Structural Restoration of the Jasmine Complex and Implications for Pleistocene Depositional Environment within the Paria Sub-Basin*

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Abstract

The North Coast Marine Area is best known for its prolific biogenic gas fields. These producing fields, along with most discoveries in the Paria Sub-Basin, target Upper Miocene-Pliocene sandstone reservoirs, which drape over the Patao High. Some 18 km due north of Tobago’s Buccoo Reef, the LL9-1 well discovered Pleistocene gas charged sandstones, currently referred to as the Iris gas discovery of NCMA-4. Similar Pleistocene gas charged sandstones were encountered in the HH6-1 well to the southwest in NCMA-3. These Pleistocene reservoirs are now formally called the UP5 sands of the NC120 sequence stratigraphic unit.

Acquisition and interpretation of 3D seismic data over NCMA-4 and Block-22 revealed a number of low impedance amplitude anomalies at this stratigraphic level. These WSW-ENE trending amplitude anomalies are aerially extensive and form what is termed as the Jasmine complex. This series of undrilled exploration prospects are stratigraphic traps that appear to be structurally related to NE-SW trending reverse faults associated with the right lateral restraining bend between the North Coast Fault Zone and the North Tobago Fault. Structural restorations of key seismic cross-sections throughout the complex were used to define the depositional relationship between the Jasmine complex and the cored basin floor fans of Iris. The integration of
regional well data, seismic impedance volumes, field analogues, present-day drainage and ocean current models established a gross depositional map for the Pleistocene NC120 UP5 sands.
Structural restoration of the Jasmine Complex and implications for Pleistocene depositional environment within the Paria Sub-Basin, Trinidad & Tobago

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• Structural framework by Needham Geosciences
Outline

• Introduction
  • NCMA Regional Structural Setting

• Pleistocene gas discoveries
  • LL9-1, HH6-1, IRIS-1 Core

• Jasmine Complex

• Structural Restorations

• Proposed Pleistocene (NC120) Gross Depositional Map

• Key Points
Regional Geological Setting

North Coast Marine Area

- Main producing fields - depositional clastic wedge latest Miocene to early Pliocene in age
- Thicker Miocene succession as basin deepens to north

From Neill et al. 2014
Regional Geological Setting

North Coast Marine Area Stratigraphy

<table>
<thead>
<tr>
<th>Age</th>
<th>NCMA AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holocene</td>
<td>Mount Irvine Group</td>
</tr>
<tr>
<td>Pleistocene</td>
<td>NCMA 2</td>
</tr>
<tr>
<td>Late Pliocene</td>
<td>NCMA</td>
</tr>
<tr>
<td>Early Pliocene</td>
<td>NCMA 3</td>
</tr>
<tr>
<td>Late Miocene</td>
<td>NCMA 4</td>
</tr>
<tr>
<td>Middle Miocene</td>
<td>Uplift</td>
</tr>
<tr>
<td>Early Miocene</td>
<td>NOT ASSIGNED</td>
</tr>
<tr>
<td>Miocene Sand</td>
<td></td>
</tr>
<tr>
<td>Rocky Bay Group</td>
<td></td>
</tr>
<tr>
<td>Holocene</td>
<td></td>
</tr>
</tbody>
</table>

Key
- WELL
- Producing field
- Gas discovery
- Prospect

Regional Well Database

- NCMA 2
- NCMA 3
- NCMA 4

Sancoche
Cassra
CASSRA-1
CASSRA-2
MARACAS-1
WELL 191M
Poinsetta Heliconia Bougainvillea
Poinsetia-1A
Glossina Cerolia
Hibiscus Ixora
NCMA-4
HH6-1
ALICE-1
TRINIDAD

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Regional Geological Setting

NCMA-1 | NCMA-2 | NCMA-4 | Block 22
---|---|---|---
Chaconia | Poinsettia | Orchid | Iris, Cassra, Sancoche

UP 5 Sands

M-series Sands

25 km
**Well Data : LL9-1 & Iris-1 UP5 Gas Discovery**

**LL9-1**
- Drilled by Deminex, 1975
- Water Depth: 524 ft  
  TD: 7050’ MD (Basement – Quartz Diorite)
- Source Rock: Interbedded Pleistocene shales, biogenic gas
- Reservoir: Encountered UP5c and UP5b, with a possible water contact in the latter.
- Trap Type: Combination (structural & stratigraphic)
- Results: DST (3612 – 3633 ft), 32/64” choke, 8.9 mmscf/d;

**IRIS-1**
- Drilled by Centrica, 2013 penetrating three UP5 reservoirs – UP5a, b & c. No water contact was observed. All sandstones were fully cored.

