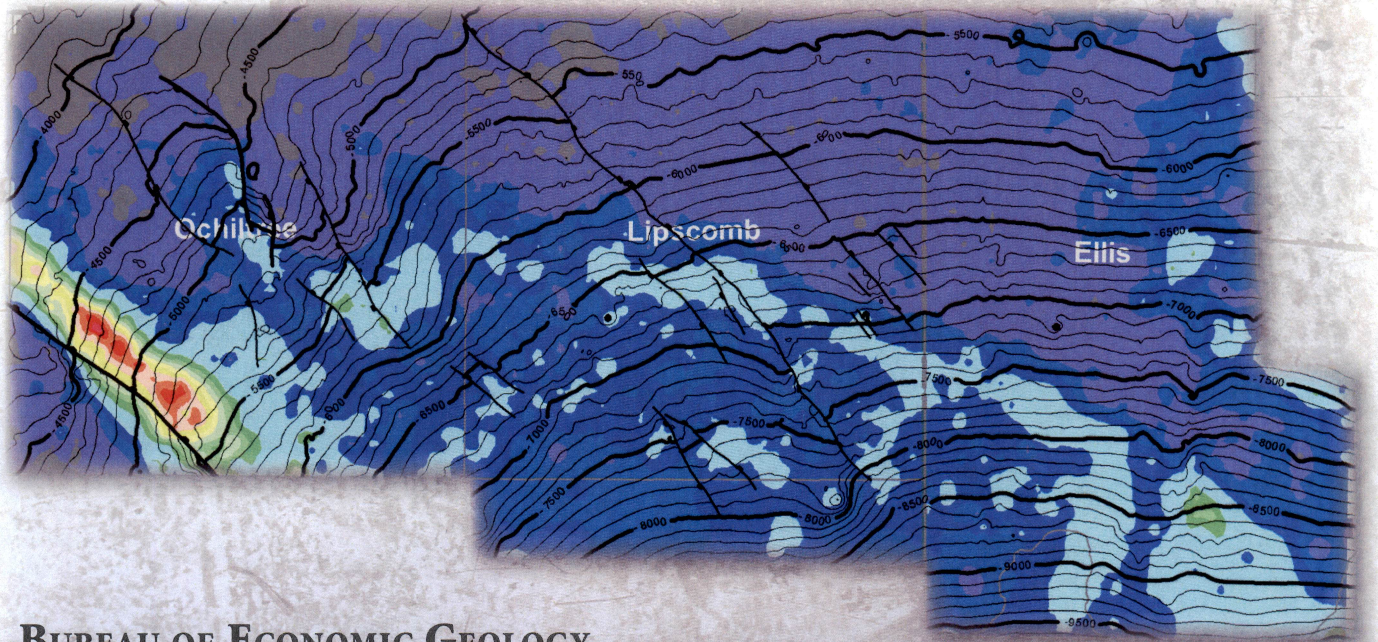
Bureau of Economic Geology
State of Texas Advanced Resource Recovery *and*
Petroleum Technology Transfer Council

Present

Sequence Stratigraphy, Depositional Systems, and Production Trends in the Atoka Series and Mid-Pennsylvanian Cleveland and Marmaton Formations, Western Anadarko Basin

David L. Carr, Tucker F. Hentz,
William A. Ambrose, Eric C. Potter,
and Sigrid J. Clift

Tuesday, November 10, 2009
Ellison Miles Institute
Brookhaven College, Farmers Branch, Texas
8:30 a.m. – 4:00 p.m.



Bureau of Economic Geology
Scott W. Tinker, Director
Jackson School of Geosciences
The University of Texas at Austin

No. SW0019

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PTTC gratefully acknowledges support of industry, academia,
and the DOE's National Energy Technology Laboratory.
This material is based upon work supported by the
Department of Energy under Award No. DE-FE0001175.

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Workshop Agenda

Morning Session – 8:30 a.m.-11:20

I. Introduction and Welcome
Eric Potter, Bureau of Economic Geology

II. Atoka Series, Play Overview
David Carr, Bureau of Economic Geology

Break – 10:15-10:30

III. Sequence stratigraphy and depositional fabric of the Marmaton and Cleveland Formations
Tucker Hentz, Bureau of Economic Geology

Lunch

We will break for lunch at 11:20 for those who are attending the DGS luncheon meeting. Workshop will convene again at 1:00.

For those who are not attending the DGS luncheon meeting, lunch will be provided in the workshop classroom.

Afternoon Session – 1:00 p.m.-4:00 p.m.

IV. Tidally dominated depositional systems and sedimentary processes, with application to the Marmaton and Cleveland Formations
Bill Ambrose, Bureau of Economic Geology

V. Core workshop
Bill Ambrose, David Carr, Tucker Hentz

Instructor Profiles

William A. Ambrose is a geologist specializing in sedimentology and reservoir characterization. He received a M.A. degree in geological sciences in 1983 from the University of Texas at Austin. His contact information is--email: william.ambrose@beg.utexas.edu , telephone: 512-471-0258.

David L. Carr is a geologist whose interests lie in clastic sedimentology and stratigraphy and their application to exploration, production, and gas-storage activities. He earned his M.A. degree geological sciences in 1983 from the University of Texas at Austin. His contact information is: email – david.carr@beg.utexas.edu, telephone – (512) 471-1806, address – Bureau of Economic Geology, The University of Texas at Austin, University Station, Box X, Austin, TX 78713-8924.

Tucker F. Hentz is a geologist with the Bureau of Economic Geology specializing in sequence stratigraphy and basin analysis. He received his M.S. degree in geology in 1982 from The University of Kansas. His contact information is: email – tucker.hentz@beg.utexas.edu, telephone – (512) 471-7281.

Eric Potter is Associate Director of the Bureau of Economic Geology and is responsible for managing the Bureau's energy-related research. Eric received a B.A. degree in Geology at Dartmouth College in 1972 and a M.S. degree in Geology at Oregon State University in 1975.

Sequence Stratigraphy, Depositional Systems, and Production Trends in the Atoka Series and Mid-Pennsylvanian Cleveland and Marmaton Formations, Western Anadarko Basin

Workshop Presented by the
Bureau of Economic Geology
State of Texas Advanced Resource Recovery (STARR) Program
and *PTTC Texas and SE New Mexico Region*

November 10, 2009
Ellison Miles Geotechnology Institute, Dallas

Bureau of Economic Geology

Introduction

Eric Potter
BEG Program Director
for Fossil Energy

The STARR Program

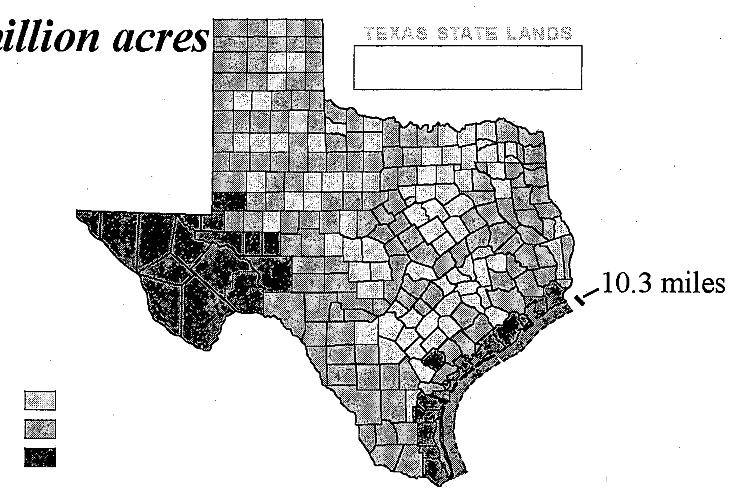
Funding from Texas Legislature, and logistical support from the General Land Office and the Railroad Commission

Mission: Increase income to the State through working with operators to...

- Help locate new wells (infill, step-outs, wildcats)
- Recommend recompletions
- Recommend drilling deeper untested reservoirs
- Recommend secondary or tertiary recovery programs
- Define or expand new plays, including unconventional

State Lands and Waters

20.4 million acres



STARR Program Structure

Reservoir Characterization
- 5 Companies
- 7 Reservoirs

New Venture Studies
- Regional Frio Study
- N. TX/Eastern Shelf exploration trend
- Bone Spring play analysis
- Woodbine exploration trend

Unconventional Resources
- Barnett/Haynesville Shale-Gas Plays

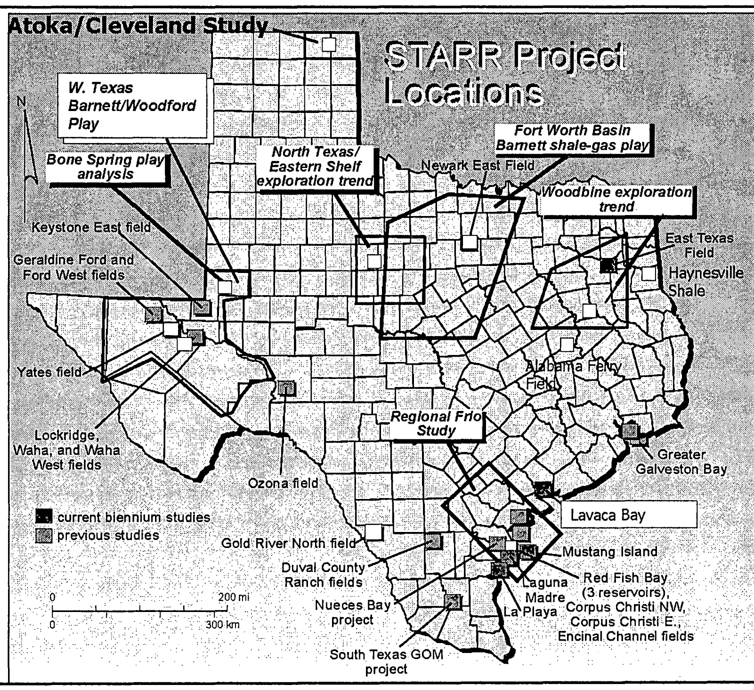
STARR Partnerships with Companies

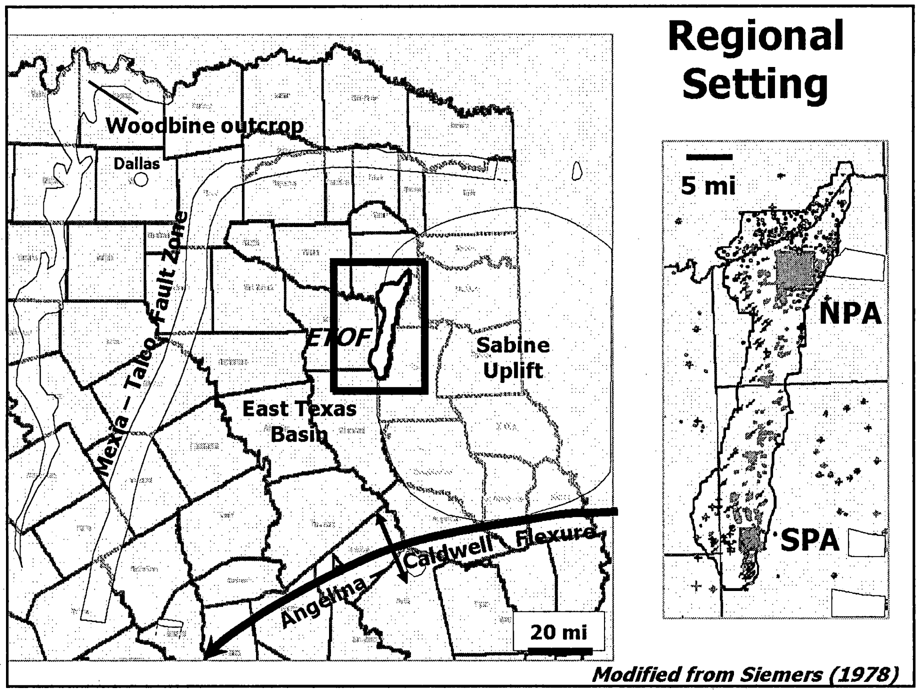
- **No cost to operators**
- **Publication of some results**

BEG's STARR partner selection criteria:
- **Potential economic value to Texas**
- **Operator's willingness to share data**
- **Operator's financial ability to drill, recomplete, and/or initiate an enhanced recovery program**
- **Willingness of operator to write letter describing outcome of STARR recommendations**

STARR Team Members

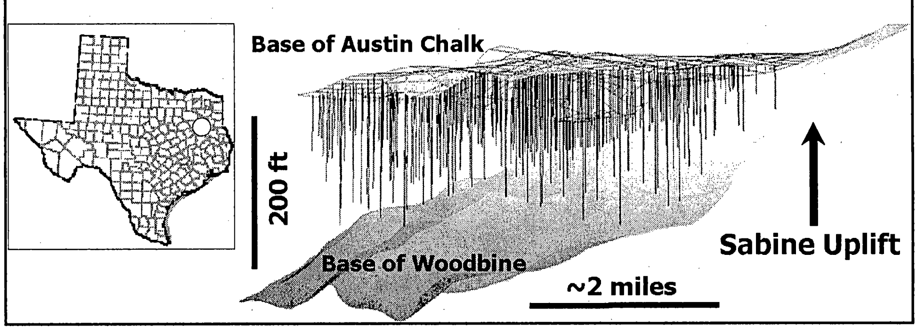
Ursula Hammes, co-PI
Bill Ambrose, co-PI
Frank Brown (sequence stratigrapher)
Florence Bonnaffe (geologist)
Cari Breton (GIS)
David Carr (geologist)
Ray Eastwood (petrophysicist)
Julia Gale (structural geologist)
Tucker Hentz (geologist)
Brandon Johnson (geophysicist)
Lorena Moscardelli (seismic interpreter, geologist)
Chris Ogiesoba (geophysicist)
Fred Wang (petroleum engineer)
Hongliu Zeng (geophysicist)
Scott Hamlin (geologist)



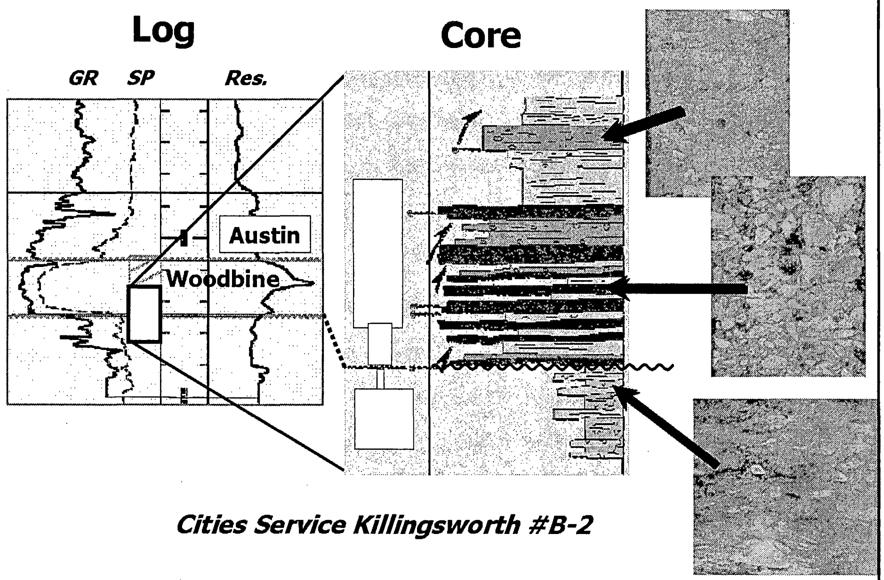


Vital Statistics: East Texas Field

- Discovered in 1930
- Combination trap
- Strong water drive
- Depth ~3,500 ft
- ~31,000 wells
- 4.3-acre spacing
- 7.03 Bbbl oil in place
- 5.42 Bbbl produced
- 77% recovery efficiency



