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 splays 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.

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

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Basins Project-UTIG
Damuth, Nelson, Olson, 2006

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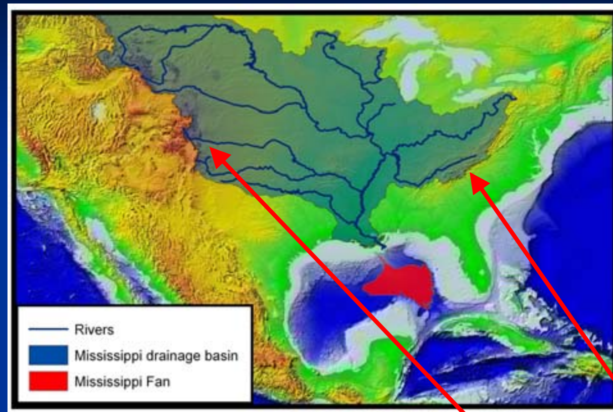
TOPICS

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

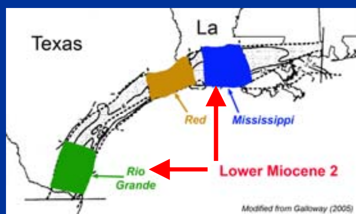
- MISSISSIPPI FAN MUD-RICH TURBIDITE SYSTEM:
EXAMPLE OF MIXED TURBIDITE AND MTD
FAN DEPOSITIONAL PATTERN

- RIO GRANDE FAN SAND BRAID PLAIN TURBIDITE SYSTEM:
POTENTIAL ANALOGUE FOR FRIO AND WILCOX PLAYS IN THE
NORTHWESTERN GULF OF MEXICO

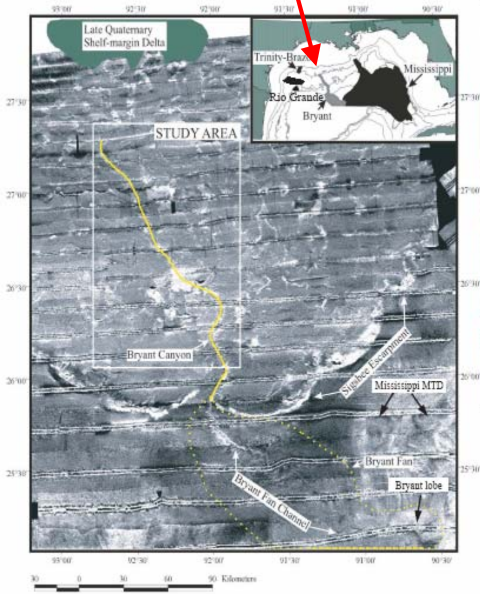
Mississippi Drainage History Control



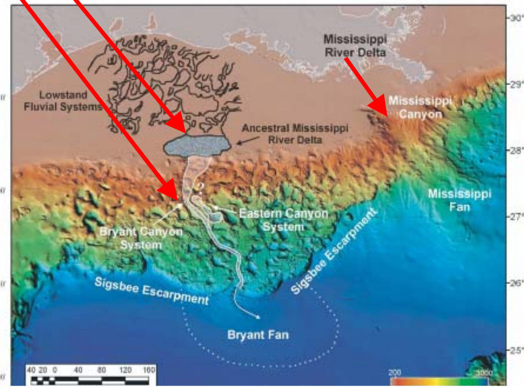
TWICHELL ET AL., 2009



BRYANT CANYON AND FAN & ANCESTRAL MISSISSIPPI DELTA



GLORIA SIDESCAN IMAGE



SWATH BATHYMETRIC IMAGE

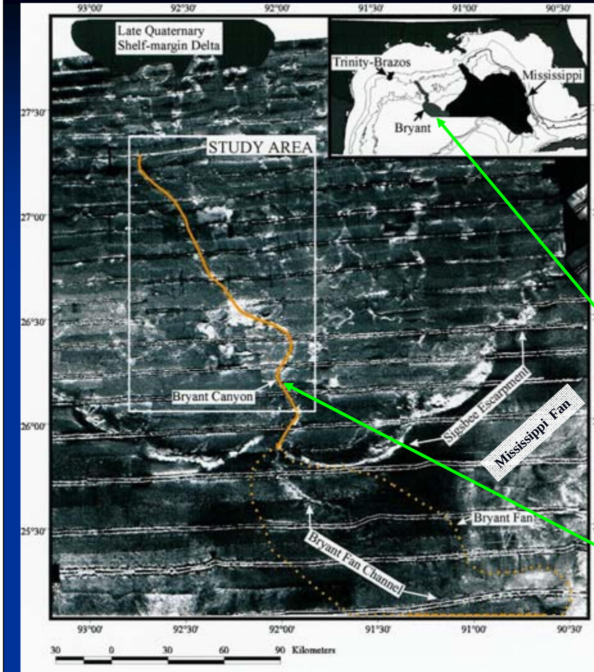
BRYANT CANYON SYSTEM FORMED DURING ISOTOPIC STAGE 6 (130,000-160,000 BP)

Tripsanas et al., 2004

BRYANT CANYON AND FAN STUDY AREA

CANYON STUDY AREA

FAN STUDY AREA



GLORIA SIDESCAN SONAR IMAGE (Twichell et al., 2000)

Note location and scale of Bryant Fan (200 km) compared to Mississippi Fan (600 km)

See Bryant Canyon pathway (orange line) of 15 linked mini-basins and bypass channels

Presenter's Notes:

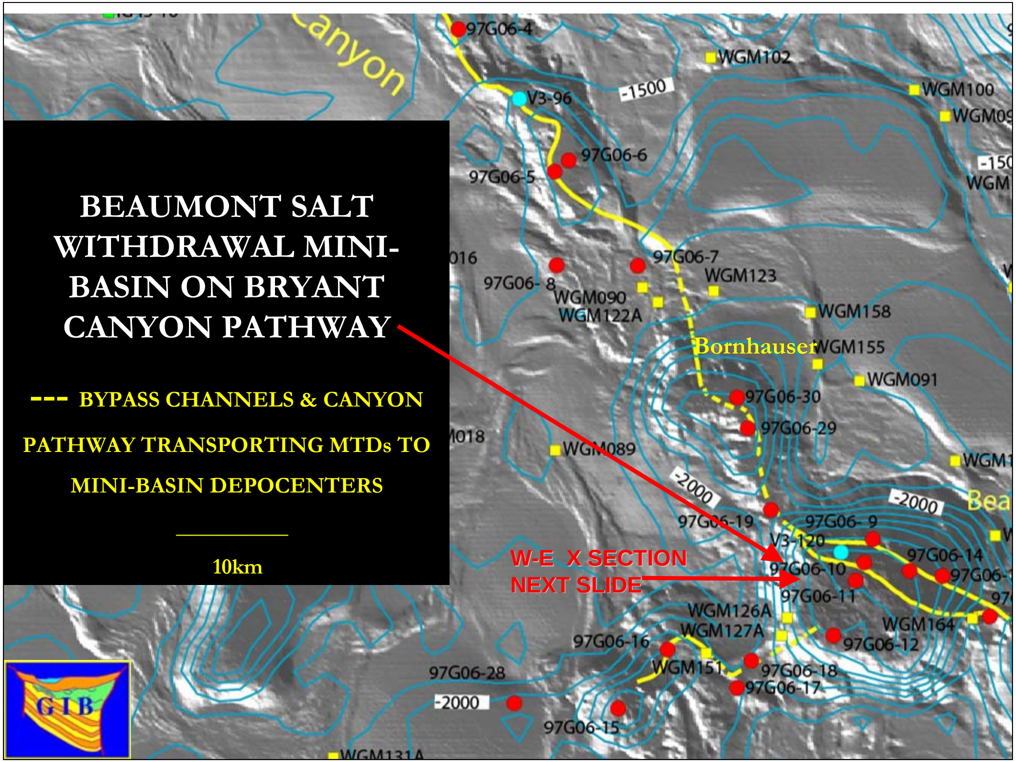
Bryant Canyon/Fan study area shown on Gloria sidescan mosaic (source: Twichell et al., 2000)

- 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).
- Mississippi Fan debris sheet with chaotic surface laps against distal Bryant Fan.

BEAUMONT SALT WITHDRAWAL MINI-BASIN ON BRYANT CANYON PATHWAY

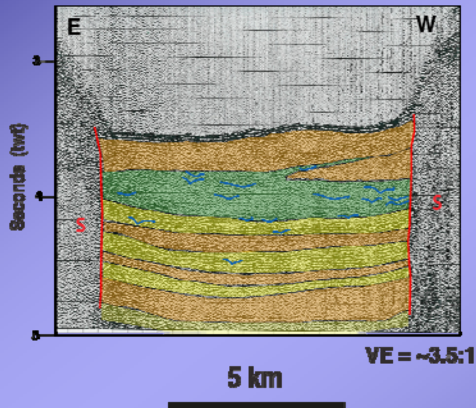
--- BYPASS CHANNELS & CANYON PATHWAY TRANSPORTING MTDs TO MINI-BASIN DEPOCENTERS

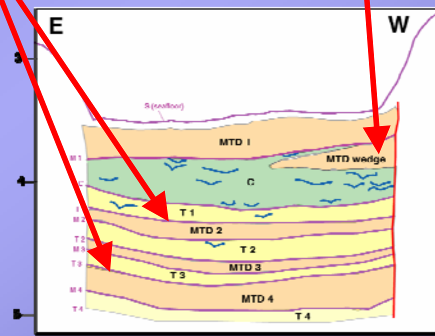
10km

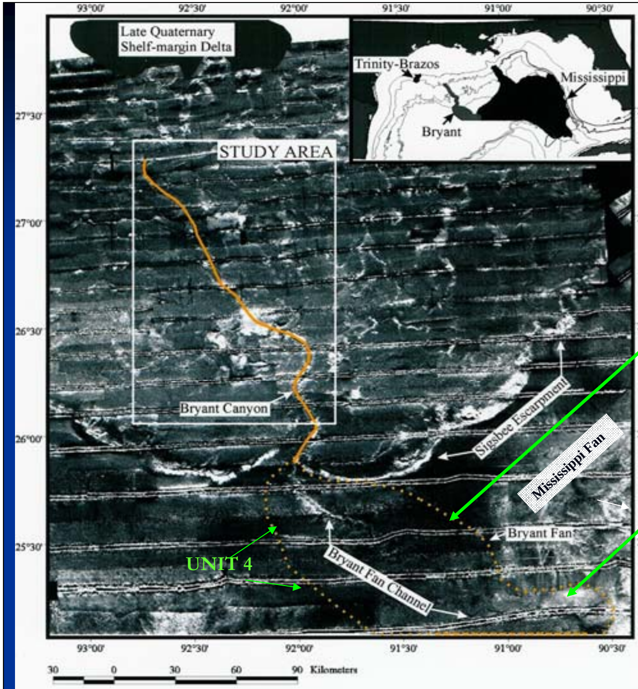


GOM MINI-BASIN MTD SHEETS AND WEDGES

Large scale = extrabasinal sheets & Intermediate-scale= intrabasinal wedges







GLORIA SIDESCAN SONAR IMAGE (Twichell et al., 2000)

BRYANT CANYON AND FAN STUDY AREA

CANYON STUDY AREA

FAN STUDY AREA

Bryant Fan (200 km length) youngest (unit 4) channel levee complex is outlined (orange dots)