**LL9-1**
- Net reservoir – 40.5ft, Net Pay - 19ft, Avg porosity – 31%.

**IRIS-1**
- Net reservoir – 68ft, Net Pay – 38.3ft, N:G 34%, Avg porosity – 29%.
Iris Sedimentology – UP5a

Dm-scale beds of high-concentration sandy turbidites. Well std, lower fine grained and ‘clean’ to slightly silty. Carb debris and small mudclasts common. ‘Linked’ debrites (pebbly sst). Consistent with medial - distal part of lobe/fan.

© Centrica plc, 2013
Dm- to m-scale beds of deformed pebbly sandstones with thin low concentration sandy turbidites. Well std, lower fine grained and ‘clean’ to slightly silty. **Consistent with overbank / channel margin deposition.**
Depositional Model – UP5c

Lobate features, at least 2 separate lobes with ‘finger-like’ distributary channel features

Meandering channel features

Spectral decomposition from standard seismic volume
Well Data: HH6-1 UP5 Gas Discovery

- Drilled jointly by Deminex/Agip 1971
- Water Depth: 260 ft  TD: 12351' MD (Basement – Igneous)
- Source Rock: Interbedded Pleistocene shales, biogenic gas
- Reservoir: One signif. gas bearing sdst, 5018 - 5030ft MD (UP5 gas sand)
- Trap Type: Combination (structural & stratigraphic)
- Results: DST 1 (9845 – 10202ft), 11bbls salt water/93mins (Basal Sand)
- Results: DST II (5018 - 5030ft), 32/64” choke, 7.5 mm/scf/d (UP5 gas sand)

**UP5 Properties:**

- Interval Thickness: -12ft
- Net Pay: -7ft
- N/G: -60%
- Porosity: -30%
HH6-1 Tie-in Reflectivity
HH6-1 Tie-in Lambda-Rho

HH 6-1 drilled a bit of attic gas on a heavily faulted structure at the UPS level as Jasmine SW.
Jasmine – UP5 (NC 120)

UP5

• WSW to ENE trending bright amplitudes that closely correlate with the UP5 (NC120-Late Pliocene/Pleistocene) gas charged sandstones proven at Iris. A mere 7km south westerly, HH6-1 encountered gas at the UP5 level.
• Jasmine comprises of four primary segments: Jasmine North, Jasmine Central, Jasmine South, and Jasmine South West. Jasmine South and SW are more structurally defined by a combination of NE-SW trending reverse faults and NW-SE trending normal faults.
Fold growth

Fold and bedding geometries show that reverse slip initiated during Basal Sand deposition but may have been less active from above M6. Further movement with a vertically decreasing amount of throw occurred up to UP5 and slightly later.
Relationship of folds and faults

- Right lateral movement on the North Coast fault Zone and the North Tobago/Patao fault generates a restraining overlap and produces shortening in the form of reverse faults and folds.
- Intermittent growth during Basal Sand to UP5 shows that displacement transfer sometimes more efficient and shortening does not occur.
- Normal faults in Jasmine form perpendicular to shortening structures.
Determining the NC120 (UP5) GDE at Jasmine

Evaluation of GDE based on:
- Extended regional seismic mapping at NC120/UP5 level revealed northerly trending 150m wide slope channels with associated 4-5km basin floor fans

- Well data at HH6-1 & ALMA-1 suggests Outer Shelf deposits with strong inner shelf influence, CU ssts. Biostrat data from NCMA-1 also suggests Outer Shelf deposition.

Data courtesy of Niko Resources:
- Flattened seismic volume on the 'HH6-1 Gas' pick and then took a couple of time slices. Reds and yellows are troughs, blues are peaks.