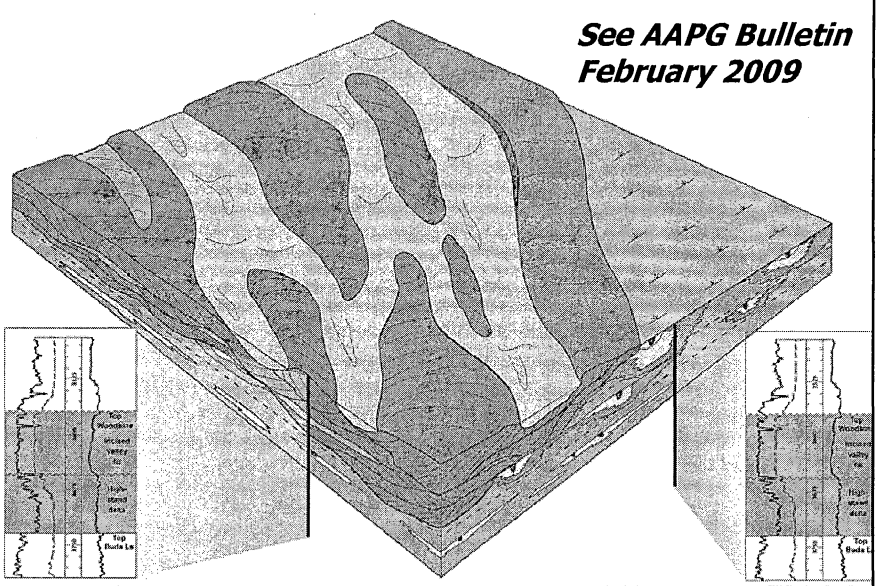
Lowstand Fluvial Section



Cities Service Killingsworth #B-2

Woodbine Depositional Model

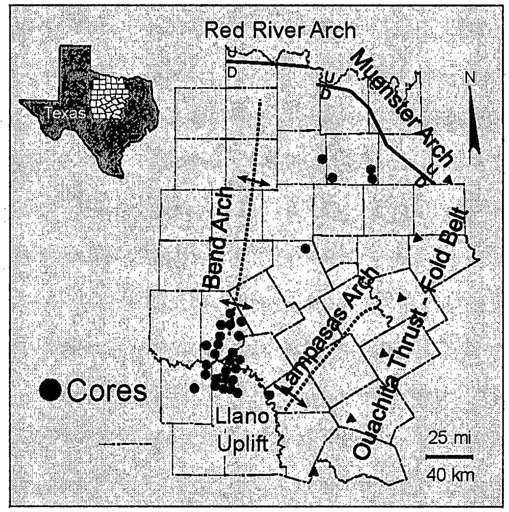
See AAPG Bulletin February 2009



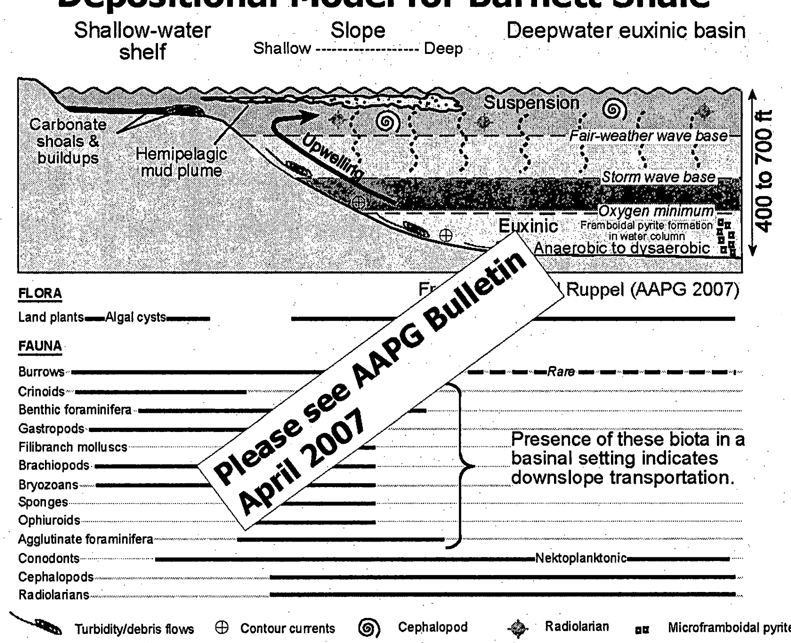
Shale Gas Systems
Barnett Formation

Fort Worth Basin

- Tectonic elements
- Core distribution



Depositional Model for Barnett Shale



STARR Financial Model

- STARR Project must be revenue neutral to be re-funded by the Legislature each biennium
- Presently funded at $1.5 million annually
- STARR return on State's investment was >6:1 in last biennium, despite stringent credit criteria
- Partnerships with companies are critical to program's success
- Remember, it's free!

Agenda for today's workshop

Morning Session (8:30 a.m.-Noon)

- **Atoka Series**
  -Play Overview (David L. Carr)
- **Cleveland Formation and Marmaton Group**
  -Sequence Stratigraphy (Tucker F. Hentz)

Lunch (Noon-1:00 p.m.)

-Optional Luncheon (Jerry Lucia, speaker)

Afternoon Session (1:00 p.m.-4:00 p.m.)

- **Cleveland Formation and Marmaton Group**
  -Tidal Depositional Systems (William A. Ambrose)
  -Core Workshop (Carr, Hentz, Clift, Potter, Ambrose)

Atoka/Cleveland Team

Dave Carr

Tucker Hentz

Sigrid Clift

Bill Ambrose

Atoka and Cleveland/Marmaton Plays

- **Atoka Series**
  Variable rock types: limestone and shale
  High-TOC shales (avg. 4-6%; some >10%)

- **Cleveland Formation and Marmaton Group**
  Low-permeability sandstones
  High degree of interbedded sandstones and shales
  Narrow sandstone-body geometries
  Partitioning of sandstones in sequences

Databases

Atoka Series

>500 *Wells*

Shell #1 Molesworth core – 84 ft

Production data from 525 vertical and 20 horizontal wells

Cleveland Formation and Marmaton Group

>1,100 *Wells*

Cores from 7 wells

Production data from >900 wells

Production Characteristics

Atoka Series

Main production: Thirteen Finger Ls-variable quality

Cumulative production in Ochiltree and Lipscomb Counties
185 Bcf and 6.7 MMBO

Potential for unconventional shale-gas production

Some structural control on production trends

Production Characteristics

Cleveland Formation and Marmaton Group

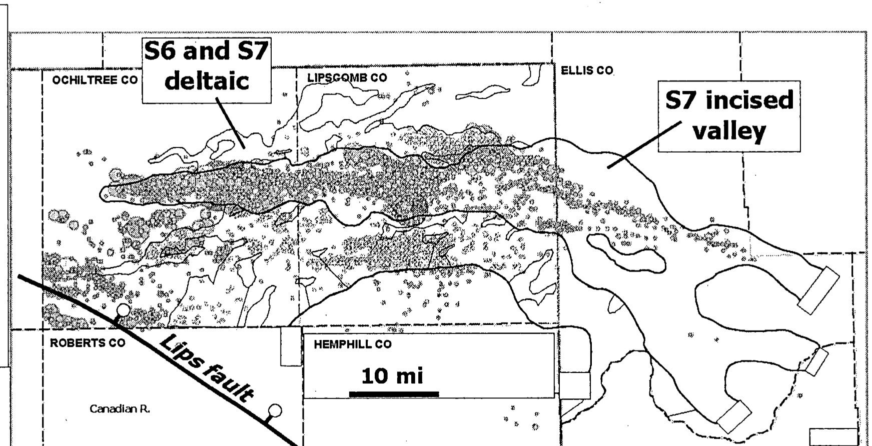
Cleveland production trends related to lowstand sequence and structure (updip pinchout, local structures, Lips fault)

Low-permeability, well-cemented, heterogeneous sandstones

Marmaton (Hepler sand): mostly thin, locally thick, pay sandstones

Cumulative production (Cleveland) in Ochiltree and Lipscomb Counties 1.1 Tcf and 32.4 MMBO

Cumulative Cleveland Gas Production (per well)



Bcf

☐ ≥5 ☐ 4–5 ☐ 3–4 ☐ 2–3 ☐ 1–2 ☐ <1

Questions?

Reconnaissance of the Atoka Group (Middle Pennsylvanian) Northwest Anadarko Basin

David L. Carr, Kitty Milliken, Laura Zahm,
Tucker F. Hentz & William A. Ambrose

1909-2009

Acknowledgments

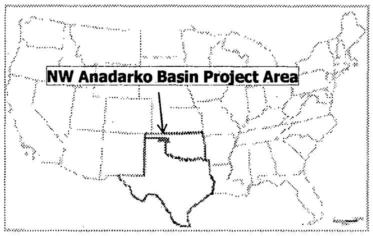
Jones Energy, Ltd.

Brigham Exploration | **Chesapeake Energy** | **Texas American Resources**

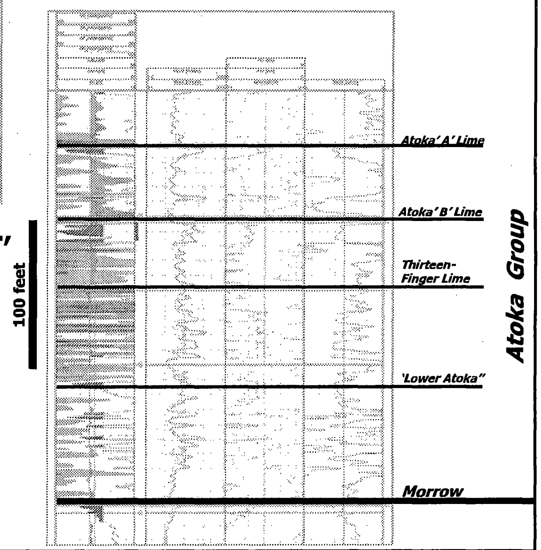
State of Texas Advanced Resource Recovery

**Publication was authorized by the Director, Bureau of Economic Geology,
The University of Texas at Austin**

Atoka Play: Where is it? What is it?



- Ochiltree & Lipscomb Co., TX; Ellis Co., OK
- Historically a minor secondary target
- Most vertical-well completions in Atoka 'B' Lime (aka Novi)



Reconnaissance of Atoka Geology

Sufficient whole core data is lacking in public domain but we have nonetheless have made some progress in evaluating several areas:

- Mudrocks
- Carbonate reservoirs
- 'Tyson Sand' reservoir, Lipscomb Co.
- Depositional environments
- Sequence stratigraphy
- Relationship of systems tracts to production

Outline

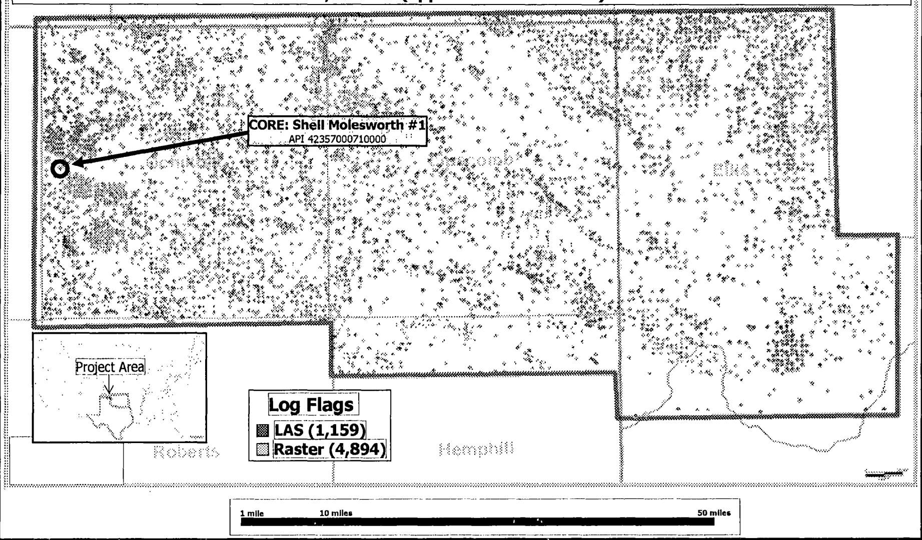
1. **Intro: Data, Methods & Geologic Setting**
2. **Production History & Current Activity**
3. **Core Calibration: Shell Molesworth #1**
    1. Facies
    2. Inferred Depositional Environments
    3. Organic Richness
    4. Petrophysical Properties
4. **Sequence Stratigraphy**
5. **Facies Mapping/Paleogeography**

Data Set

1. **Well and Production Data (courtesy Jones Energy; infilled w/IHS and DrillingInfo)**
2. **Raster images for 3500 wells (courtesy Jones Energy)**
3. **LAS data for 1100 wells (courtesy Chesapeake, Texas Amer. Res., Brigham Expl., Jones Energy)**
4. **Core: Shell Molesworth #1**
    1. Visual description
    2. Thin Sections
    3. RockEval-Organic Geochemistry

Data Distribution

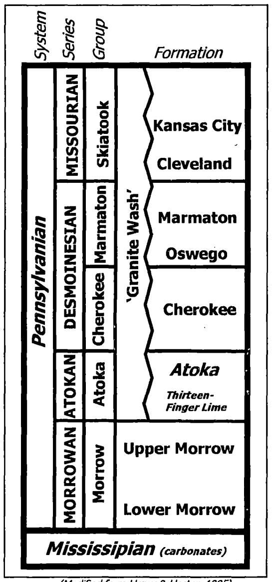
7,468 Atoka penetrations in Project Area comprising Lipscomb and Ochiltree Co.'s, TX and Ellis Co., OK
3,230 mi^2 (approx. 2 million acres)