Note high backscatter lobe with apparent high sand content

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.
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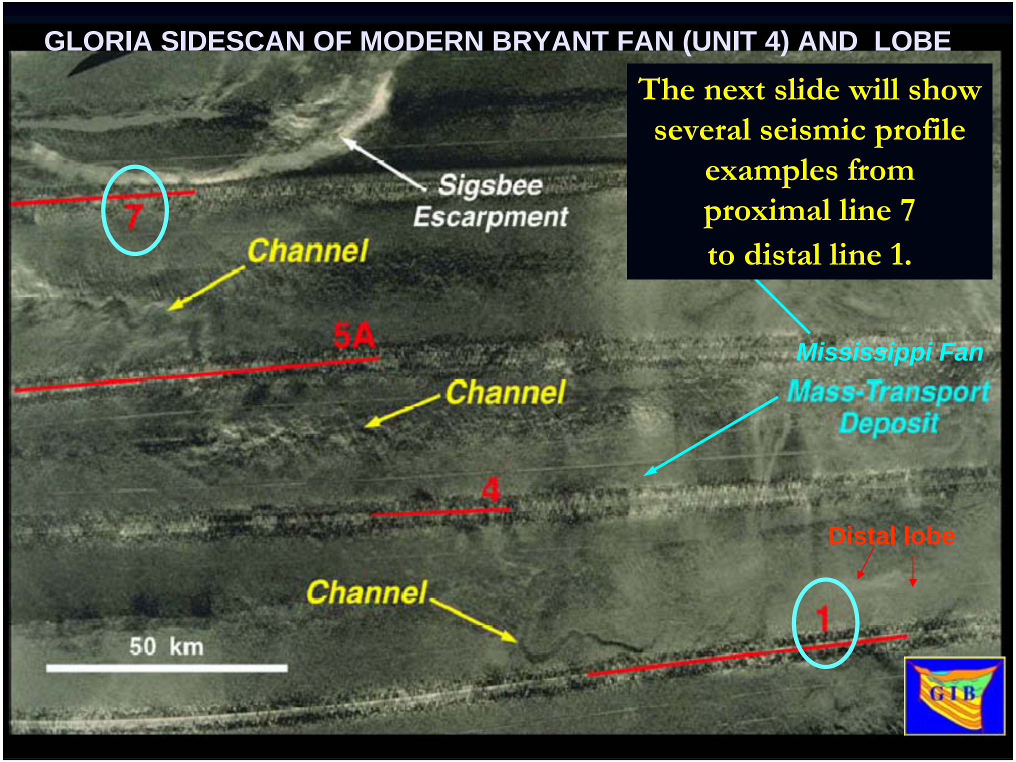
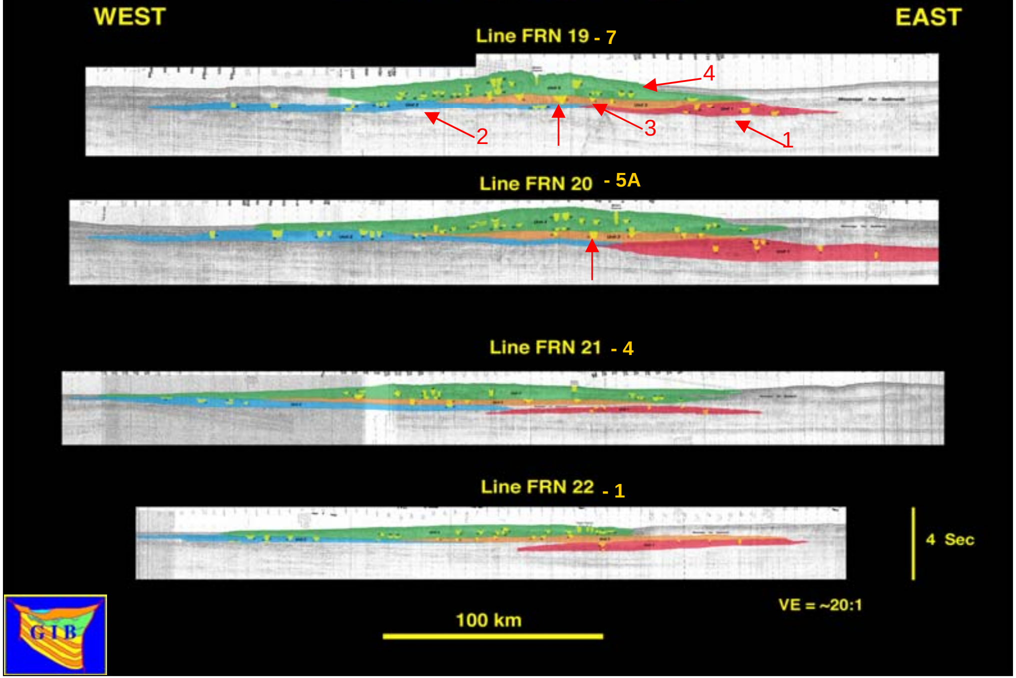


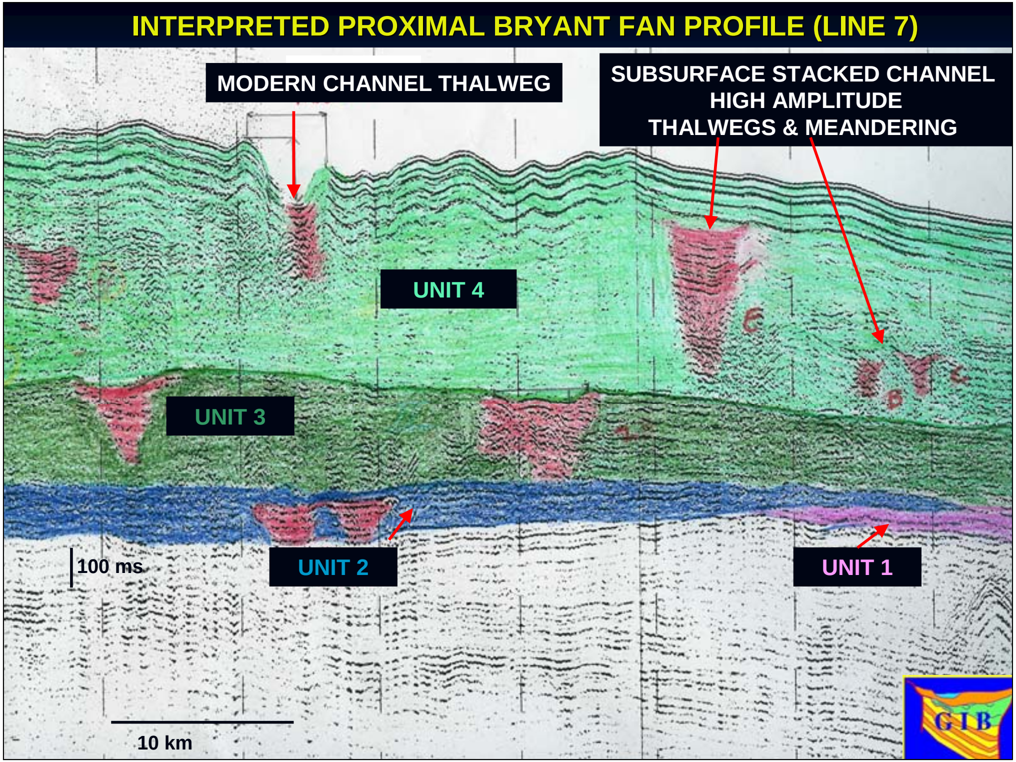
Presenter's Notes:

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.

BRYANT SUBMARINE FAN GROWTH UNITS 1-4 AND COMPENSATION CYCLES

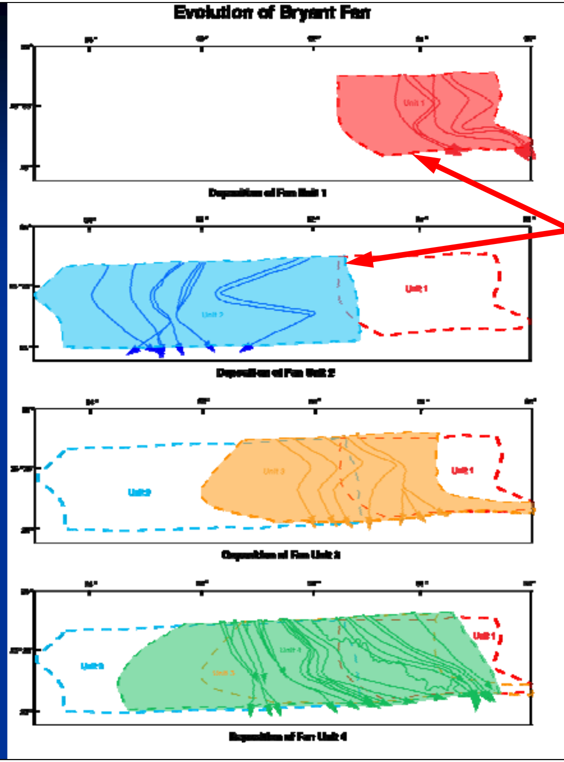




Presenter's Notes:

Line 7 seismic profile interpretation

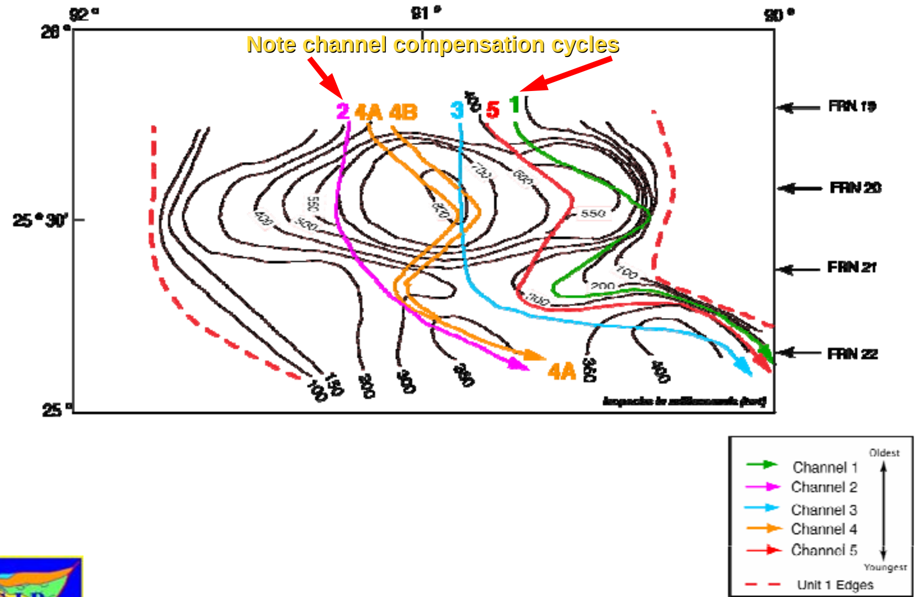
- Note stacked main channel levee complex units 1-4.
- See high relief of youngest surface channel (150m) compared to compacted subsurface channels (~40m).
- Numerous single channel thalwegs (see numbers & letters) can be traced proximal to distal.



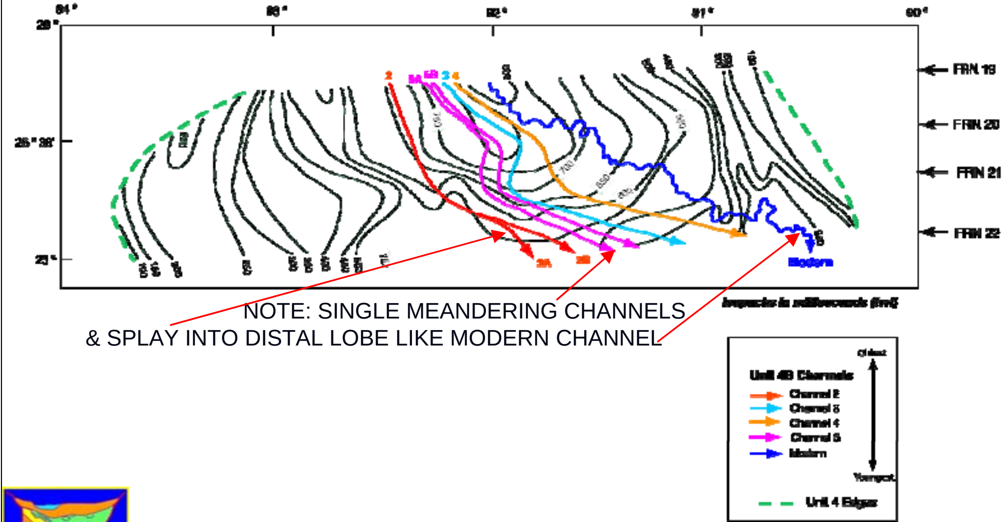
BRYANT FAN UNITS 1 - 4 DEPOSIT PATTERNS

note compensation cycles

BRYANT FAN UNIT 1
Thickness and Channel Locations



BRYANT FAN UNIT 4
Total Thickness and Subunit 4B Channel Locations



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

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

110+ cannot determine total length because of limited profile coverage

Damuth, Nelson and Olson (2006)

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

Channel Levee Units	Length (km)	Average Width (km)	Thickness (ms)			Number of Thalweg Channels in Unit	Distal Lobe Length (km)
			Max	Min	Average		
SS 3 (youngest)	125	150	400	100	250	7	
SS 2	200	200	200	100	150	8	20
SS 1 (oldest)	200	140	285	100	190	9	38

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

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

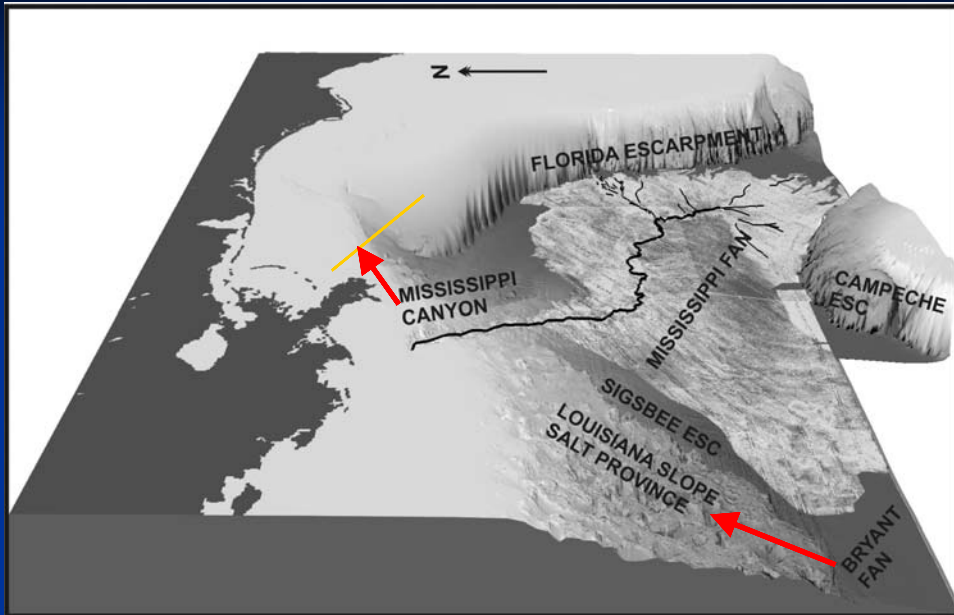
Presenter's Notes:

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

•Size (length, width & thickness) of channel levee complexes similar to Bryant.

