Factors Controlling Modern Submarine Fan Architecture and Implications for Paleogene to Miocene Petroleum Plays in the Gulf of Mexico*

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Abstract

Modern submarine fans of the northern Gulf of Mexico (GOM) display various architectures that can serve as modern analogues for hydrocarbon reservoirs. Bryant Fan has been fed by relatively sand-rich, shelf-margin deltas and narrow canyons through a chain of 15 mini-basins (2-15 km diameter). Approximately 50% of seismic facies in the mini-basins consist of mass-transport deposits (MTDs) composed of wedges of chaotic mud and sheets of chaotic mud and sand. The Bryant mini-basin pathway apparently traps these MTDs, producing a Bryant Fan architecture with few MTDs, compensation cycles of stacked channel-levee complexes, and non-bifurcated aggrading channels that extend >200 km to feed single, distal sand-rich depositional lobes of ~30 km in length. The Bryant Canyon/Fan architecture provides an analogue for the Miocene systems in the Mississippi Canyon area. In contrast, the mud-rich Mississippi Delta and present-day 20-km wide gullied canyon sediment source of MTDs control an architecture of multiple mid-fan channel bifurcations and outer fan channel splay systems in the 200 km long distal lobes of the mud-rich Mississippi Fan. Extensive MTDs are deposited during lowering and rising sea level episodes and are intermixed at all scales (~400 km debris sheets to 10-cm thick MTD beds) with the channel and lobe turbidite facies. Possible analogues to Mississippi Fan, with intermixing of extensive MTD’s, may be found in some subsurface turbidite systems of the GOM margin. The most sand-rich architecture is found in the Rio Grande Fan, where multiple canyons provide a line source of coarse-grained sediment from adjacent mountain sources to the fan, which is located on a continental-slope plateau. Factors, such as the relatively steep fan gradient (1:250), incised rather than leveed channels, architecture of numerous channels throughout the surface and subsurface, seismic facies and sediment cores, indicate that the Rio Grande Fan is a braided, sand-rich system. Rio Grande Fan provides an analogue for some Paleogene subsurface petroleum plays in the northwestern GOM such as the Wilcox and Frio.
Selected References


Lui, J.Y. and W.R. Bryant, 2000, Seafloor relief of Northern Gulf of Mexico deep water map: Texas A&M University, 1 bathymetric map.


FACTORS CONTROLLING MODERN SUBMARINE FAN ARCHITECTURE AND IMPLICATIONS FOR PALEOGENE TO MIOCENE PETROLEUM PLAYS IN THE GULF OF MEXICO

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TOPICS

• BRYANT FAN SAND-RICH TURBIDITE SYSTEM: POTENTIAL ANALOGUE FOR MISSISSIPPI CANYON ABYSSAL FAN PLAYS

• MISSISSIPPI FAN MUD-RICH TURBIDITE SYSTEM: EXAMPLE OF MIXED TURBIDITE AND MTD FAN DEPOSITIONAL PATTERN

• RIO GRANDE FAN SAND BRAID PLAIN TURBIDITE SYSTEM: POTENTIAL ANALOGUE FOR FRIO AND WILCOX PLAYS IN THE NORTHWESTERN GULF OF MEXICO
Mississippi Drainage History Control

Twichell et al., 2009
Tripsanas et al., 2004

BRYANT CANYON AND FAN & ANCESTRAL MISSISSIPPI DELTA

SWATH BATHYMETRIC IMAGE

BRYANT CANYON SYSTEM FORMED DURING ISOTOPIC STAGE 6 (130,000-160,000 BP)

Tripsanas et al., 2004
Bryant Canyon/Fan study area shown on Gloria sidescan mosaic (source: Twichell et al., 2000)

- Note location and scale of Bryant compared to Trinity Brazos and Mississippi Fan.
- See Bryant Canyon pathway (orange line) of linked mini-basins and bypass channels.
- Bryant Fan youngest (unit 4) channel levee complex is outlined (orange dots).
- Mississippi Fan debris sheet with chaotic surface laps against distal Bryant Fan.
BEAUMONT SALT WITHDRAWAL MINI-BASIN ON BRYANT CANYON PATHWAY

--- BYPASS CHANNELS & CANYON PATHWAY TRANSPORTING MTDs TO MINI-BASIN DEPOCENTERS

10km

W-E X SECTION NEXT SLIDE
GOM MINI-BASIN MTD SHEETS AND WEDGES

Large scale = extrabasinal sheets & Intermediate-scale = intrabasinal wedges
**Presenter’s Notes:**

Bryant Canyon/Fan study area shown on Gloria sidescan mosaic (source: Twichell et al., 2000)

- Note location and scale of Bryant compared to Trinity Brazos and Mississippi Fan.
- See Bryant Canyon pathway (orange line) of linked mini-basins and bypass channels.
- Bryant Fan youngest (unit 4) channel levee complex is outlined (orange dots).
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Mississippi Fan

Distal lobe

GLORIA SIDESCAN OF MODERN BRYANT FAN (UNIT 4) AND LOBE

The next slide will show several seismic profile examples from proximal line 7 to distal line 1.