Methods

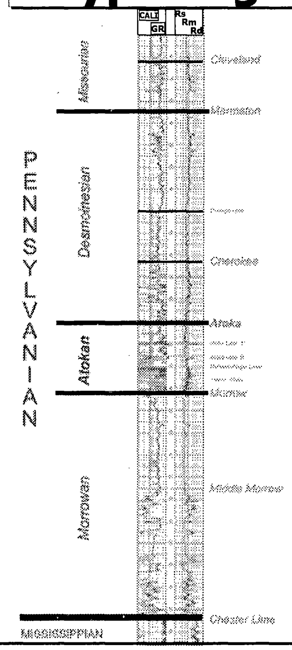
1. **Core: Shell Molesworth #1**
   1. Visual description
   2. Thin Sections
   3. Organic Richness--RockEval
2. **Log Analysis – tied facies to log signatures**
   1. Raster data for ~3,500 wells (courtesy Jones Energy)
   2. LAS data for 1,164 wells (courtesy Chesapeake, Texas Amer. Res., Brigham Expl., Jones Energy)
3. **Constructed Regional cross sections: Sequence Stratigraphy correlations**
4. **Mapping of facies/petrophysical properties**
5. **Series of maps demonstrate evolution of paleogeography**

NW Anadarko Stratigraphic Column



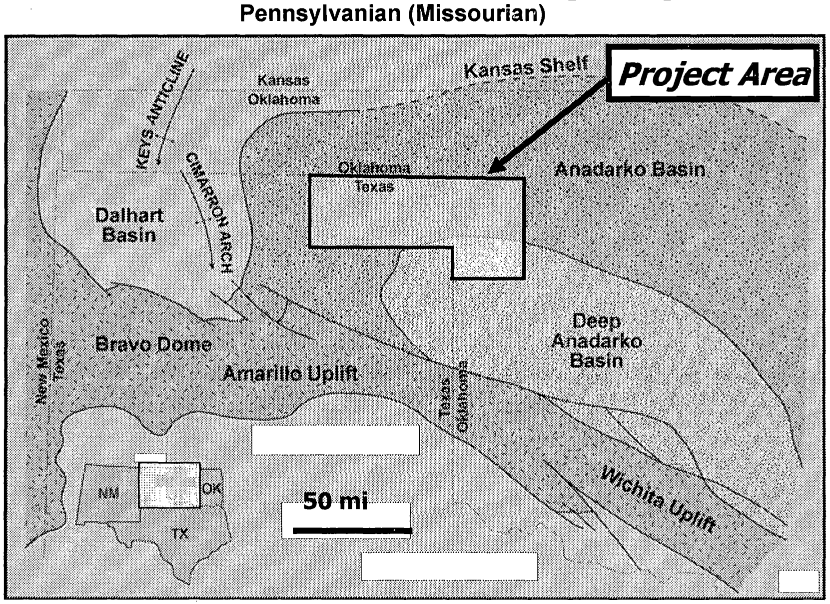
(Modified from Henry & Hester, 1995)

Type Log

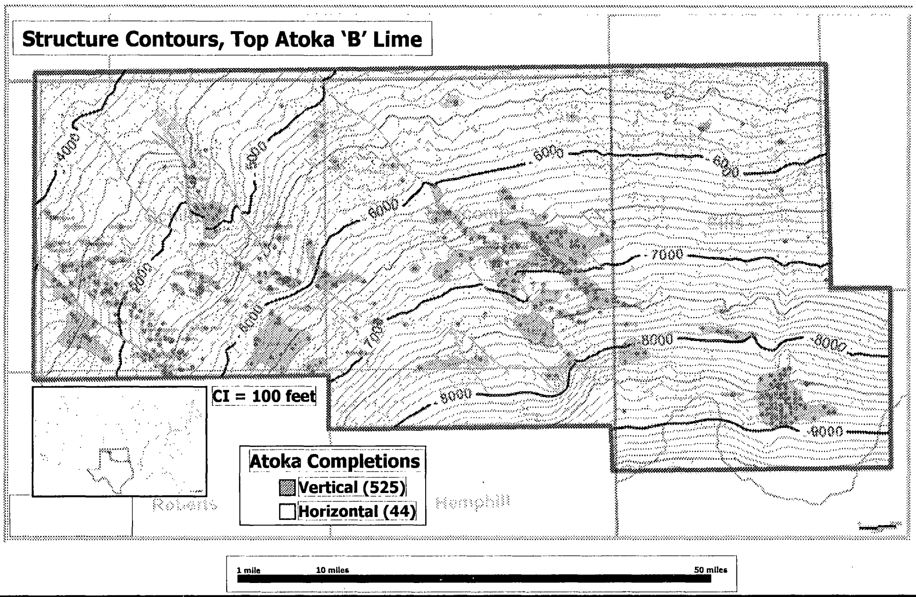


Anadarko Basin Paleogeography

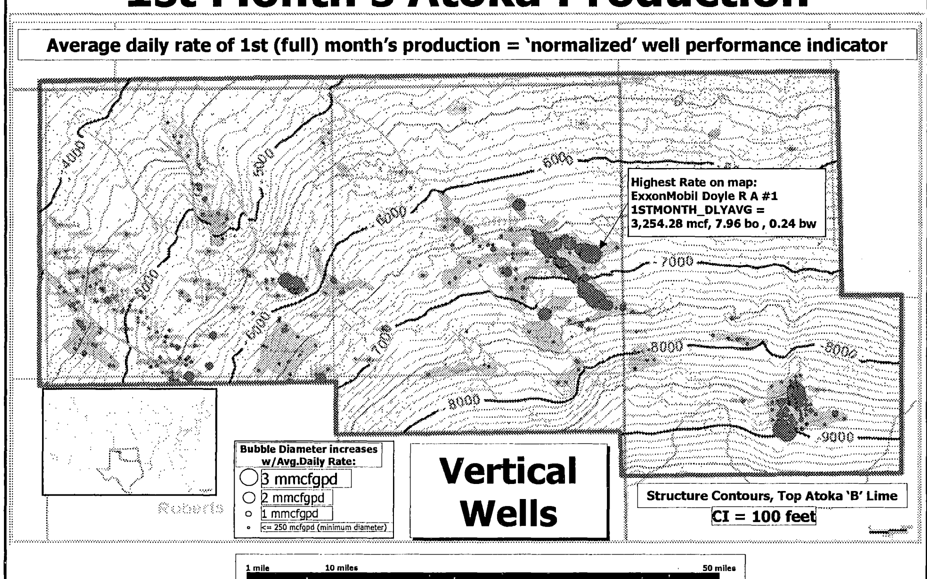
Pennsylvanian (Missourian)



Atoka Production Map



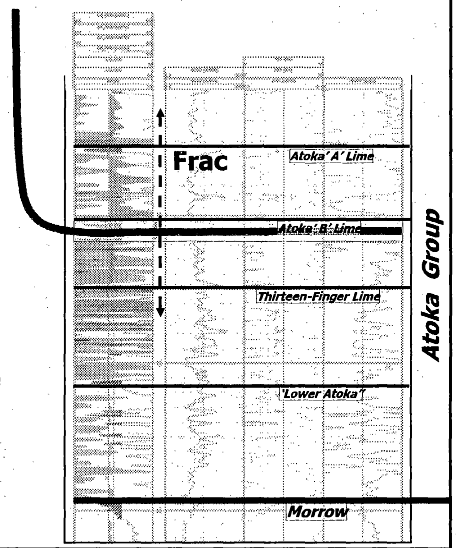
Bubble Map: Average Daily Rates of 1st Month's Atoka Production



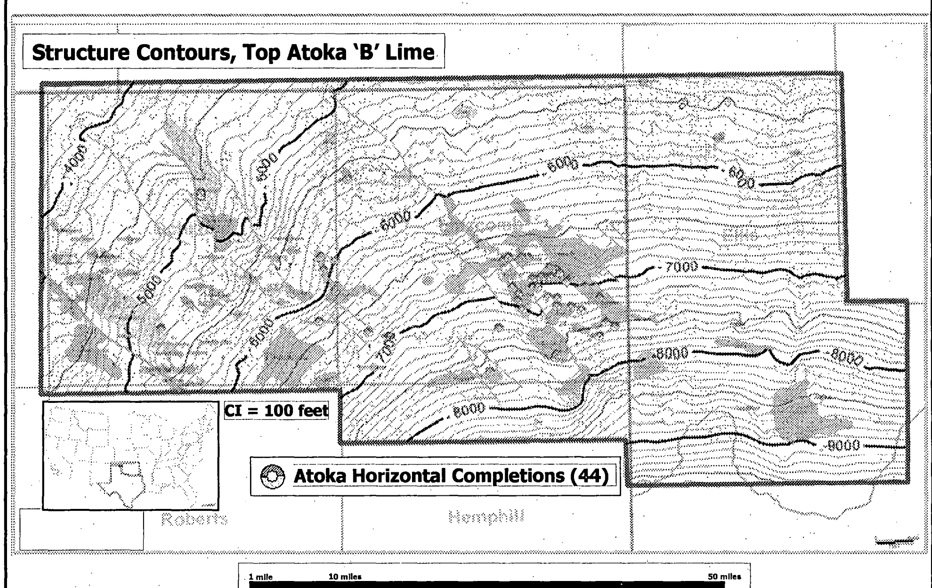
Emerging Atoka Horizontal Lime/Shale Play

- Historically a minor secondary target
- Most vertical-well completions in Atoka 'B' Lime (aka Novi)
- Emerging horizontal/ fracture stimulation play targeting the Atoka 'B' Lime

How much of this increase is the result of hydraulic fractures reaching into the adjacent organic-rich shales?

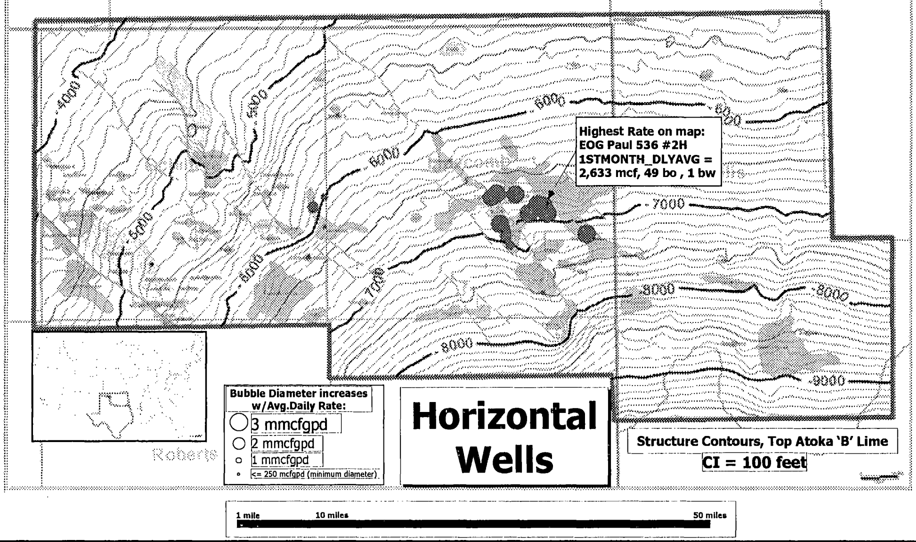


Map of Emerging Atoka Horizontal Play



Bubble Map: Average Daily Rates of 1st Month's Atoka Production

Average daily rate of 1st (full) month's production = 'normalized' well performance indicator



Atoka Production Statistics: Vertical Wells (n = 525)

	Cumulative Production			Average Daily Rates									Days on Prod.
	GAS (mcf)	OIL (bbl)	WATER (bbl)	GAS avg rate mcfgpd	GAS max rate mcfgpd	GAS min rate mcfgpd	OIL avg rate bopd	OIL max rate bopd	OIL min rate bopd	WTR avg rate bwpd	WTR max rate bwpd	WTR min rate bwpd	
sum	219,463,496	10,843,959	683,033	-	-	-	-	-	-	-	-	-	1,601,448
average	417,231	20,616	1,299	180.4	575.8	45.9	13.7	1,095.8	122.4	2.3	87.4	11.1	3,045
max	17,316,336	1,674,521	102,076	4,215.2	898.9	48.8	1,000.5	1,419.2	1,019.6	100.0	140.3	59.1	17,017

*Data Sources: IHS Energy, DrillingInfo ; Lipscomb and Ochiltree Co.'s, TX, Ellis Co., OK; current to March 2009

Atoka Production Statistics: Horizontal Wells (n = 21)

Texas County	Well	TD	Compl. Date	Cumulative Production: GAS	OIL	WATER bbl	Average Daily Rates: GAS avg rate mcfgpd	GAS max rate mcfgpd	GAS min rate mcfgpd	OIL avg rate bopd	OIL max rate bopd	OIL min rate bopd	WTR avg rate bwpd	WTR max rate bwpd	WTR min rate bwpd	Days on Prod.
LIPSCOMB	PAUL 536 #2H	12,589	6-Apr-08	482,854	146	7,438	2,633	4,959	1,604	0.87	2	0	49	90	28	183
LIPSCOMB	LANDERS 522 #3H	10,000	3-Jun-08	315,461	74	-	2,566	4,549	895	0.60	2	0		-	-	123
LIPSCOMB	APPEL 438 #3H	10,000	11-Jul-08	158,457	265	-	2,559	3,870	2,240	4.60	9	4		-	-	62
LIPSCOMB	SAINT 520 #3H	10,000	29-Jul-08	184,474	-	-	1,885	2,428	1,009		-	-		-	-	62
LIPSCOMB	PAUL 536 #1H	11,780	9-Oct-07	561,839	281	7,167	1,494	4,295	729	1.44	7	0	21	61	10	336
LIPSCOMB	PRICE TRUST 604 #2H	11,660	24-Sep-07	535,549	287	21,829	1,463	4,004	542	0.73	3	0	60	163	22	365
LIPSCOMB	WEIS 452 #4H	11,684	14-Nov-07	398,668	137	7,732	1,310	2,614	575	0.50	2	0	25	51	11	305
LIPSCOMB	BEARD 606 #2H	11,298	5-Jul-07	483,983	91	3,035	1,057	3,198	340	0.49	1	0	14	28	7	458
LIPSCOMB	PRICE TRUST 604 #1H	11,600	3-Mar-07	577,860	21,640	16,799	1,051	1,640	771	39.59	118	21	20	58	10	550
LIPSCOMB	BUCHER 429 #1H	11,776	5-Sep-07	316,193	140	761	796	1,869	289	0.51	1	0	4	6	2	397
OCHILTREE	DANIEL 580 #2H	10,800	30-Apr-08	114,853	716	5,233	754	1,141	242	4.48	9	1	34	51	11	153
LIPSCOMB	JAMES ROLAND WHEAT 3 #2H	11,919	11-Mar-08	115,467	-	4,698	613	873	380		-	-	32	31	14	184
LIPSCOMB	WEIS #3H-452	11,695	1-Oct-07	363,857	83	-	563	1,287	334	0.18	1	0		-	-	640
OCHILTREE	DANIEL 596 #1H	9,000	31-Jul-08	29,604	766	-	477	508	455	12.19	13	12		-	-	62
LIPSCOMB	BEARD #606-1H	10,536	29-Mar-06	265,307	74	-	322	926	111	0.27	1	0		-	-	915
OCHILTREE	URBAN, ROBERT H. 109 #2H	12,700	21-Dec-07	75,169	2,569	2,860	277	476	79	9.34	28	1	11	27	1	275
OCHILTREE	DICKINSON 471 #3H	10,374	22-Jun-06	122,832	1,193	2,909	158	331	28	1.50	9	0	4	8	1	793
LIPSCOMB	JONES TRUST 169 #2H	11,571	14-Sep-06	63,958	35	187	118	542	39	0.38	1	0	1	3	0	590
OCHILTREE	WALLVILLE 331 #1H	11,093	19-Jan-07	24,278	3,320	1,284	40	127	9	6.55	22	0	2	8	0	609
LIPSCOMB	DOONEY #997-2H	9,739	24-Oct-08	4,791	830	224	5	9	9	1.05	2	0	1	2	9	151
ROBERTS	COURSON RANCH 136 #13H	9,479	3-Nov-08	168	100	-	1			3.33	3	3		-	-	132
			sum	5,000,816	33,333	75,434	na	na	na	na	na	na	na	na	na	8,026
			average	238,125	1,587	3,594	949.9	1,942.9	517.2	4.7	10.7	3.1	19.1	28.9	5.8	382
			max	577,860	21,640	21,829	2,633.0	4,959.0	2,239.9	39.6	118.1	20.8	59.8	163.2	27.8	915
			min	168	0	0	1.4	8.7	0.9	0.2	0.0	0.0	0.8	0.8	0.0	62