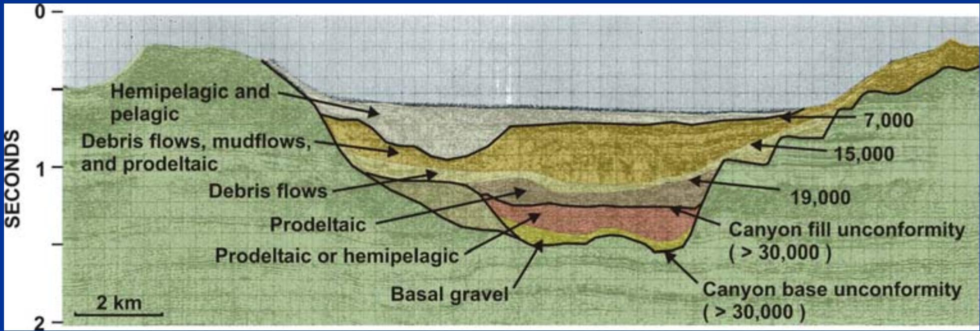
•Number of channel thalwegs similar to Bryant.

MISSISSIPPI FAN SETTING COMPARED TO BRYANT



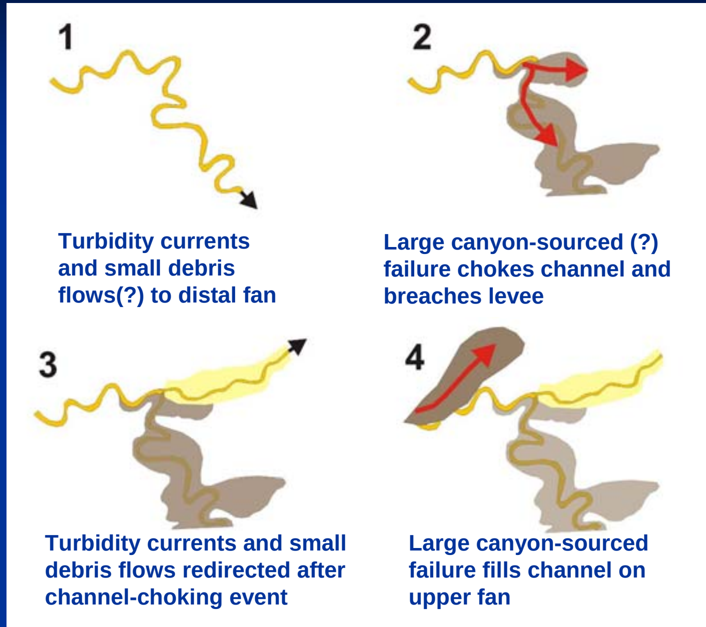
Twichell et al.,(2009)

Timing of canyon failures

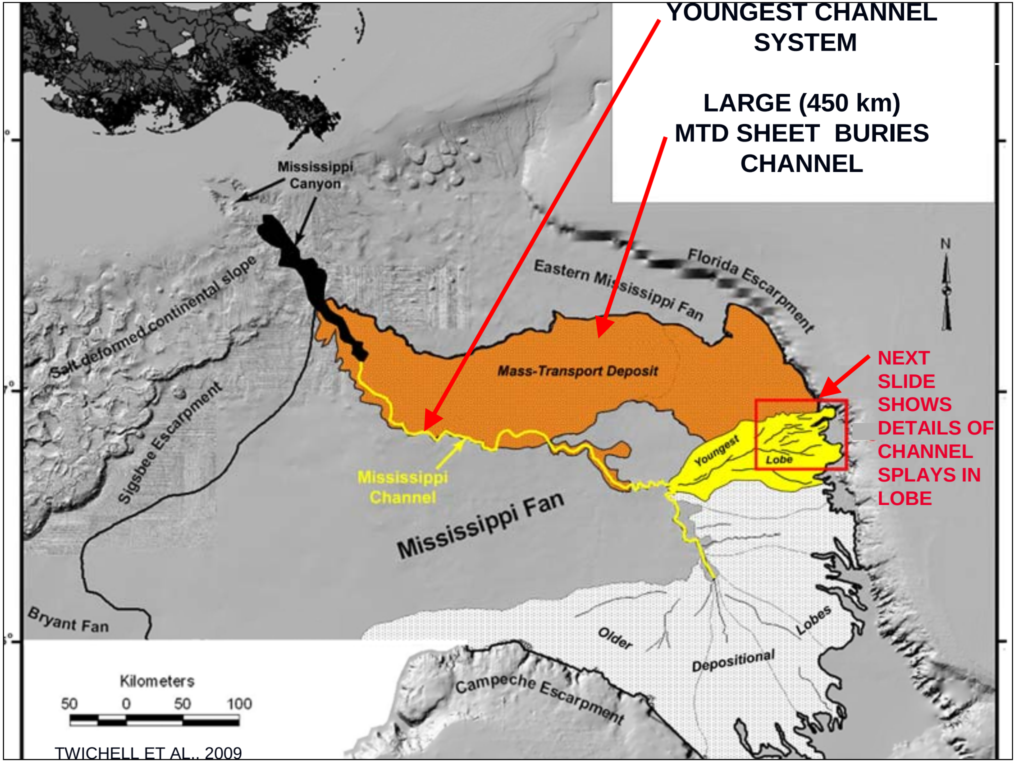


(modified from Goodwin and Prior, 1989)

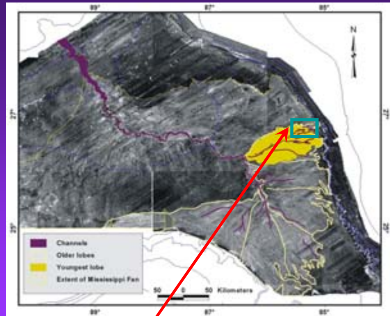
Effect of shelf-edge processes on distal fan

