Abstract

In 2005, Pioneer Natural Resources (PNR) embarked on an aggressive, 6-rig exploration and development drilling program within the middle Albian (Edwards Formation) portion of the Stuart City shelf margin of south Texas. As a result of this ongoing program, a new characterization of this economically important Tethyan shelf margin is beginning to emerge. The revised characterization draws upon an extensive pool of new geologic, geophysical, and engineering data sets, including modern wireline logs for over 80 deep pilot holes within the Stuart City margin, several new extensive Edwards Formation cores, drilling and production data for both horizontal and vertical wells, and approximately 1000 mi$^2$ (2600 km$^2$) of high-fold 3D seismic complementing several hundred line miles of existing 2D seismic data. A number of new gas discoveries, including one significant accumulation (Moray Field, Dewitt County), have spurred further exploration and development and acquisition of additional data.

Previous characterizations of the Stuart City shelf margin have focused primarily on general depositional and diagenetic models, including a description of facies based on data from a relatively small number of wells. These studies have led to a “one model fits all” approach to characterize the entire 250+ mile-long (> 400 km) reef margin. The newly acquired PNR data set highlights key differences in depositional settings and reservoir quality of the trend along strike. Preliminary results indicate multiple geologic models are required to accurately characterize this complex and heterogeneous reef/bank margin system. Geologic heterogeneity along strike appears to be fundamentally controlled by deep structure related to basement configuration and faulting and salt-related tectonics. Important secondary controls include the physiographic forms of the Edwards and underlying Sligo shelf margins and the nature and timing of subsidence of the Edwards margin related to development of isolated fault blocks along various portions of the margin. In addition, recognition and correlation of the Regional Dense Marker Bed (RDMB), an important middle Albian stratigraphic datum within the massive Edwards shelf margin succession, have been crucial to understanding changes within the Stuart City margin along strike and in the development of area-specific geologic models.
Edwards (Stuart City)
Shelf Margin of South Texas: New Data, New Concepts

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Pioneer Natural Resources
Irving, Texas
Outline

• Introduction to Stuart City trend and the Early Cretaceous world

• Stuart City shelf margin: previous work

• Description of the Pioneer Natural Resources (PNR) data set (2005 - present)

• New concepts and models

• Ongoing work and path forward
The Edwards (Stuart City) shelf margin trend

- A narrow belt of Lower Cretaceous reef/bank and associated sediments that extends for > 250 mi. across south Texas
- Middle Albian Edwards shelf margin underlain by Barremian-Lower Aptian Sligo shelf margin
- Dry gas fields in combination traps (discov. 1960’s) 11,000 - 14,000 ft; up to 350° F; avg. por. 5%
- Horizontal drilling revitalized play in late 1990’s; aided by today’s higher commodity prices

Dry gas fields:
- Washburn: 60 BCF
- Dilworth: 220 BCF
- Kawitt: 15 BCF
- Word: 600 BCF
- Yoakum: 40 BCF
- Pawnee: 390 BCF
- Buchel: 35 BCF
- Stuart City: 45 BCF

50 miles
Early - mid Cretaceous world

South Texas

- Post-Pangea breakup
- Opening of Tethys seaway
- Large % continental shelves in low (tropical) latitudes
- Greenhouse climate
- Low amp. high freq sea-level cycles during long-term rise
- Signif. global anoxic events in Albian, Turonian
- Rise of the rudist bivalves as main reef builders

(see Markello et al., 2008)
The Rudists.....Cretaceous bivalve reef builders

Distinctive shell wall

Upper valve

Lower valve

1 in.

Distinctive shell wall

AC, B, T
Rudist growth forms & reef models (Kaufmann and Sohl 1974)

MODEL OF CARIBBEAN RUDIST FRAMEWORK DISTRIBUTION

- Intertidal, Shallow Subtidal Assemblage
- Inner Lagoon Foreslope Assemblage
- Middle Lagoon Foreslope Assemblage
- Outer Lagoon Foreslope Assemblage
- Lagoon Center Assemblage
- Back Barrier Slope Assemblage
- Rudist Barrier Assemblage
- Shallow Barrier Foreslope Assemblage
- Outer Barrier Foreslope Assemblage

ISLAND SHELF EDGE
Mid-Late Albian Paleogeography

(from Kerans, 2002)

- Shallow water carbonate platform
- Deep shelf / Intrashelf basin
- Slope & basin