Average Gas Rates indicate a 5-fold increase for horizontal completions

*Data Sources: IHS Energy, DrillingInfo ; Lipscomb and Ochiltree Co.'s, TX; current to March 2009

Atoka Production Statistics:* Vertical - Horizontal Well Comparison

	n, # wells	Cumulative Production*: Gas (Bcfg)	Oil (MMBO)	Wtr (MMBW)	Per Well Averages*: Cum.Gas (MMcfg)	Cum. Oil (MBO)	Cum. Wtr (MBW)	Days on Prod.	Avg. Daily Rates: Gas (Mcfg)	Oil (BOPD)	Wtr (BWPD)
Vertical	525	219.4	10.80	0.68	417.2	20.6	2.3	3,045	180.4	13.7	2.3
Horizontal	20	5.0	0.03	0.08	949.9	1.6		382	949.9	4.7	19.1

*Data Sources: IHS Energy, DrillingInfo ; Lipscomb and Ochiltree Co.'s, TX, Ellis Co., OK; current to March 2009

Atoka IP Statistics*

VERTICAL	IP GAS mcfgpd	IP OIL bopd	IP WTR bowd	IP BHP psi	IP BHT °F	Average Perf Depth (MD, ft)
average	783	45	4	1,626	193	9,282
min	0	0	0	61	139	7,587
max	22,000	818	145	4,562	257	13,475

HORIZONTAL	IP GAS mcfgpd	IP OIL bopd	IP WTR bowd	IP BHP psi	IP BHT °F	Average Perf Depth (MD, ft)
average	2,765	28	66	1,335	168	10,638
min	22	1	0	389	114	9,811
max	7,036	128	360	3,559	255	11,528

*Data Sources: IHS Energy, DrillingInfo ; Lipscomb and Ochiltree Co.'s, TX, Ellis Co., OK

Atoka IP Statistics*

Comparison of Vertical vs. Horizontal Wells

VERTICAL

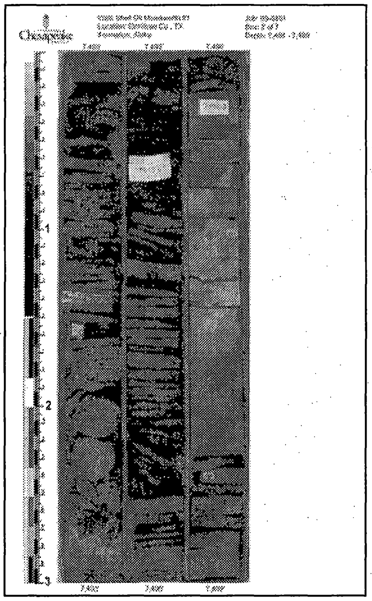
Initial Potential Tests	IP GAS mcfgpd	IP OIL bopd	IP WTR bowd	IP BHP psi	IP BHT °F	Average Perf Depth (MD, ft)
average	783.2	45.4	4.1	1,625.7	193.1	9,281.6
min	0.0	0.0	0.0	61.0	139.0	7,587.0
max	22,000.0	818.0	145.0	4,562.0	257.0	13,475.0

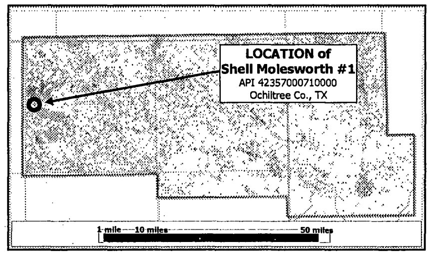
HORIZONTAL

Horizontal Well	IP GAS mcfgpd	IP OIL bopd	IP WTR bowd	IP BHP psi	IP BHT °F	Average Perf Depth (MD, ft)
PRICE TRUST 604 #2H	7036	5	360	1363	154	10534
PAUL 536 #2H	6502		120	1454	182	11129
PAUL 536 #1H	5396		81	683	181	10708
LANDERS 522 #3H	4755		0	1525	114	10851
BEARD 606 #2H	4475		43	538	168	10366
APPEL 438 #3H	4083		145		189	11528
WEIS 452 #4H	3974	8	79	3559	144	10702
SAINT 520 #3H	3800		148	619	174	10834
BUCHER 429 #1H	2652		9	2813	149	10715
PRICE TRUST 604 #1H	2092	128	63			
JAMES ROLAND WHEAT 3 #2H	1989	1	70	1128	170	10942
HURN 355" #2H"	1409	11	5		255	10068
JONES TRUST 169 #2H	858		5	1336	173	11012
DANIEL 560 #2H	1587	15	71	389	144	9909
DANIEL 586 #1H	619	6	30		154	10468
URBAN, ROBERT H. 108 #2H	510	40	45			
DICKINSON 471 #3H	458	35	14	612	169	9811
WALLVILLE 321 #1H	327	50	20			
DOONEY #997-2H	22	5	5			
average	2,765.5	27.6	65.7	1,334.9	168.0	10,638.5
min	22.0	1.0	0.0	389.0	114.0	9,811.0
max	7,036.0	128.0	360.0	3,559.0	255.0	11,528.0
Initial Potential Tests	IP GAS mcfgpd	IP OIL bopd	IP WTR bowd	IP BHP psi	IP BHT °F	Average Perf Depth (MD, ft)

*Data Sources: IHS Energy, DrillingInfo ; Lipscomb and Ochiltree Co.'s, TX, Ellis Co., OK

Core Calibration: Shell Molesworth #1

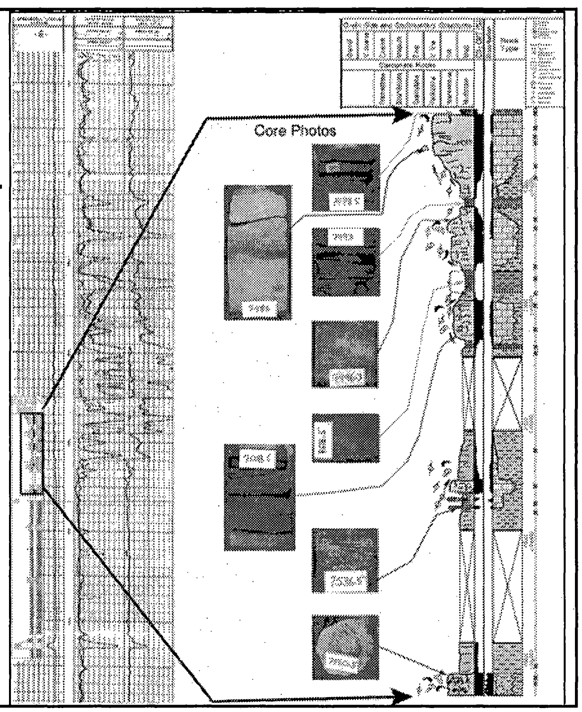




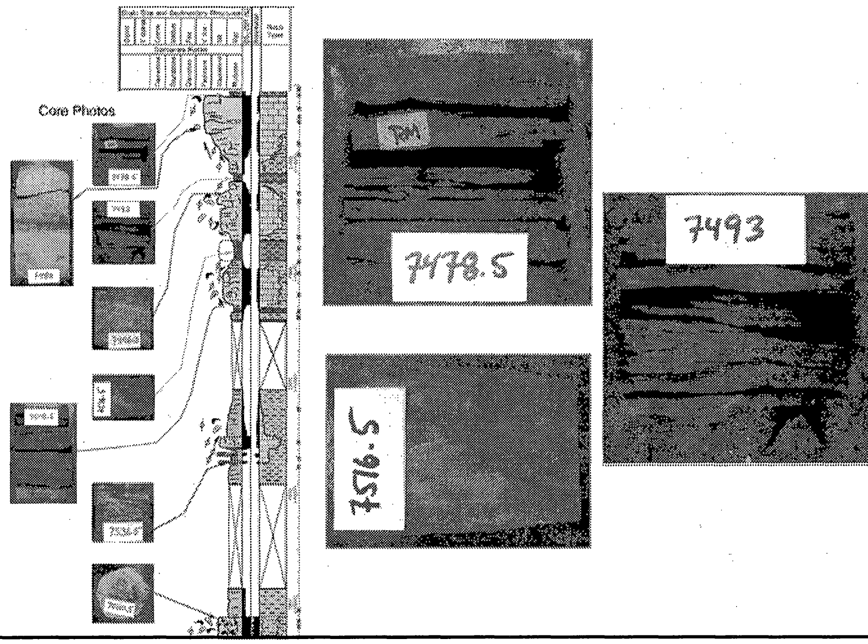
CORE CONDITION.--This dry hole was drilled in 1957 on the western edge of Ochiltree County. Shell cored 84 feet of 'Lower Atoka' (informal name used herein) and 786 ft of Morrow. There was fair core recovery in Atoka: 70 ft (83%) was recovered but there are several substantial missing sections. Some recovered sections are rubbly. However, this is the only Atoka core we were able find and based on resistivity log comparison to other wells, the facies in the Molesworth #1 core are probably representative of the Atoka in general.

Core Description:

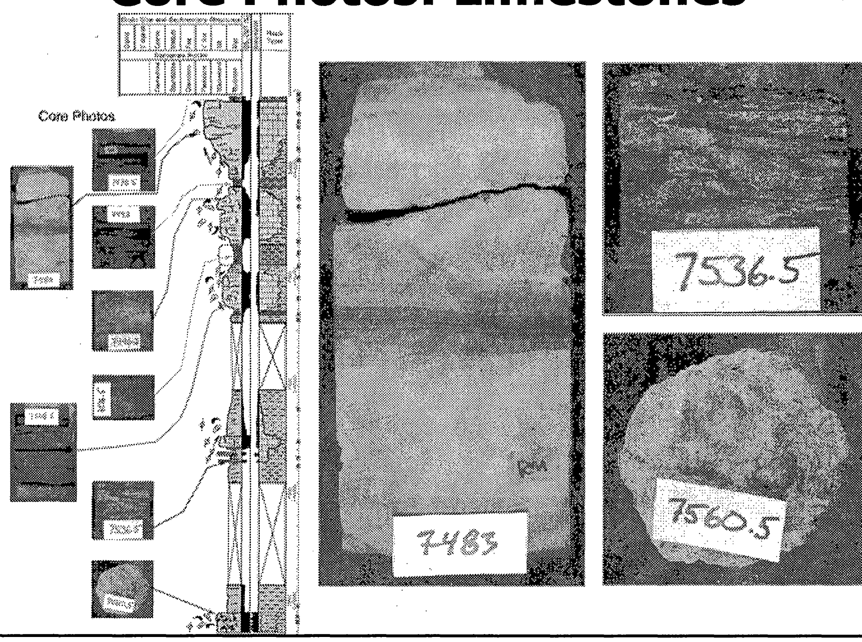
Shell Molesworth #1



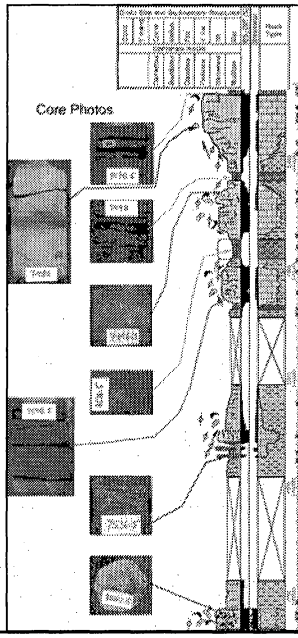
Core Photos: Mudrocks

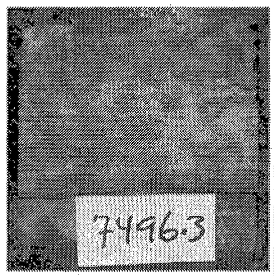


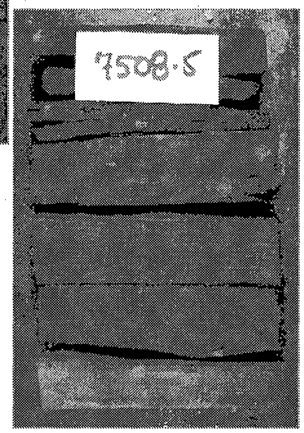
Core Photos: Limestones

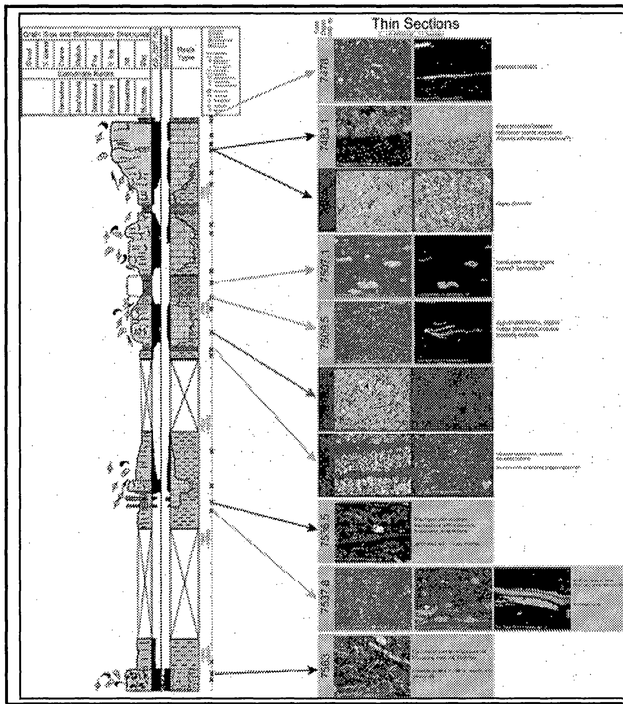


Core Photos: Dolostones









Thin Sections: Shell Molesworth #1 Core

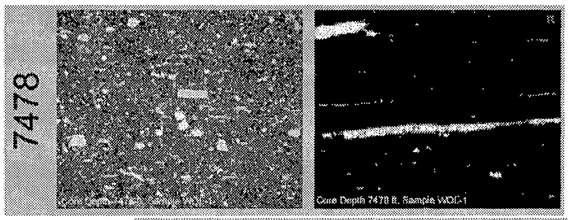
Color-to-Facies Key

Carbonate Mudstone, well-sorted with imbricated skeletal fragments composed of brachiopods, molluscs, thin-shelled mollusca, foraminifera, and rare polychaete tubes