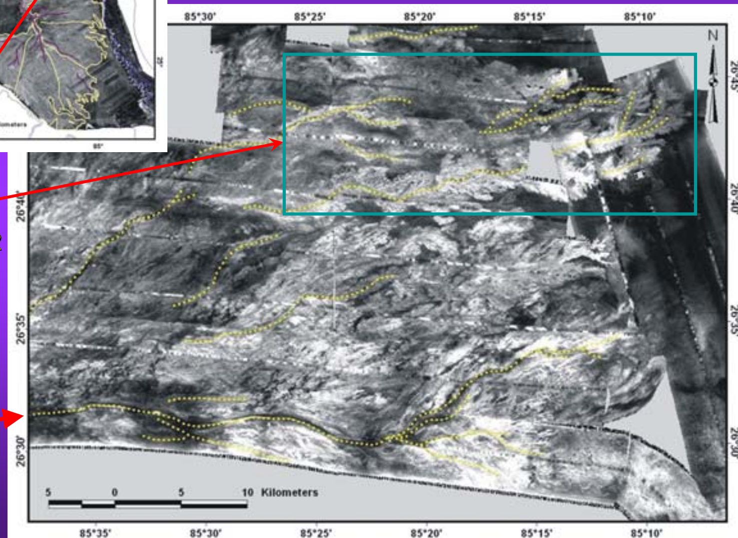


Twichell et al.,(2009)


YOUNGEST CHANNEL SYSTEM
LARGE (450 km) MTD SHEET BURIES CHANNEL
NEXT SLIDE SHOWS DETAILS OF CHANNEL SPLAYS IN LOBE
Mississippi Canyon
Salt-deformed continental slope
Sigsbee Escarpment
Eastern Mississippi Fan
Florida Escarpment
Mass-Transport Deposit
Mississippi Channel
Mississippi Fan
Youngest Lobe
Older Depositional Lobes
Campeche Escarpment
Bryant Fan
N
Kilometers
50
0
50
100
TWICHELL ET AL., 2009

Deep-tow sidescan sonar image of youngest (yellow) Mississippi Fan distal lobe

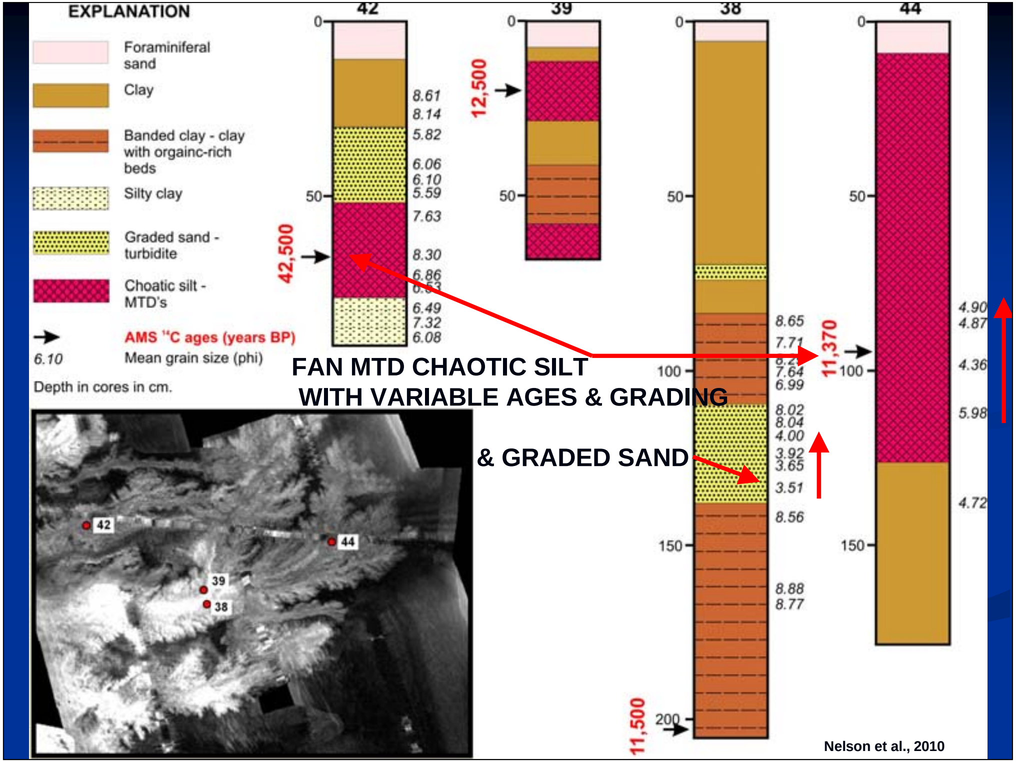




YOUNGEST OUTER FAN LOBE

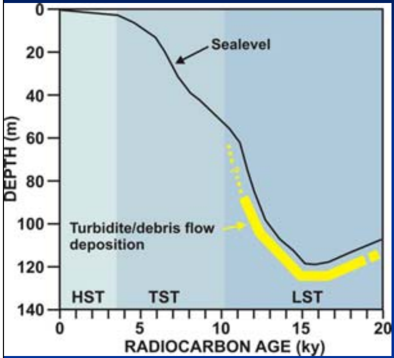
YELLOW DOTTED LINES TRACE CHANNEL SPLAYS

Twichell et al., 2009

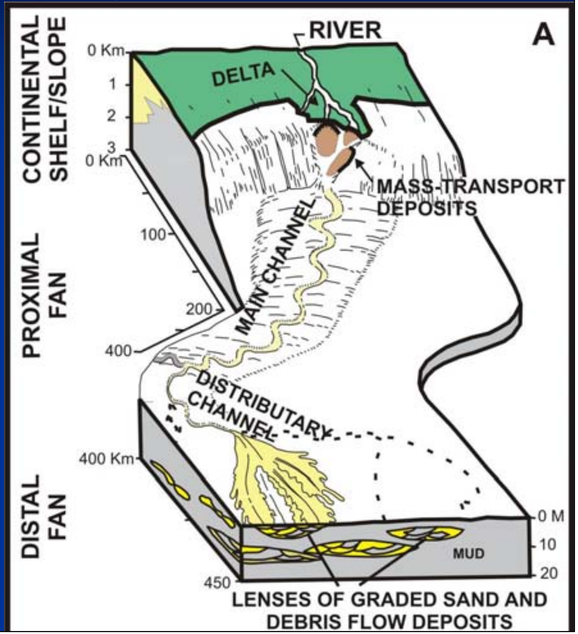


EXPLANATION
Foraminiferal sand
Clay
Banded clay - clay with orgainc-rich beds
Silty clay
Graded sand - turbidite
Choatic silt - MTD's
AMS ¹⁴C ages (years BP)
6.10 Mean grain size (phi)
Depth in cores in cm.
42
39
38
44
8.61
8.14
5.82
6.06
6.10
5.59
7.63
8.30
6.86
6.49
7.32
6.08
42,500
12,500
8.65
7.71
7.64
6.99
8.02
8.04
4.00
3.92
3.65
3.51
8.56
8.88
8.77
11,370
11,500
4.90
4.87
4.36
5.98
4.72
0
50
100
150
200
FAN MTD CHAOTIC SILT
WITH VARIABLE AGES & GRADING
& GRADED SAND
Nelson et al., 2010