Stuart City trend: reef/bank margin

Google Earth
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Bebout and Loucks (1974)

• 1st comprehensive description of Stuart City facies

• Based on analysis of >10,000 ft. of core from 20 wells along trend

• Recognized 5 major environments:
  • shelf lagoon
  • shelf margin
  • upper shelf slope
  • lower shelf slope
  • open marine (basin)

• Identified 14 separate depositional facies within the 5 environments

• Noted cement types, porosity types and distribution; commented on timing of diagenesis (early cementation)
• Shelf margin consists of progradational package of requieniid boundstones & caprinid-algal packstones
• Skeletal grainstones show evidence of brief subaerial exposure
• Note outboard margin: interpreted "patch reefs" on upper slope

(Bebout & Loucks, 1974)
Middle Albian Comanche shelf margin (Scott, 1990)

- Forereef slope
- Distal
- Proximal
- Coral-rudist packstone
- Reef frame
- Coral – stromatoporoid boundstone
- Shoals Grnstone
- Rudist-coral packstone
- Reef flat
- Forereef slope
- Proximal
- Bioclast packstone
- Distal
- Forereef basin
- Bioturbated mudstone
- Oncolite wackestone

- Open Lagoon
  - Mollusk-miliolid-orbitolinid wackestone

- Caprinids
- Toucasids
- Massive corals
- Branching corals
- Laminar corals
- Oncolites
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Pawnee (Edwards reef) Field
Bee & Live Oak Counties, TX

17 wells (no horizontals)
- 4,000 acres (160 - 320 ac. sp.)
- Producing 8.5 MMCFPD

80 wells (63 horizontals)
- 5,500 acres (80 ac. sp.)
- 3-D seismic coverage
- Producing 50 MMCFPD

Gross Production (MMCF/D)

Vertical infills begin
Aggressive horizontal infill program begins

50 MMCF
• Edwards viewed as a continuous trend
• Considered more of a “resource” type play
• Pawnee was main analog / laboratory:
  “the whole trend looks just like Pawnee”
The PNR Edwards concept circa 2004

- Edwards viewed as a continuous trend
- Considered more of a “resource” type play
- Pawnee was main analog / laboratory: “the whole trend”

![Map of Edwards shelf edge and other locations](image-url)
PNR Edwards Trend data acquisition (’05 – ’08)

- 10,000 line-miles of previously acquired 2D seismic
- > 300,000 acres under lease
- 85 (and counting) deep pilot holes w/ full log suites
- 7 new extensive conventional cores
- 1000 mi² of new 3D seismic (full fold across margin)
- Several new gas discoveries; one significant (Moray Field)
- Numerous production and engineering data (por/perm, cap. pressure, production rates, decline rates, pressure, etc.)
PNR drilling activity, 2005-2008

- Lasalle Co.
  - Washburn Ranch Field
    - 4 wells

- Live Oak Co.
  - Three Rivers Field
    - 14 wells

- Karnes Co.
  - SW Kenedy Field
    - 2 wells
  - NE Dewitt Co.
    - Moray & Sawfish Fields (new)
      - 32 wells
      - 4 cores

- Bee Co.
  - Pawnee Field
    - 8 wells
    - 2 cores

- Lavaca Co.
  - Word Field extension
    - 13 wells
    - 1 core

- Central Dewitt Co.
  - 6 wells

- Edwards shelf edge

- Sligo shelf edge

Locations and Field Overview:
- Sligo Co., Washburn Ranch Field: 4 wells
- Live Oak Co., Three Rivers Field: 14 wells
- Karnes Co., SW Kenedy Field: 2 wells
- NE Dewitt Co., Moray & Sawfish Fields (new): 32 wells, 4 cores
- Bee Co., Pawnee Field: 8 wells, 2 cores
- Lavaca Co., Word Field extension: 13 wells, 1 core
- Central Dewitt Co.: 6 wells
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SO...WHAT HAVE WE LEARNED?