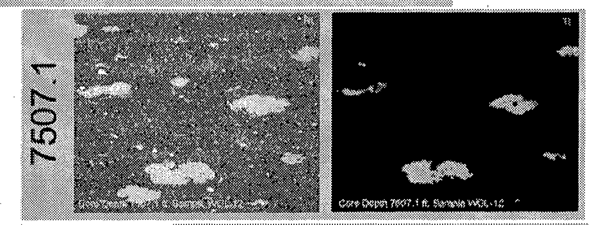
Dolomitic Mudstone, finely crystalline dolomite, well-sorted, virtually devoid of skeletal material

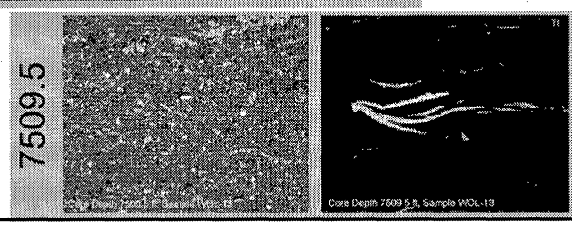
Organic-rich Mudstone, black with distinct bedding lamination, thin-walled mollusca generally aligned with shale partings, forams as minor component

Thin Section Photos: Mudrocks

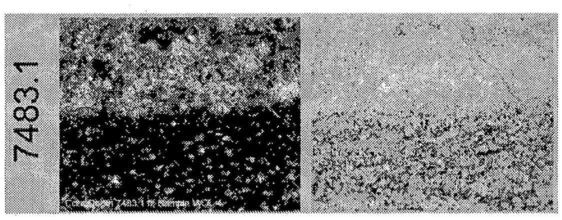


Organic-rich Mudstone, black with distinct bedding lamination, thin-walled mollusca generally aligned with shale partings, forams as minor component

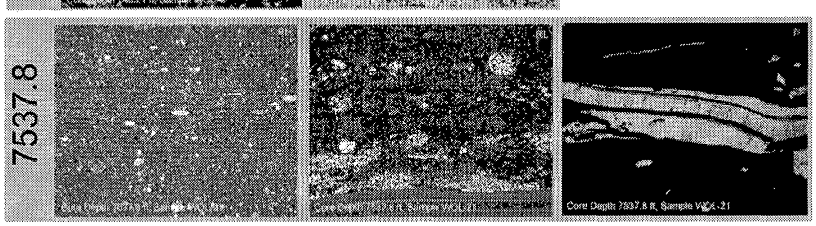


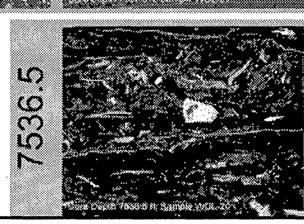


Thin Section Photos: Limestones

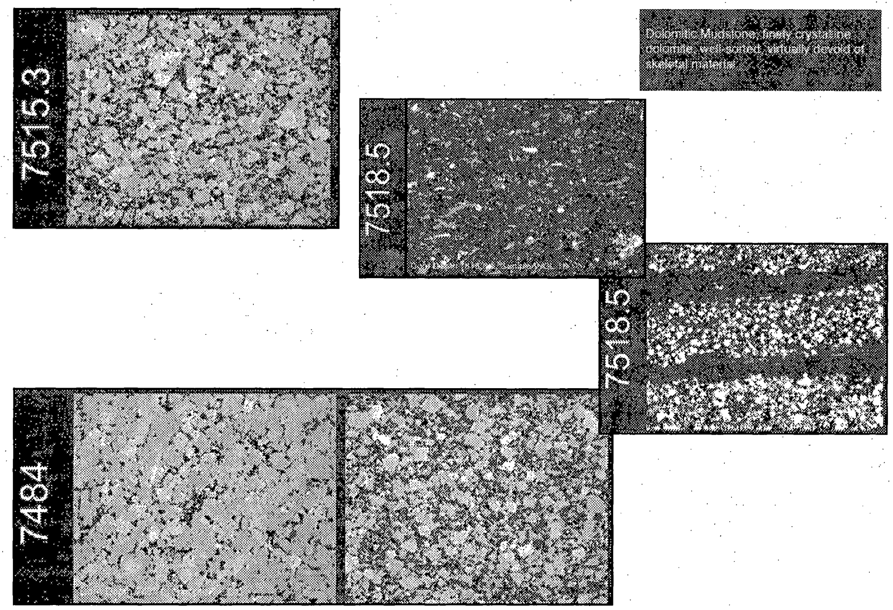


Carbonate Mudstone, well-sorted with imbricated skeletal fragments composed of brachiopods, mollusca, thin-shelled mollusca, foraminifers, and rare polychaete tubes





Thin Section Photos: Dolostones



Interpretation of Depositional environment: Shell Molesworth #1 Core

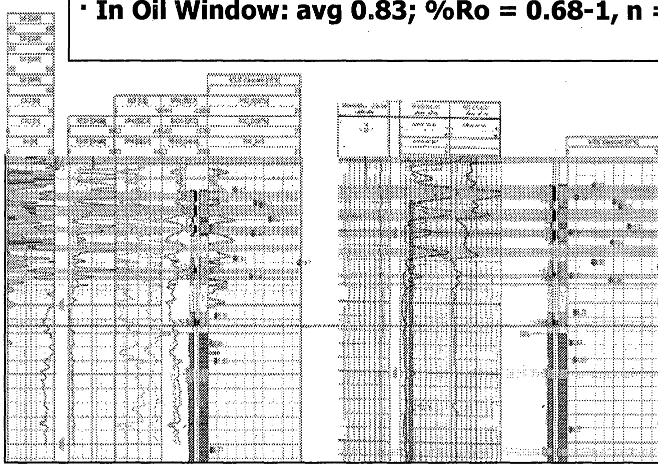
Deep-water environment:

- **Restricted, anoxic deep marine basin**
- **Interrupted by episodic transport of fine material probably by density flows**
  - **Most transport grains derived from basin-rimming carbonate complexes**
  - **Minor siliciclastic input**

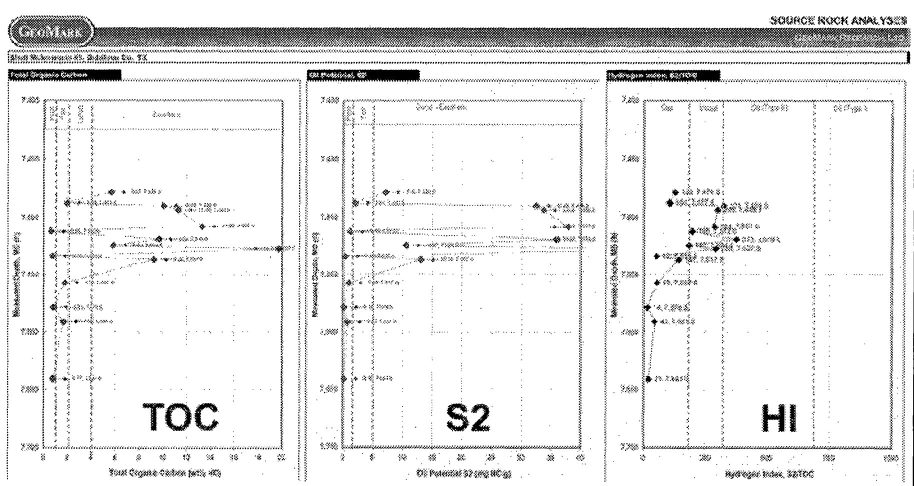
→ Low-order marine condensed section

Organic Richness: Shell Molesworth #1

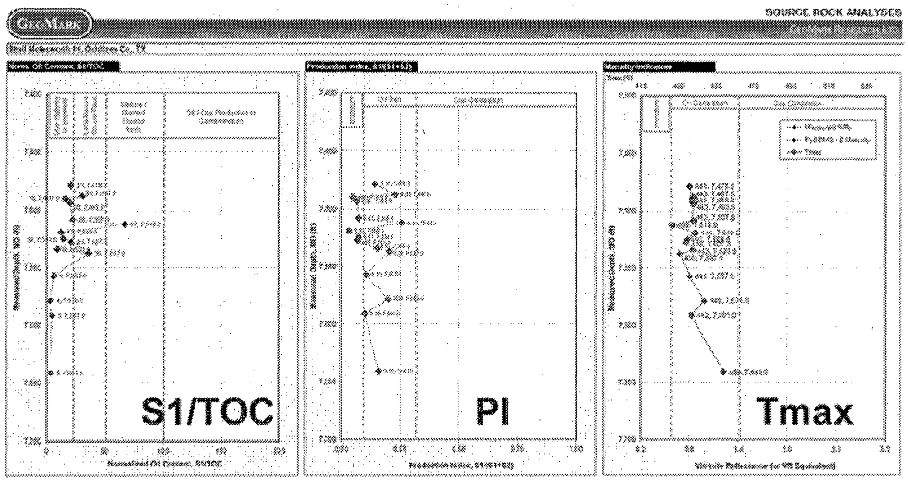
Rock Eval & Vitrinite Reflectance Results
- **High TOC Shales: avg 10.6%; range 5.7%-19.%, n = 8**
- **Type II Kerogen**
- **In Oil Window: avg 0.83; %Ro = 0.68-1, n = 2**



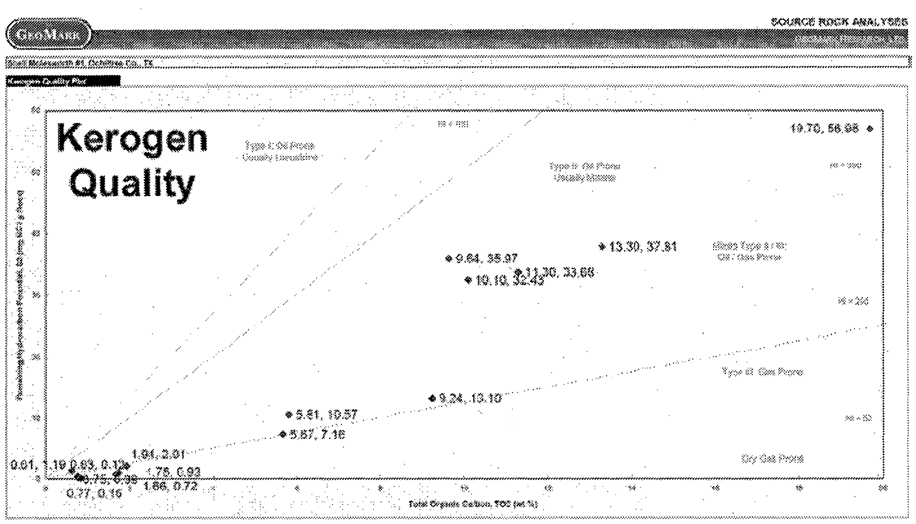
RockEval Results 1, Shell Molesworth #1



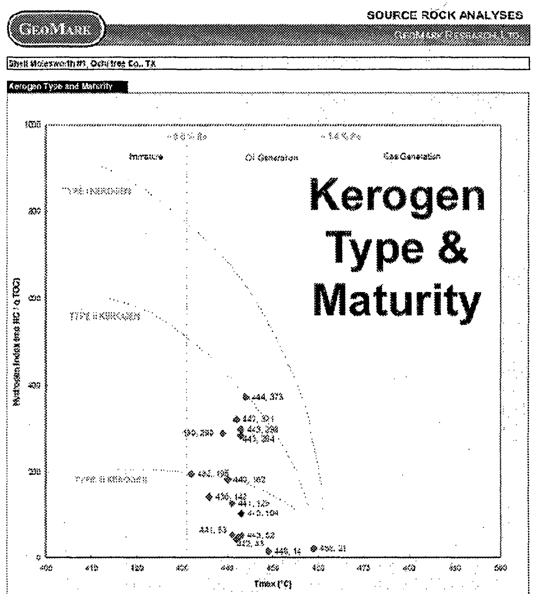
RockEval Results 2, Shell Molesworth #1



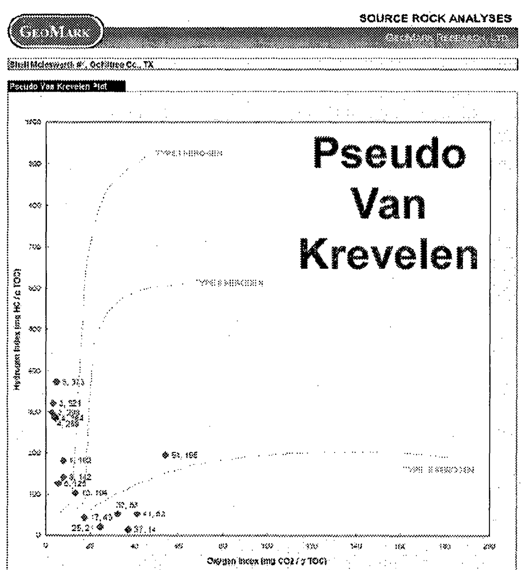
RockEval Results 3, Shell Molesworth #1



RockEval Results 4, Shell Molesworth #1



RockEval Results 4, Shell Molesworth #1



Maturity: Shell Molesworth #1

Vitrinite Reflectance Data and Comments

Sample Depth (core, MD)	Sample Type	% Ro (Mean %)	Std. Dev.	No. of Vit. Grains (%)	No. Autoch. Vitrinite (%)	No. Alloch Vitrinite (%)	No. Supp. Vitrinite (%)	All VRo (mean %)
7507.9	crushed	0.68	0.04	50	8	41	1	1.01
7537.0	crushed	1	0.07	29	12	11	6	1.05

% Ro = mean random vitrinite reflectance; Std. Dev. = standard deviation of Ro measurement
No.Autoch.Vitrinite = Number of autochthonous vitrinite (first cycle) grains measured
No.Alloch.Vitrinite = Number of allochthonous vitrinite (recycled) grains measured
No.Supp.Vitrinite = Number of suppressed vitrinite (lower VRo) grains measured
All VRo (mean %) = mean vitrinite reflectance of all measured vitrinite grains

Visual Kerogen, Thermal Alteration Index, and Vitrinite Reflectance Data based on Transmitted and Reflected Light Microscopy

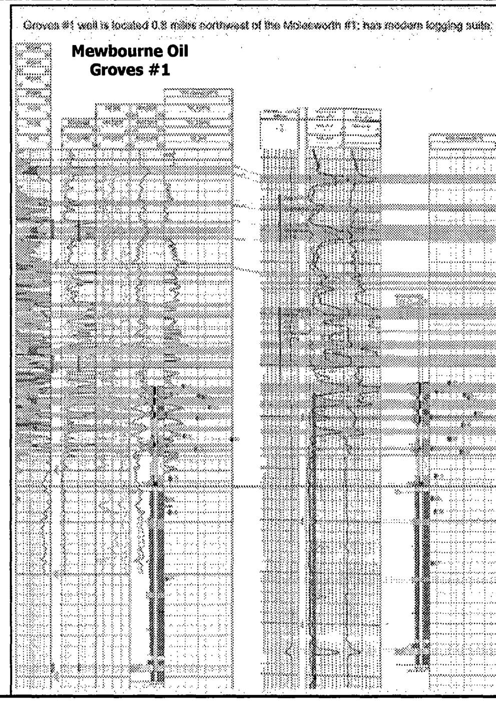
RockEval Data, Shell Molesworth #1

GeoMark — SOURCE ROCK ANALYSES — GeoMark Research, Ltd.