Turbidite and debris flow deposition prior to <11,370 BP

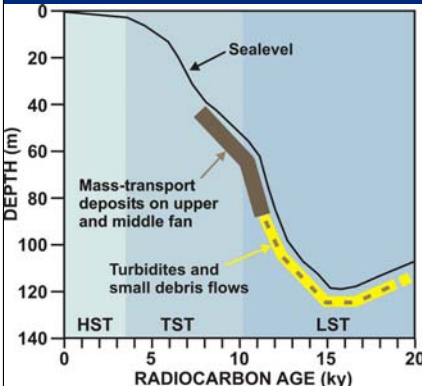


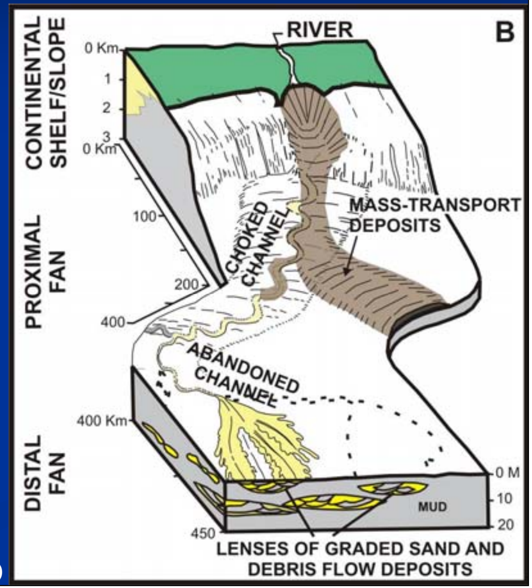
Sealevel curve and system tracts simplified from Fillon et al. (2004) – SEPM # 79



Twichell et al.,(2009)

Mass-transport deposits from Mississippi Canyon 7,500-11,370 BP

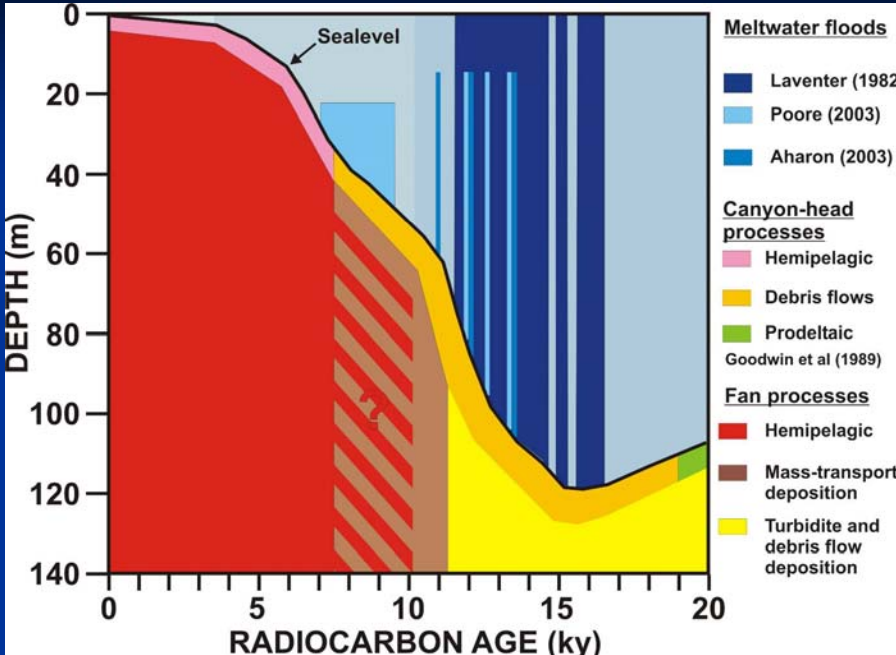




Sealevel curve and system tracts simplified from Fillon et al. (2004) – SEPM # 79

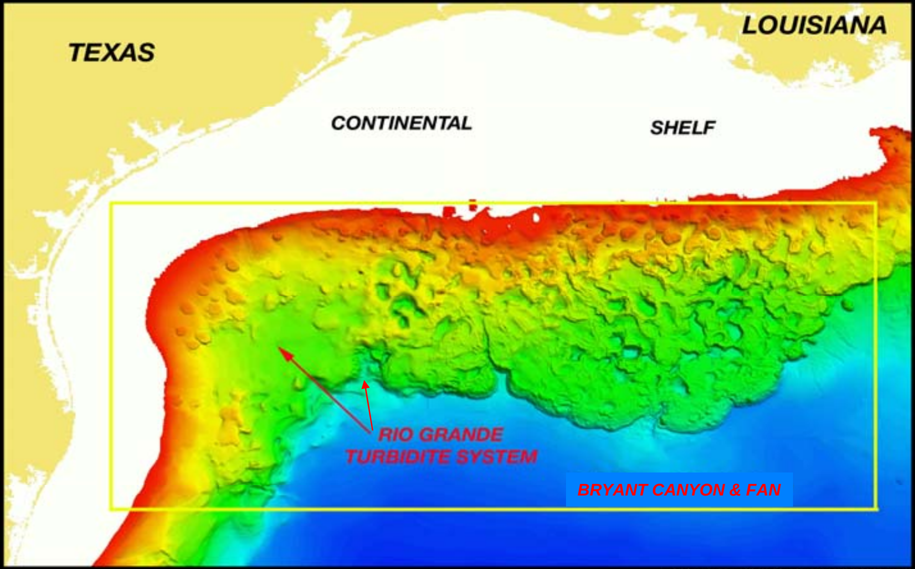
Twichell et al.,(2009)

RELATION OF FAN PROCESSES TO EXTERNAL CONTROLS



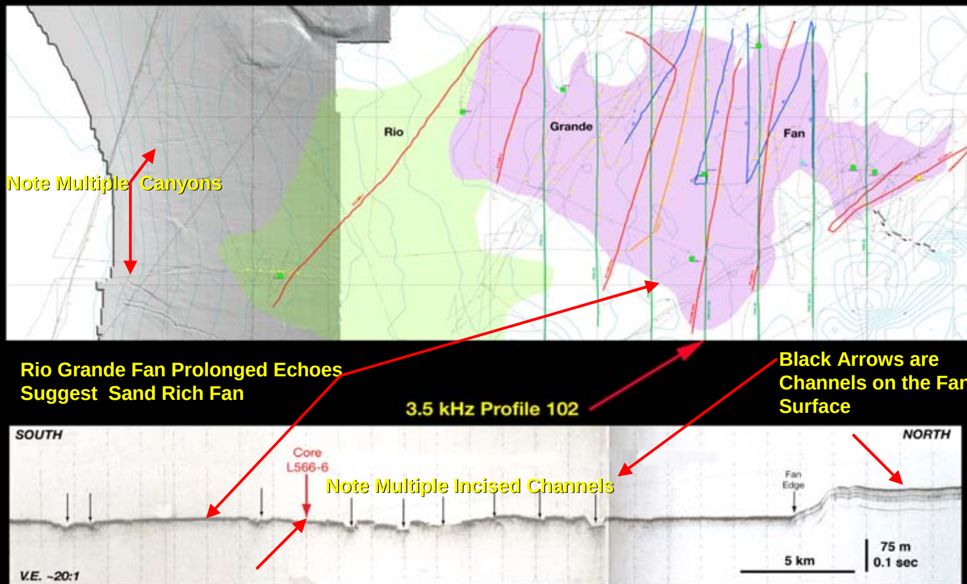
Twichell et al.,(2009)

