone: 868-62-MOEII
868-623-6708

Email: bidround@energy.gov.tt
hinniss@energy.gov.tt

Web: www.energy.gov.tt

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