Shell Molesworth #1, Ochiltree Co., TX

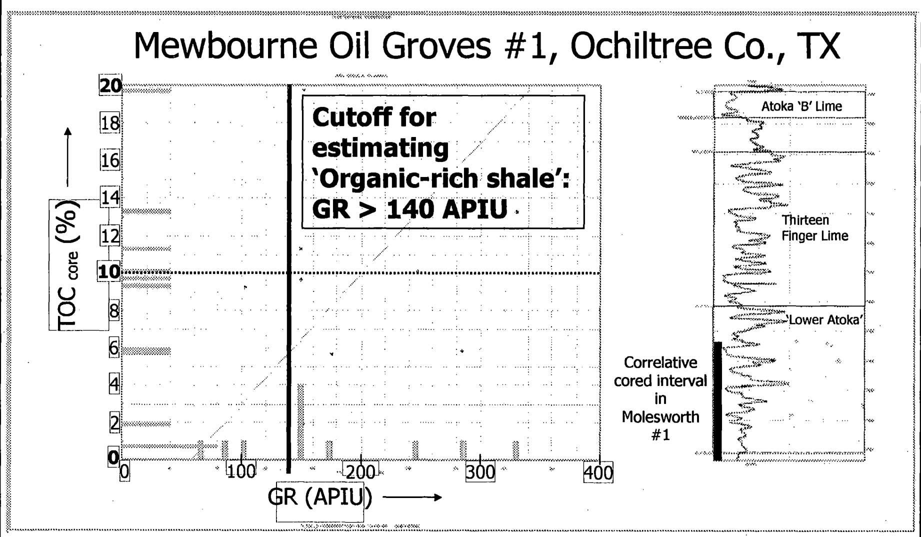
Formation	Depth (MD, ft)	Lithology (DLC interp.)	Leco TOC (wt% HC)	Rock-Eval S1 (mg HC/g)	Rock-Eval S2 (mg HC/g)	Rock-Eval S3 (mg CO2/g)	Measured %Ro (Vitrinite Refl.)	Tmax (°C)	Hydrogen Index (S2x100/TOC)	Oxygen Index (S3x100/TOC)	S2/S3 Conc. (mg HC/mg CO2)	S1/TOC Norm. Oil Content	Production Index (S1/(S1+S2))
L. Atoka	7,478.3	black shale	5.67	1.19	7.16	0.32		441	126	5	22	21	0
L. Atoka	7,487.5	calcareous shale	1.94	0.59	2.01	0.26		443	104	13	8	31	0
L. Atoka	7,489.8	black shale	10.10	1.62	32.43	0.34		442	321	3	95	16	0
L. Atoka	7,493.5	black shale	11.30	2.28	33.68	0.31		443	298	3	109	20	0
L. Atoka	7,507.9	black shale	13.30	3.01	37.81	0.58	0.84	443	284	4	65	23	0
L. Atoka	7,512.0	dk gray limestone	0.61	0.11	1.19	0.31		432	195	51	4	87	0
L. Atoka	7,519.0	black shale	9.61	1.20	35.97	0.48		444	372	5	75	12	0
L. Atoka	7,524.5	black shale	5.81	0.84	10.57	0.35		440	182	6	30	14	0
L. Atoka	7,527.3	calcareous shale	19.70	4.14	56.98	0.78		439	289	4	73	21	0
L. Atoka	7,533.0	dk gray limestone	0.76	0.07	0.39	0.31		443	52	41	1	9	0
L. Atoka	7,537.0	black shale	9.24	3.37	13.10	0.73	1.00	439	142	8	18	36	0
L. Atoka	7,557.0	calcareous shale	1.75	0.11	0.93	0.57		441	53	33	2	6	0
L. Atoka	7,578.6	calcareous shale	0.88	0.03	0.12	0.31		440	14	37	0	4	0
U. Morrow	7,591.0	calcareous shale	1.66	0.09	0.72	0.29		442	43	17	2	5	0
U. Morrow	7,641.0	calcareous shale	0.77	0.03	0.16	0.19		460	21	25	1	4	0

No Modern Logging Suite Available: Used Offset Well as Surrogate



Cross Plot: TOC vs. Gamma Ray

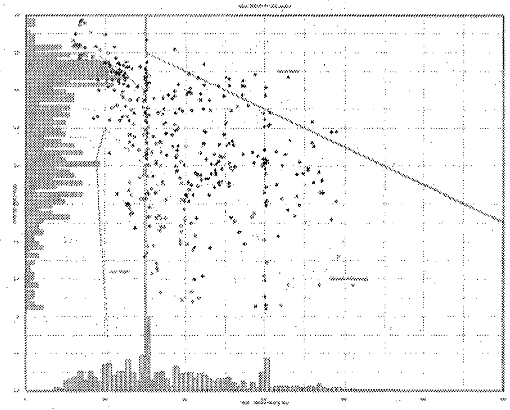
Surrogate offset well to Shell Molesworth #1

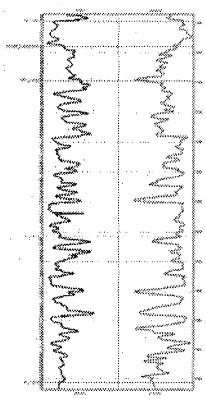


Cross Plot: RHOB vs. Gamma Ray

Surrogate offset well to Shell Molesworth #1

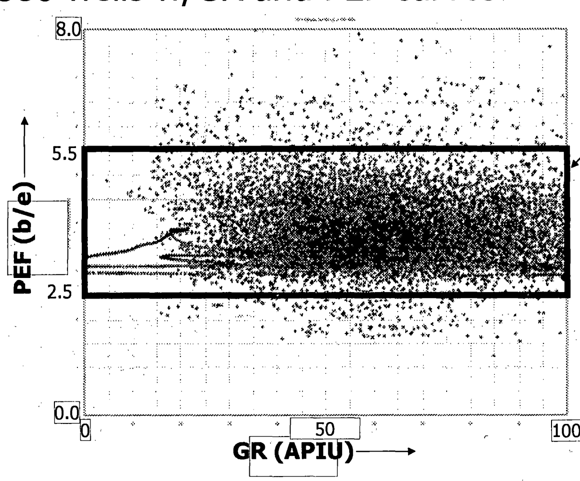
Mewbourne Oil Groves #1, Ochiltree Co., TX





Cross Plot: Atoka 'B' Lime PEF vs. Gamma Ray (GR < 100 APIU)

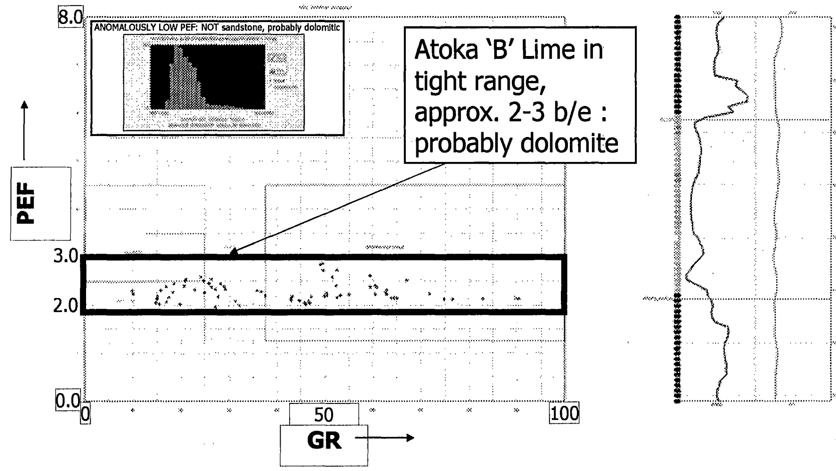
580 wells w/GR and PEF curves



Atoka 'B' Lime is mixture of dolomite and limestone

Cross Plot: Atoka 'B' Lime PEF vs. Gamma Ray

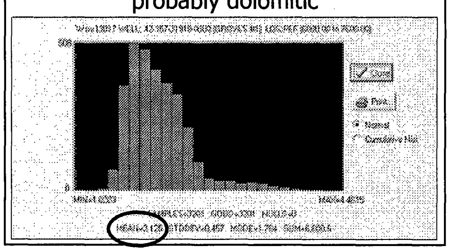
Mewbourne Oil Groves #1, Ochiltree Co., TX



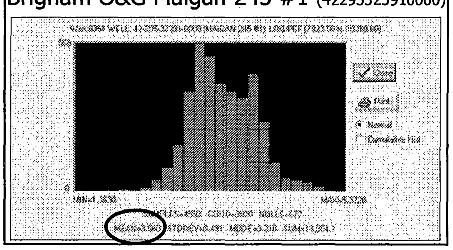
Histogram Comparison of PEF curves

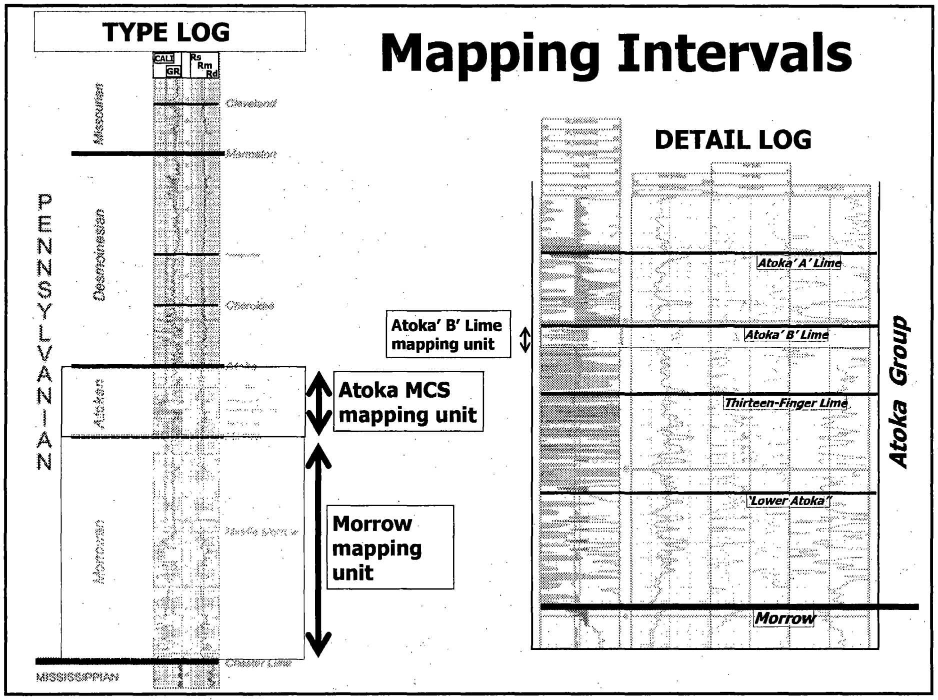
Same stratigraphic section: 200 ft above Kansas City (MFS_8) and 100 ft below top Morrow (SB_1)

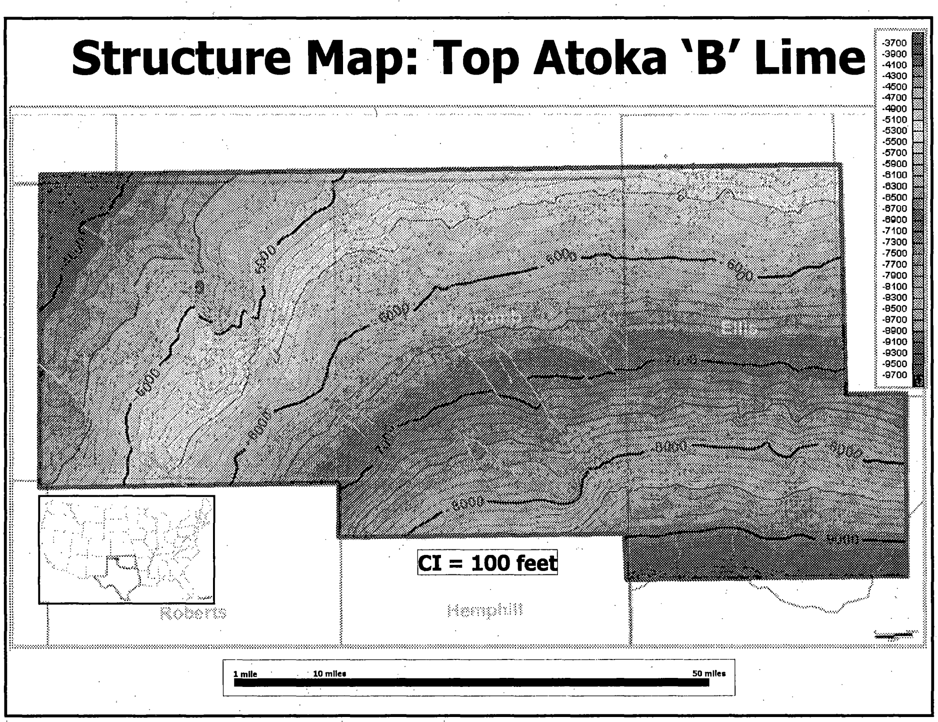
PEF is anomalously low: NOT sandstone, probably dolomitic



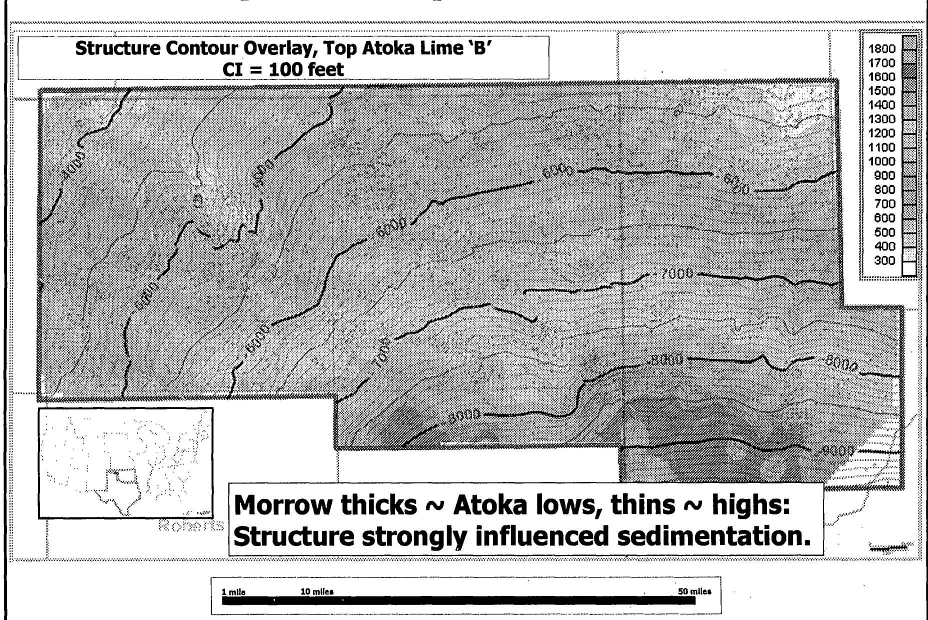
'Typical' PEF distribution:
Brigham O&G Maigan 245 #1 (42295323910000)