RIO GRANDE FAN LOCATION ON SLOPE PLATEAU SHOWING SALT TECTONICS & STRUCTURAL CONTROLS



Seafloor Relief Map by Lui and Bryant
(Texas Sea Grant College Program)

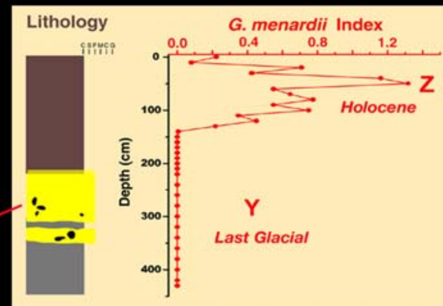
Rio Grande Fan 3.5 kHz Seismic Facies



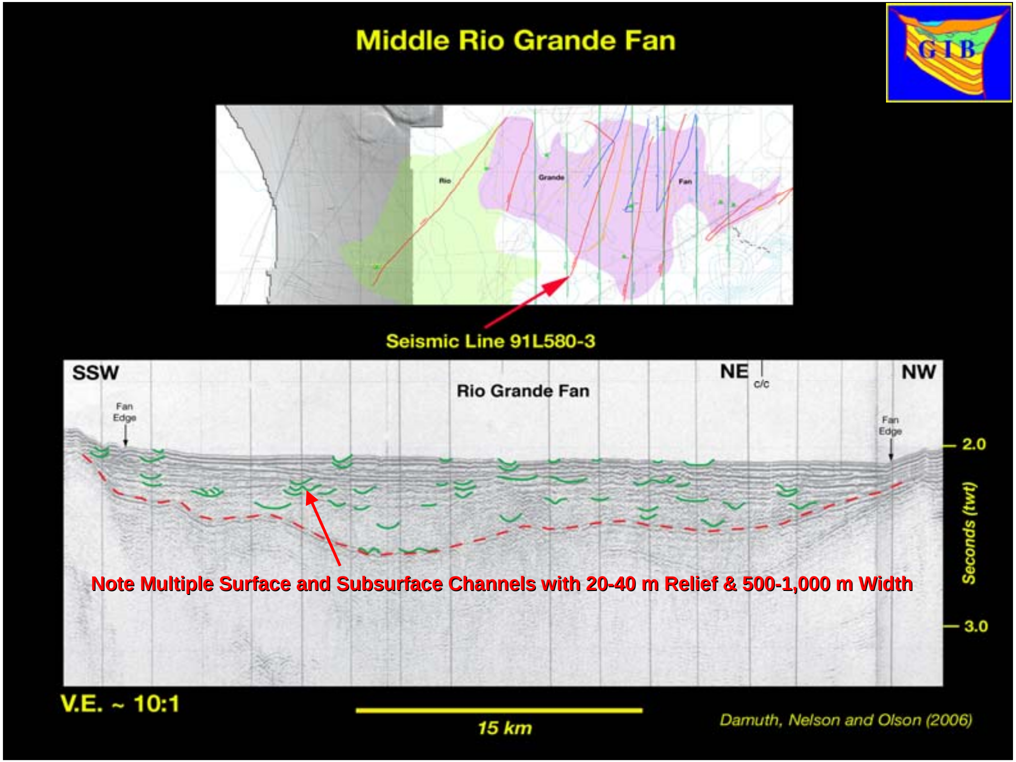
Damuth, Nelson and Olson (2006)

Sand Beds of Lower Rio Grande Fan

Deformed Sand Beds with Mud Clasts

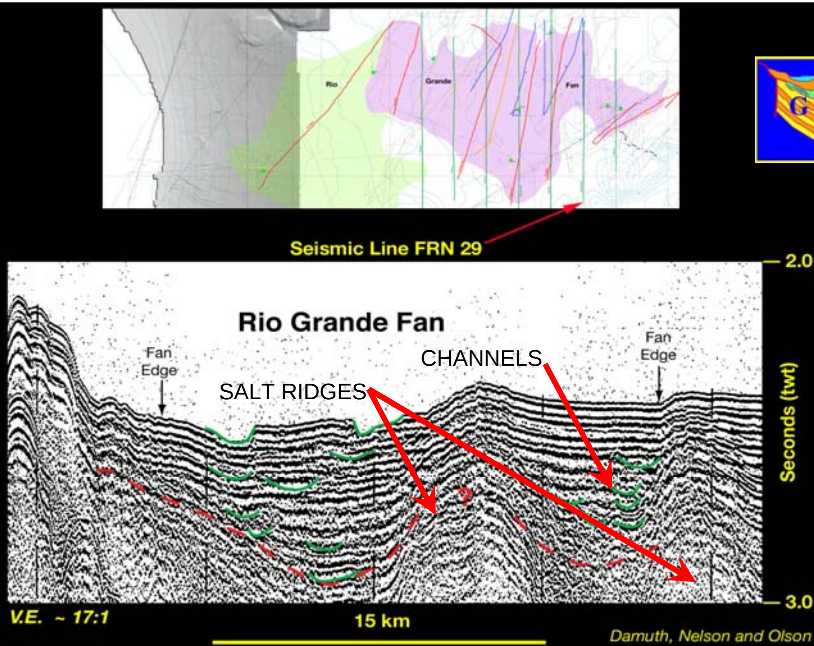


Damuth, Nelson and Olson (2006)



Middle Rio Grande Fan
GIB
Rio
Grande
Fan
Seismic Line 91L580-3
SSW
NE
c/c
NW
Rio Grande Fan
Fan Edge
Fan Edge
2.0
3.0
Seconds (twt)
Note Multiple Surface and Subsurface Channels with 20-40 m Relief & 500-1,000 m Width
V.E. ~ 10:1
15 km
Damuth, Nelson and Olson (2006)

SALT TECTONIC CONTROL OF RIO GRANDE FAN SHAPE & CHANNELS ON GULF OF MEXICO PASSIVE MARGIN SLOPE



NORTHERN GULF OF MEXICO SUBMARINE FANS

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