Presenter’s Notes:

Bryant Fan over Gloria sidescan mosaic showing modern channel and seismic cross sections 1,5A,7

- Bryant Fan details shown on abyssal sea floor south of Sigsbee Escarpment.
- Single channel with some proximal and distal meandering observed at surface.
- Channel ends in a 10 X 30 km distal lobe with high backscatter indicating sand-rich.
- Location of proximal (line 7) to distal (line 1) seismic profile examples.
Presenter's Notes:

Line 7 seismic profile interpretation

- Note stacked main channel levee complex units 1-4.
- See high relief of youngest surface channel (150m) compared to compacted subsurface channels (~40m).
- Numerous single channel thalwegs (see numbers & letters) can be traced proximal to distal.
BRYANT FAN
UNITS 1 - 4
DEPOSIT
PATTERNS

note compensation cycles
Note channel compensation cycles
NOTE: SINGLE MEANDERING CHANNELS & SPLAY INTO DISTAL LOBE LIKE MODERN CHANNEL
**BRYANT FAN GROWTH UNITS**

Note: a low number of channel thalwegs (~6-9) except for thicker unit 4

The number of channel thalwegs is constant proximal to distal indicating a lack of channel bifurcation

<table>
<thead>
<tr>
<th>Channel Levee Units</th>
<th>Length (km)</th>
<th>Average Width (km)</th>
<th>Maximum Thickness (ms)</th>
<th>Average Thickness (ms)</th>
<th>Number of Thalweg Channels in Unit</th>
<th>Distal Lobe Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIT 4 (youngest)</td>
<td>190</td>
<td>289</td>
<td>706</td>
<td>476</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>UNIT 3</td>
<td>110+</td>
<td>205</td>
<td>294</td>
<td>182</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>UNIT 2</td>
<td>97+</td>
<td>239</td>
<td>325</td>
<td>188</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>UNIT 1 (oldest)</td>
<td>139+</td>
<td>145</td>
<td>494</td>
<td>311</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

110+ cannot determine total length because of limited profile coverage

*Presenter's Notes:*

Table of Modern Bryant Fan Channel-levee Complex Characteristics

- Low number of channel thalwegs (~6-9) except for thicker unit 4,
- Number of channel thalwegs constant proximal to distal, indicating lack of channel bifurcation.
### MID-MIOCENE *MCAVLU FAN GROWTH UNITS*

Note: size (length, width, thickness) of channel levee complexes similar to Bryant

Number of channel thalwegs similar to Bryant

<table>
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<th>Length (km)</th>
<th>Average Width (km)</th>
<th>Thickness (ms)</th>
<th>Number of Thalweg Channels in Unit</th>
<th>Distal Lobe Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS 3 (youngest)</td>
<td>125</td>
<td>150</td>
<td>400</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>SS 2</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>SS 1 (oldest)</td>
<td>200</td>
<td>140</td>
<td>285</td>
<td>9</td>
<td>38</td>
</tr>
</tbody>
</table>

*MCAVLU FAN- POTENTIAL RESERVOIR SANDS FOR ATLANTIS AND NEPTUNE FIELDS.

SS1-SS3 DATA SOURCE FROM COMBELLAS, 2003; COMBELLAS AND GALLOWAY, 2006

**Presenter’s Notes:**

Table of Mid-Miocene Mcavlu Fan Channel-levee Complex Characteristics

- Size (length, width & thickness) of channel levee complexes similar to Bryant.
- Number of channel thalwegs similar to Bryant.
MISSISSIPPI FAN SETTING COMPARED TO BRYANT

Twichell et al., (2009)
Timing of canyon failures

(modified from Goodwin and Prior, 1989)
Effect of shelf-edge processes on distal fan

1. Turbidity currents and small debris flows (?) to distal fan

2. Large canyon-sourced (?) failure chokes channel and breaches levee

3. Turbidity currents and small debris flows redirected after channel-choking event

4. Large canyon-sourced failure fills channel on upper fan

Twichell et al. (2009)
YOUNGEST CHANNEL SYSTEM
LARGE (450 km) MTD SHEET BURIES CHANNEL