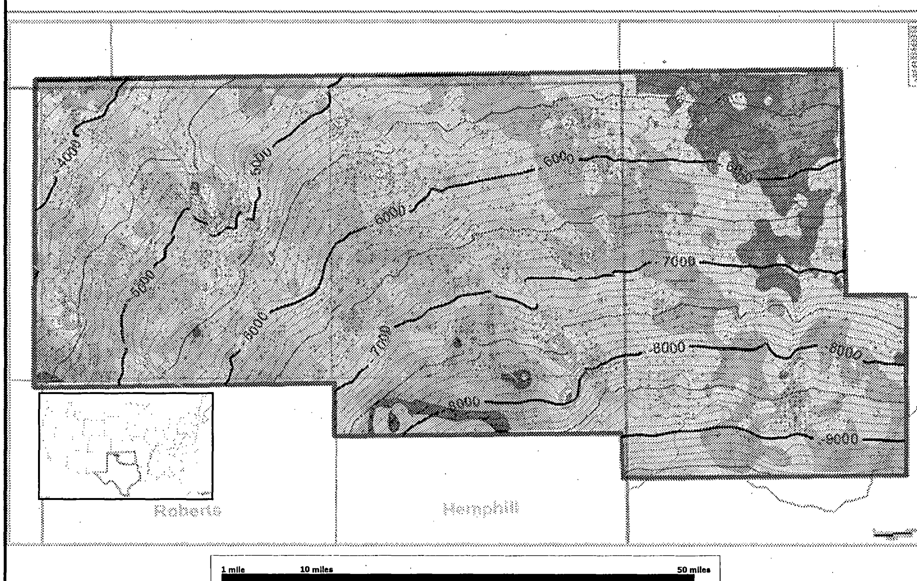

TYPE LOG
Mapping Intervals
DETAIL LOG
PENNSYLVANIAN
Atoka' B' Lime mapping unit
Atoka MCS mapping unit
Morrow mapping unit
Atoka' A' Lime
Atoka' B' Lime
Thirteen-Finger Lime
'Lower Atoka'
Morrow
Atoka Group
MISSISSIPPIAN


Structure Map: Top Atoka 'B' Lime
CI = 100 feet
Roberts
Hemphill
1 mile
10 miles
50 miles

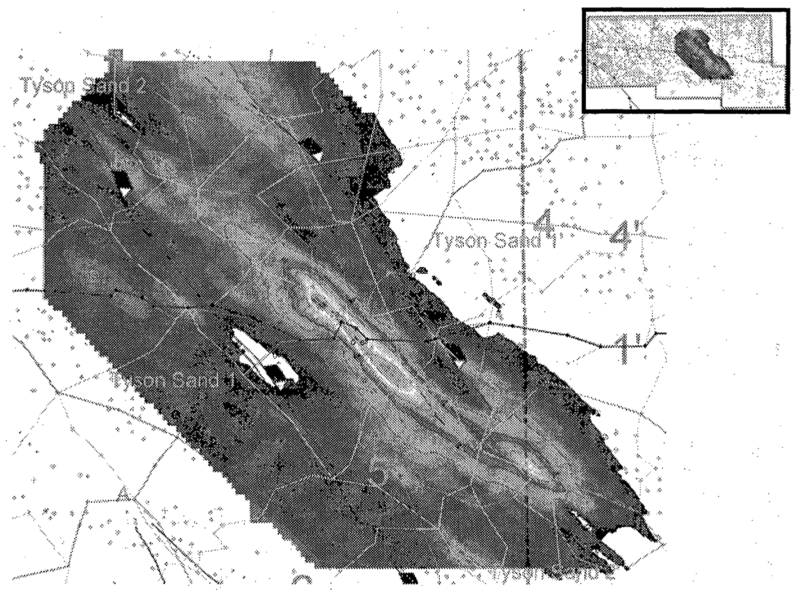
Isopach Map: Morrow Fm.



Interval Isopach Map: Atoka MCS



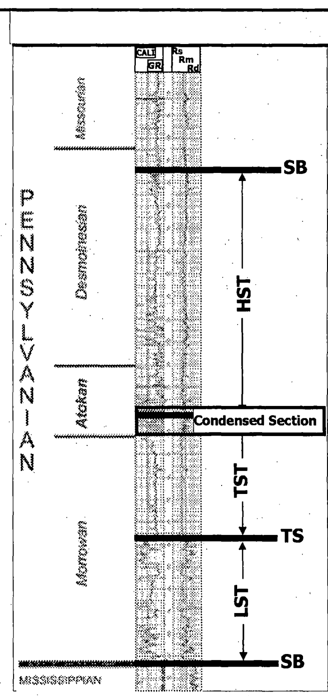
Isopach: Tyson Sand (A_FS_200 to A_ES_200)



Sequence Stratigraphic Interpretation

Large scale
(2o?)

Smaller scale
3o and higher frequency
sequences present



Summary

Study represents a reconnaissance of Atoka Lime/Shale geology. Need more whole cores to fully assess but, several conclusions can be made from the work thus far:

- **Activity:**
  - Historically a minor secondary target
  - Vertical-wells in locally-developed porosity in the Atoka 'B' Lime (aka Novi Lime)
  - Emerging horizontal/ fracture stimulation has thus far increased average gas production rates 5-fold. Some of this increase may be a result of hydraulic fractures reaching into the adjacent organic-rich shales.

- **Mudrocks:**
  - Highly organic-rich, fissile black shales.
  - Calcareous and fossiliferous adjacent to carbonate beds
  - Shell Molesworth #1 core
    - TOC avg 10.6%
    - Vitrinite reflectance averages 0.84 (oil window)
    - Average measured depth of 7522 ft
    - Estimate of total organic-rich shale footage in the Atoka done via 1100 wells with LAS-GR data yielded an average of 214 ft of 'hot shale' (GR > 140 APIU)
    - 'Upper Atoka' contains the most 'hot shale', averaging 56 feet

- **Carbonates:**
  - Shell Molesworth #1 'Lower Atoka' core: carbonates are deep-water limestones were formed by transport of carbonate skeletal debris
    - Very low porosities even though many were highly dolomitized
  - No core—no direct observations of Atoka 'B' Lime but have observed that:
    - Averages: isopach 11 ft thick, up to 37 ft; and averages 7% (limestone matrix) porosity
    - Highest porosities, up to 25%, are typically found in dolomitized zones
    - Thickest carbonate isopach values in present-day structural lows
      - Structure controlled local accommodation in Atoka and underlying Morrow Fm.

Summary (cont.)

- **Depositional Environments:**
  - Deep-water basinal position at the northwestern terminus of Anadarko Basin
  - anoxic, restricted deep-basin shale deposition was interrupted by frequent pulses of carbonate sedimentation and volumetrically minor thin sandstones, via turbidites
  - Carbonate sediment sources were probably from adjacent shallow shelf/platforms along the north and north-eastern margins of the Anadarko Basin.

- **Sequence Stratigraphy:**
  - Atoka Fm. was deposited during a major global transgressive during the Middle Pennsylvanian
  - Represents a large order (2o?) marine condensed section
  - Many higher frequency cycles
  - Sequences are volumetrically dominated by HST deposits

Acknowledgments

Jones Energy, Ltd.

Brigham Exploration | **Chesapeake Energy** | **Texas American Resources**

State of Texas Advanced Resource Recovery

Publication was authorized by the Director, Bureau of Economic Geology,
The University of Texas at Austin

Acknowledgments

Special thanks to Kitty Milliken for petrographic work and interpretations of depositional processes. I thank Laura Zahm for her valuable input to the carbonate depositional systems interpretations. Brian Jarvie at Geomark provided organic geochemical core anaylsis. Bill Ambrose and Tucker Hentz provided many insights and much support for the project.

The Bureau of Economic Geology also thanks MJ Systems for providing raster logs at low cost to many of our projects.

State of Texas Advanced Resource Recovery

Publication was authorized by the Director, Bureau of Economic Geology,
The University of Texas at Austin

Sequence Stratigraphy and Depositional Fabric of the Marmaton and Cleveland Formations, Anadarko Basin

Tucker F. Hentz

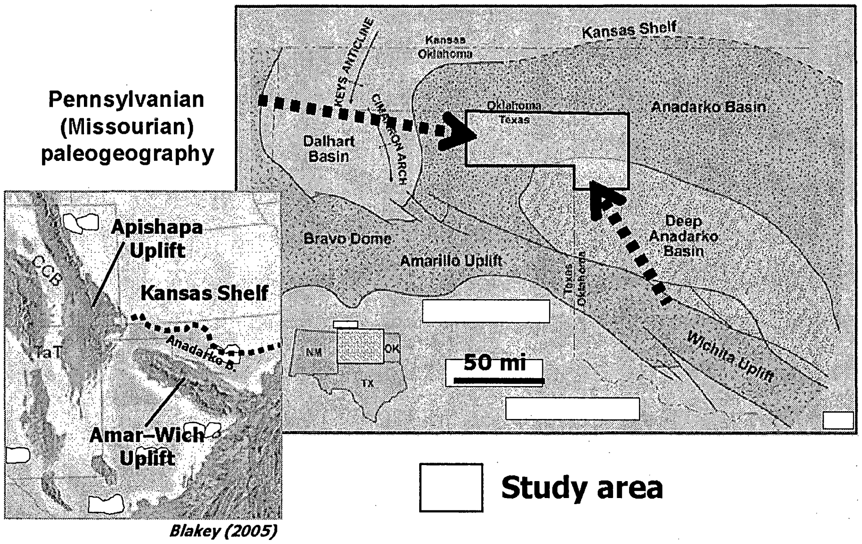
November 10, 2009

1909-2009

Focus

- Sequence-stratigraphic framework of Cleveland and Marmaton reservoirs
- Sandstone distribution and depositional settings (1,100 well logs, 7 cores)
- Shelf topography
- Relation of systems tracts and structure to production

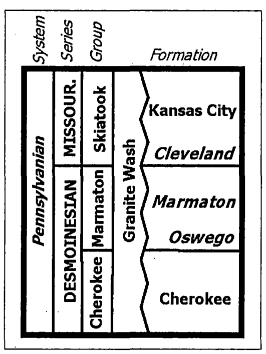
Anadarko Basin and Source Areas

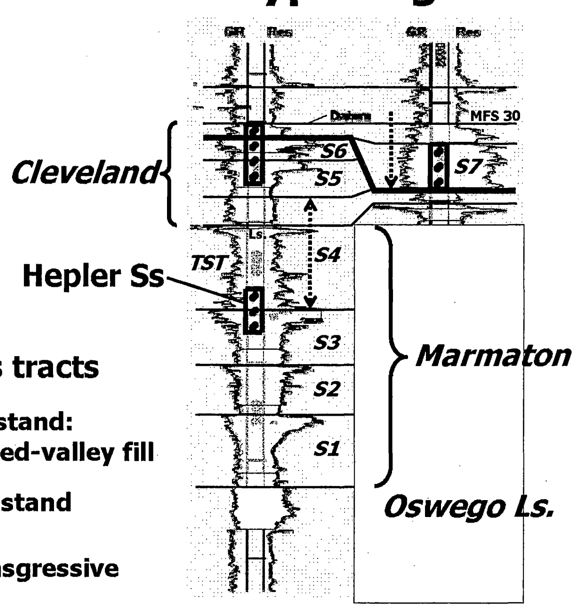


Study area

Blakey (2005)