- Salt distribution, deep Jurassic / basement faults & Sligo margin: fundamental control on development of Edwards reef
- Edwards trend is not a “simple ribbon” nor is it a true resource play
- Very complex system -- “One model” does not fit all!
- Structure, facies, diagenesis are all important

“We must make things as simple as possible… but no simpler”
- A. Einstein
Edwards Stratigraphy

- Regional Dense Marker bed separates Edwards into 2 units: “A” and “B”
- “A” and “B” are two different reef types

Regional Dense Marker Bed: shaly mudstone

Rudist-coral-strom. boundstone

Requeiniid packstone

Caprinid PS, coated grains


15,050

(see Waite et al., 2007)
A tale of two reefs: Lower vs. Upper Edwards

Upper Edwards (Edwards A)
- Regional Dense Maker Bed

Lower Edwards (Edwards B)
- Reef flat
- Reef crest
- Reef wall

Shoal
- Reef flat
- Reef crest
- Reef wall

Belize barrier reef

(Google Earth)

(Bahamas reef-shoal)
Regional strike section, Stuart City margin
(Showing lack of deep well control)
Datum: top Edwards

500 ft.
producing interval
Regional strike section, Stuart City margin
PNR deep pilot holes
Datum: top Edwards

500 ft.

producing interval

position of Regional Dense Marker bed
Regional strike section, Stuart City margin
PNR deep pilot holes

Datum: base RDMB/top Edwards “B”

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500 ft.  
producing interval

Edwards “A”
Tectonic/structural elements partition reef trend into 3 main provinces
Stuart City (Edwards reef) Trend: Sub-regions

I. LaSalle - McMullen Cos. (Rio Grande Salt Basin)

II. Live Oak Co. (Sinor Ranch/Three Rivers)

III. Bee Co. (Pawnee central)

IV. Karnes - Dewitt Cos. (Greater San Marcos Arch)

V. Lavaca Co. (Word complex)

VI. Colorado Co. (Houston Salt Basin)

30 miles
1. LaSalle - McMullen Cos. (Rio Grande Salt Basin)

- Center of the Rio Grande Salt basin
- Edwards relatively shallow (10 – 12,000 ft)
- Sligo margin is far outboard of Edwards margin
- Pay section restricted to upper portion of Edwards ‘A’ (+ 100 ft. of total gas column)
- Small bioherms with grainstone/packstone cycles
- High porosity and perm (interparticle, vuggy)
- Best wells on salt-related structural highs; depletion concerns in existing fields

Key cores: Quintana STS II-5
5. **Lavaca Co. (Word Field complex)**

- Edwards relatively deep (13,500 – 14,100 ft)
- Edwards margin outboard of Sligo margin
- Thick Edwards ‘A’ landward of main shelf edge fault
- Island/tidal flat cycles (Word) and associated low-energy, open marine muddy carbonates; highest por-perm in microporous mudstones
- Thick gas columns in Edwards ‘A’ (max at Word)
- Outboard, massive Edwards ‘B’ reef is mostly wet

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Key cores: PNR Hermes
Mobil Kahanek
Summary of new insights

• Shelf margin reef is subdivided vertically into two portions
  • Lower Edwards (‘B’): high relief, barrier-type reef margin
  • Upper Edwards (‘A’): low relief bioherms

• Geology of Edwards shelf margin controlled in part by basement configuration and salt distribution
  • Rio Grande Salt Basin / Maverick Basin
  • San Marcos Arch
  • Houston / East Texas Salt Basin

• More than one geologic model is required to fully characterize the complexities of the reef margin along strike
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3D seismic coverage along the Stuart City margin

- Existing (pre-2007) 200 sq mi
- Runge 23 sq mi
- Kenedy 18 sq mi
- Sweethome 66 sq mi
- Cuero 68 sq mi
- Pawnee 25 sq mi

San Marcos margin

Stuart City margin
3D seismic coverage along the Stuart City margin

Existing (pre-2007) 200 sq mi
Newly acquired 812 sq mi

note large footprint of new surveys

Lavaca 178 sq mi
Bonita I 178 sq mi
Sweethome 66 sq mi
Cuero 68 sq mi
Agarita / Bonita II 300 sq mi
Pawnee 25 sq mi
Kenedy 18 sq mi
Runge 23 sq mi
Sinor 142 sq mi
Marlin 192 sq mi

Existing (pre-2007) 200 sq mi
Newly acquired 812 sq mi

note large footprint of new surveys
Where is the porosity ??
“White card” method (Dravis, 1991) highlights microporosity
Closing remarks

- Deep Edwards gas play is challenging
- Conventional play with resource play elements
- Significant new gas discovery in NW Dewitt Co.
- Moving forward: 3D seismic, control costs
- One eye on the microscope, the other on commodity prices
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References