TWICHELL ET AL., 2009

NEXT SLIDE SHOWS DETAILS OF CHANNEL SPLAYS IN LOBE
Deep-tow sidescan sonar image of youngest (yellow) Mississippi Fan distal lobe
FAN MTD CHAOTIC SILT WITH VARIABLE AGES & GRADING & GRADED SAND

Nelson et al., 2010
Turbidite and debris flow deposition prior to <11,370 BP

Sealevel curve and system tracts simplified from Fillon et al. (2004) – SEPM # 79

Twichell et al.,(2009)
Mass-transport deposits from Mississippi Canyon 7,500-11,370 BP

Sealevel curve and system tracts simplified from Fillon et al. (2004) – SEPM # 79

Twitchell et al.,(2009)
RELATION OF FAN PROCESSES TO EXTERNAL CONTROLS

Twichell et al., (2009)
RIO GRANDE FAN LOCATION ON SLOPE PLATEAU SHOWING SALT TECTONICS & STRUCTURAL CONTROLS

TEXAS

CONTINENTAL

SHELIF

LOUISIANA

RIO GRANDE TURBIDITE SYSTEM

BRYANT CANYON & FAN

Sea floor Relief Map by Liu and Bryant
(Texas Sea Grant College Program)
Rio Grande Fan Prolonged Echoes Suggest Sand Rich Fan

Black Arrows are Channels on the Fan Surface

Note Multiple Canyons

Note Multiple Inclined Channels

Rio Grande Fan 3.5 kHz Seismic Facies

Sand Beds of Lower Rio Grande Fan

Deformed Sand Beds with Mud Clasts

Lithology

G. menardii Index

Holocene

Last Glacial

Damuth, Nelson and Olson (2006)
Note Multiple Surface and Subsurface Channels with 20-40 m Relief & 500-1,000 m Width
SALT TECTONIC CONTROL OF RIO GRANDE FAN SHAPE & CHANNELS ON GULF OF MEXICO PASSIVE MARGIN SLOPE
NORTHERN GULF OF MEXICO SUBMARINE FANS

FAN CHANNEL DEPOSITIONAL PATTERNS

BRYANT SINGLE
RIO GRANDE BRAIDED
MISSISSIPPI SPAYED

BRYANT - SAND-RICH; FED BY CANYON WITH MINI-BASINS THAT TRAP MUDS;
SINGLE SINUOUS CHANNEL AND LOBE; LIMITED MTDs & SPLAYS

RIO GRANDE - SAND-RICH FROM MOUNTAIN SOURCES; MULTIPLE CANYONS &
BRAIDED CHANNELS; LACKS LOBES & MTDs

MISSISSIPPI - MUD-RICH; GULLIED CANYON; MEANDERING CHANNELS;
MULTIPLE SPLAYS & LOBES; HALF TURBIDITES AND HALF MTDs

Damuth, Nelson and Olson (2006)
IMPLICATIONS FOR GOM PETROLEUM SYSTEMS

• SCALES, SEISMIC FACIES, ARCHITECTURE AND CHANNEL PATTERNS OF GOM TURBIDITE SYSTEMS VARY SIGNIFICANTLY WITH TIME AND LOCATION

• TYPES OF TURBIDITE SYSTEMS ARE CONTROLLED BY VARIATION AND LOCATION OF THE SEDIMENT INPUT WITH TIME & INTERPLAY WITH SALT TECTONICS

• IN CONTRAST, SUBMARINE FAN ARCHITECTURE VARIES SIGNIFICANTLY WITH LOCATION; i.e., FROM SAND-RICH BRAIDED CHANNEL FANS LIKE THE RIO GRANDE IN THE NORTHWEST GOM TO THE MUD-RICH MISSISSIPPI FAN

• THE RIO GRANDE ARCHITECTURE IS CHARACTERIZED BY CHANNELS THROUGHOUT THE ENTIRE SYSTEM; THE BRYANT FAN HAS STACKED CHANNELS WITH LIMITED BIFURCATIONS, LOW SINUOSITY AND SPLAYS INTO DISTAL LOBES

• THE MISSISSIPPI FAN HAS A HIGHLY SPLAYED SYSTEM OF CHANNELS AND AN EQUAL AMOUNT OF MTDs INTERMIXED WITH TURBIDITES FROM THE LARGEST (100’s km) TO SMALLEST(10’s cm) SCALES

• THE RIO GRANDE AND BRYANT FANS AND CHANNELS HAVE FEW MTDs AND LIKELY GOOD CONNECTIVITY, WHEREAS MISSISSIPPI FAN AND CHANNELS WITH MANY MTDs MAY HAVE POOR CONNECTIVITY BUT MTD SEALS FOR RESERVOIR BEDS