- Northerly trending channels on Niko Resources ‘UP5’ flattened seismic volume in vicinity of HH6-1
14. Composite line: Present

Seabed to NC140
NC140 to UP5
UP5 to M0/M2
M0/M2 to M4
M4 to M6
M6 to M7
M7 to M8
M8 to Basal Sand
Basal Sand
Basement

VE = 4
14. Composite line: NC140

Seabed to NC140
NC140 to UP5
UP5 to M0/M2
M0/M2 to M4
M4 to M6
M6 to M7
M7 to M8
M8 to Basal Sand
Basal Sand
Basement

VE = 4
14. Composite line: UP5

UP5 shelf edge
controlled by the North Tobago Fault

Significant growth stratigraphy at the North Coast Fault Zone
14. Composite line: M0/M2

VE = 4
14. Composite line: M4

NE

SW

Seabed to NC140
NC140 to UP5
UP5 to M0/M2
M0/M2 to M4
M4 to M6
M6 to M7
M7 to M8
M8 to Basal Sand
Basal Sand
Basement
14. Composite line: M6

Ne to SW

Seabed to NC140
NC140 to UP5
UP5 to M0/M2
M0/M2 to M4
M4 to M6
M6 to M7
M7 to M8
M8 to Basal Sand
Basal Sand
Basement

VE = 4
14. Composite line: M7

- Seabed to NC140
- NC140 to UP5
- UP5 to M0/M2
- M0/M2 to M4
- M4 to M6
- M6 to M7
- M7 to M8
- M8 to Basal Sand
- Basal Sand
- Basement

VE = 4
14. Composite line: M8

VE = 4
14. Composite line: Basal Sand

South Western Tobago Middle Miocene Basement uplift (prevalent dendritic drainage)
Jasmine Structural Restoration Results

- Reverse slip initiated during the Basal Sand Deposition ~ Middle Miocene
- Right lateral movement on the North Coast Fault Zone and the North Tobago/Patao Fault generates a restraining overlap producing reverse faults and folds
- Intermittent growth during Basal Sand to UP5 shows that displacement transfer sometimes more efficient and shortening does not occur
- Pleistocene right lateral movement along North Tobago Fault generates UP5 Shelf Edge
- Reverse faulting inactive after UP5, late stage normal faulting evident orthogonal to shortening structures

**Composite line: Present**
Further Shelfal Evidence & Analogues

North westward prograding clinoformal geometries best observed on the Lambda Rho volume supports that the Jasmine UP5 Complex is shelfal. Clinoforms are generally 1-2° but up to 7° in Jasmine North East. As such the UP5 interval at Iris-1 (Basin Floor Fans) would not be an appropriate analogue. Clinoforms are observed in NCMA-1 M2-Chaconia/Poinsettia gas fields and in Block-22 Cassra M0 gas discovery.
Jasmine UP5 Depositional Model

A broad ~45km shelf spans between the proximal 12ft HH6-1 sandstone and the deep water base of slope turbidite fans at Iris. Shelf edge primarily controlled by active NE directed transtensional movement along the North Tobago Fault.

Source:
- NR metamorphics
- Tobago Volcanics
- Orinoco Guyana Current ??

Brightest amplitudes may reflect improved reservoir quality associated with good porosity shelf and shoreface sands.

Dimmer amplitudes may reflect degradation in reservoir quality towards shelf edge.

Dimmest amplitudes may be associated with offshore muds.

Source: NR metamorphics - Tobago Volcanics - Orinoco Guyana Current ??

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Dimmer amplitudes may reflect degradation in reservoir quality towards shelf edge.

Dimmest amplitudes may be associated with offshore muds.
Summary

• The Jasmine Complex comprises of UP5 (NC120) amplitude anomalies.
• Extended regional mapping on the reflectivity seismic dataset at the UP5 level revealed a series of northerly trending slope channels and basin floor fans at NCMA-1
• Proposed NC120 (UP5) GDE map honours biostrat in NCMA-1, ALMA-1, HH6-1 & extensive core data at IRIS-1
• Clinoformal geometries observed on the Lambda Rho seismic data at the UP5 level in the Jasmine area validates the GDE revision.
• Structural restorations suggests that the north eastern segment of the NC120 shelf edge was controlled by active tectonics along the North Tobago Fault.

*Based on geometries, analogues, and regional well data, Jasmine UP5 is interpreted to be comprised of predominantly shelfal deposits, sourced from the Central and Eastern Northern Ranges, South Western Tobago, and reworked Orinoco sediments all being redistributed and winnowed by longshore currents.*