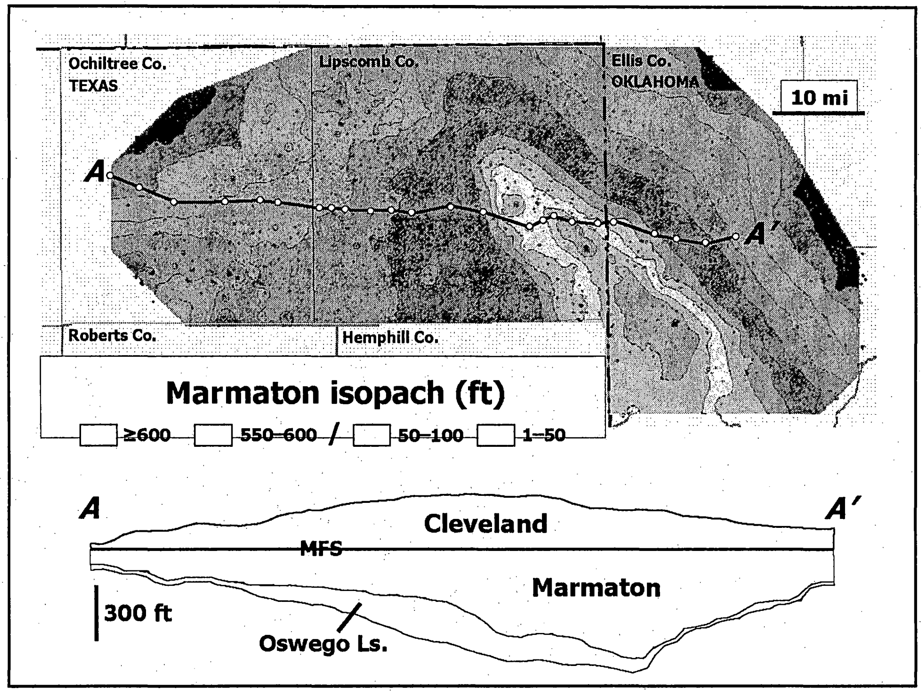
Type Logs

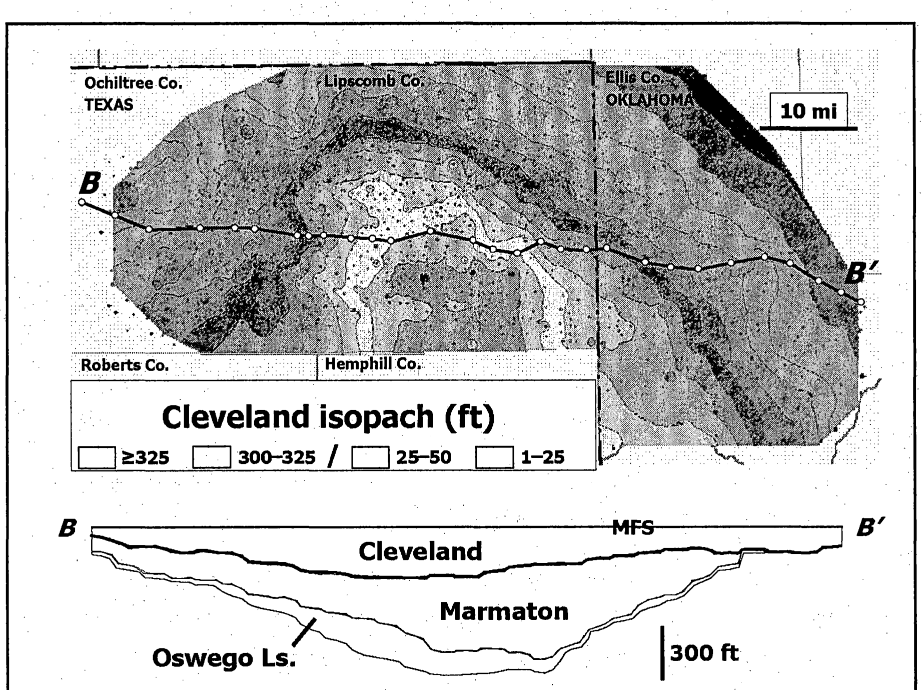




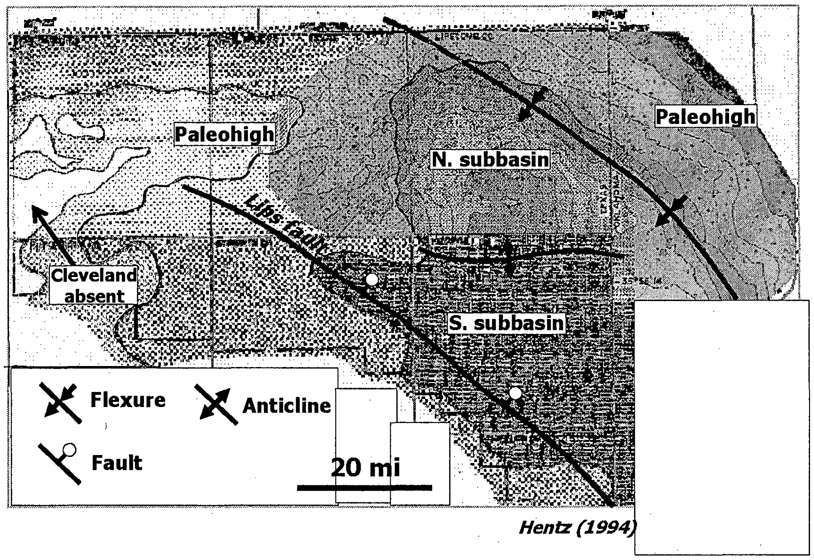
Systems tracts

- Lowstand: incised-valley fill
- Highstand
- Transgressive

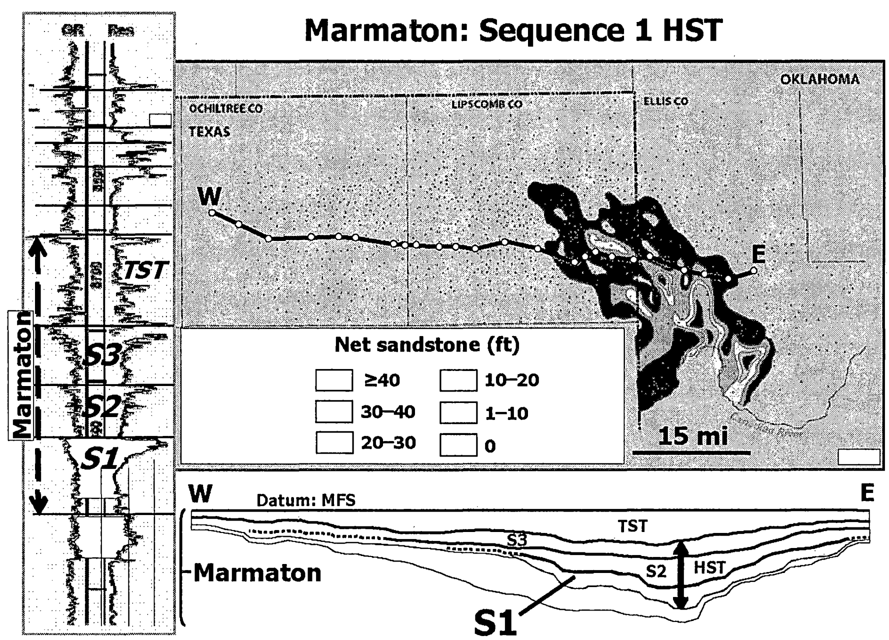

Ochiltree Co.
TEXAS
Lipscomb Co.
Ellis Co.
OKLAHOMA
10 mi
A
A′
Roberts Co.
Hemphill Co.
Marmaton isopach (ft)
≥600
550–600
/
50–100
1–50
A
A′
Cleveland
MFS
Marmaton
300 ft
Oswego Ls.

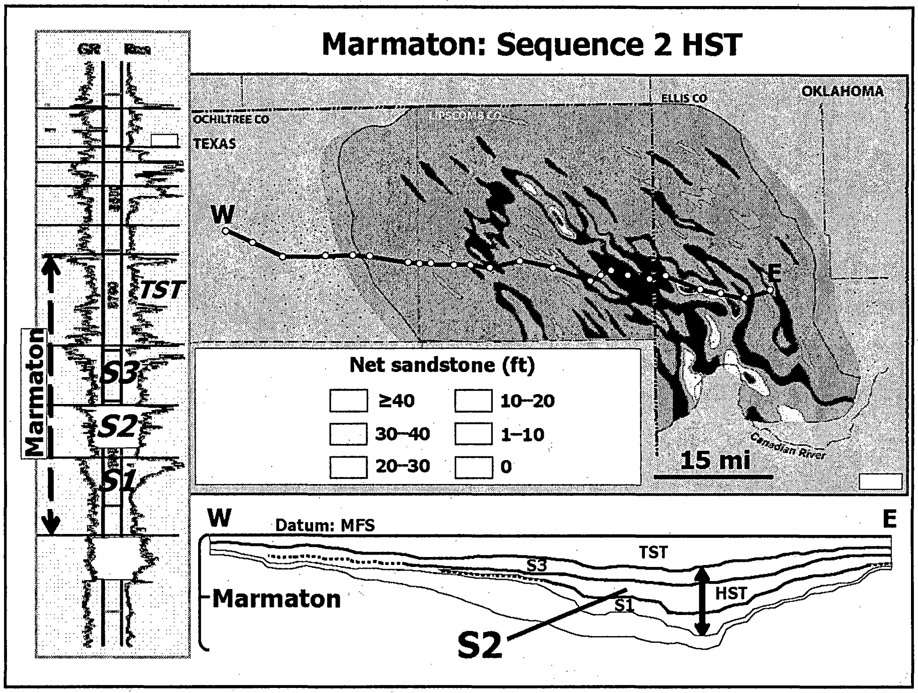

Ochiltree Co.
TEXAS
Lipscomb Co.
Ellis Co.
OKLAHOMA
10 mi
B
B′
Roberts Co.
Hemphill Co.
Cleveland isopach (ft)
≥325
300–325
/
25–50
1–25
B
B′
MFS
Cleveland
Marmaton
Oswego Ls.
300 ft

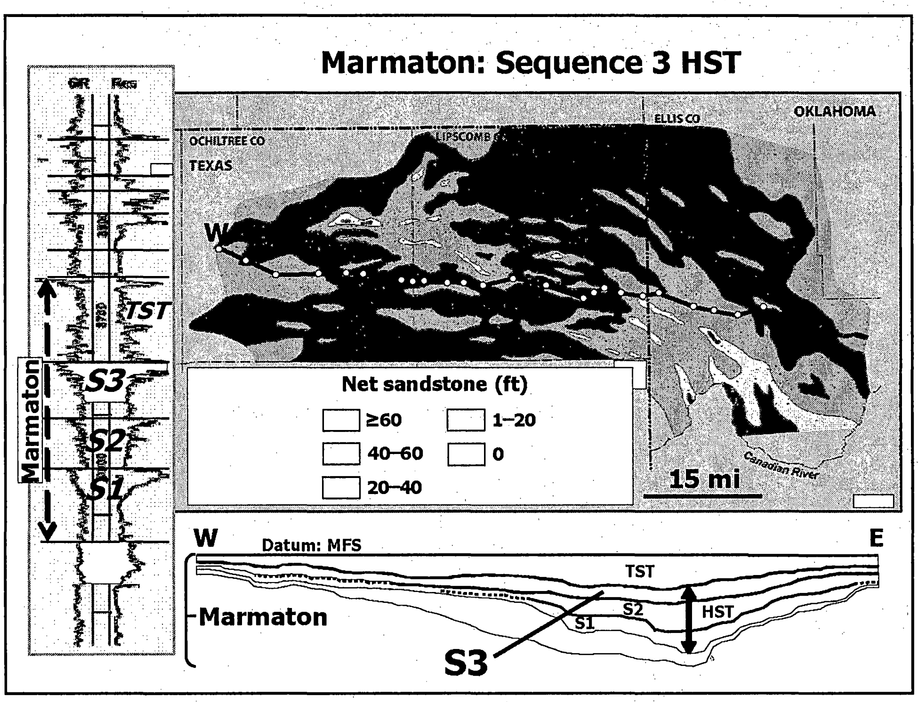
Cleveland Shelf Setting



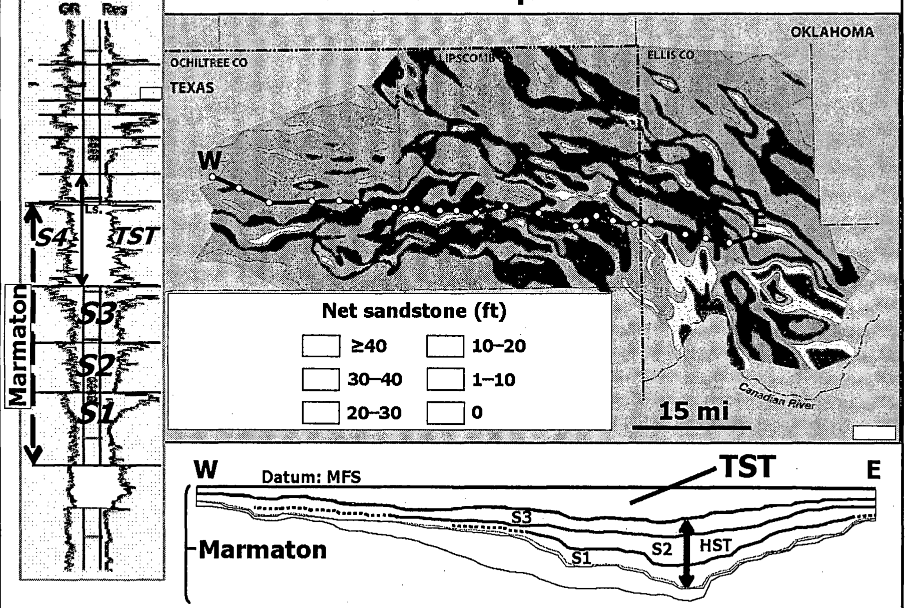
Marmaton: Sequence 1 HST



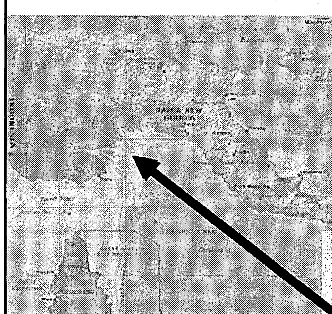

Marmaton: Sequence 2 HST
GR
Res
TST
S3
S2
S1
Marmaton
OCHILTREE CO
TEXAS
LIPSCOMB CO
ELLIS CO
OKLAHOMA
W
E
Net sandstone (ft)
≥40
10–20
30–40
1–10
20–30
0
Canadian River
15 mi
W
E
Datum: MFS
TST
S3
HST
S1
Marmaton
S2


Marmaton: Sequence 3 HST
GR
Res
TST
S3
S2
S1
Marmaton
OCHILTREE CO
TEXAS
ELLIS CO
OKLAHOMA
W
Net sandstone (ft)
≥60
1–20
40–60
0
20–40
Canadian River
15 mi
W
E
Datum: MFS
TST
S2
HST
S1
Marmaton
S3

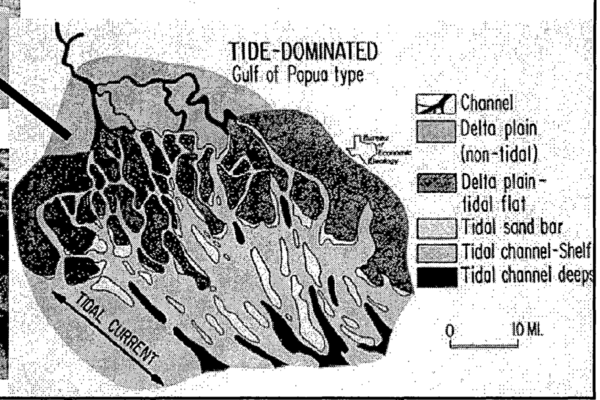
Marmaton: Sequence 4 TST



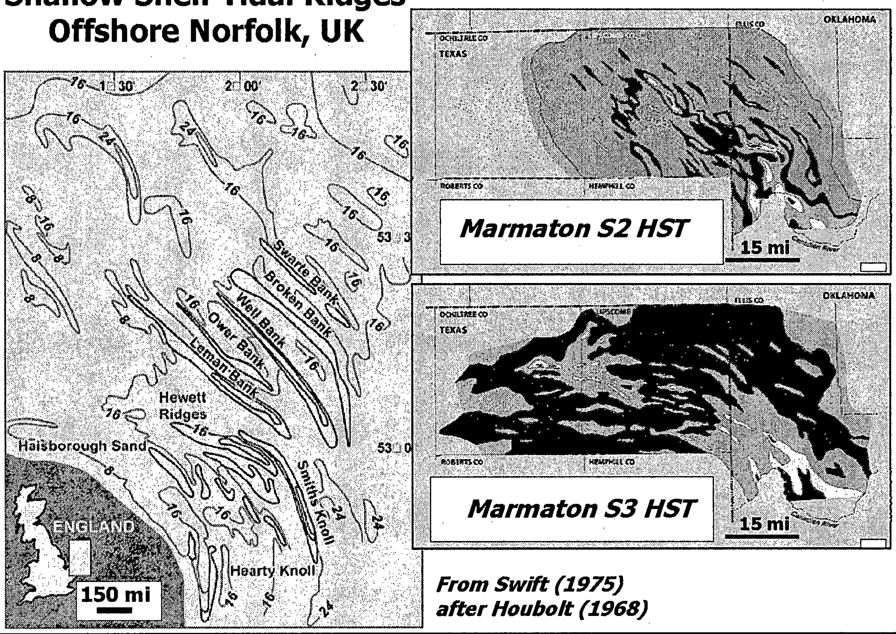
Gulf of Papua



- Tide dominated (3- to 5.5-m range)

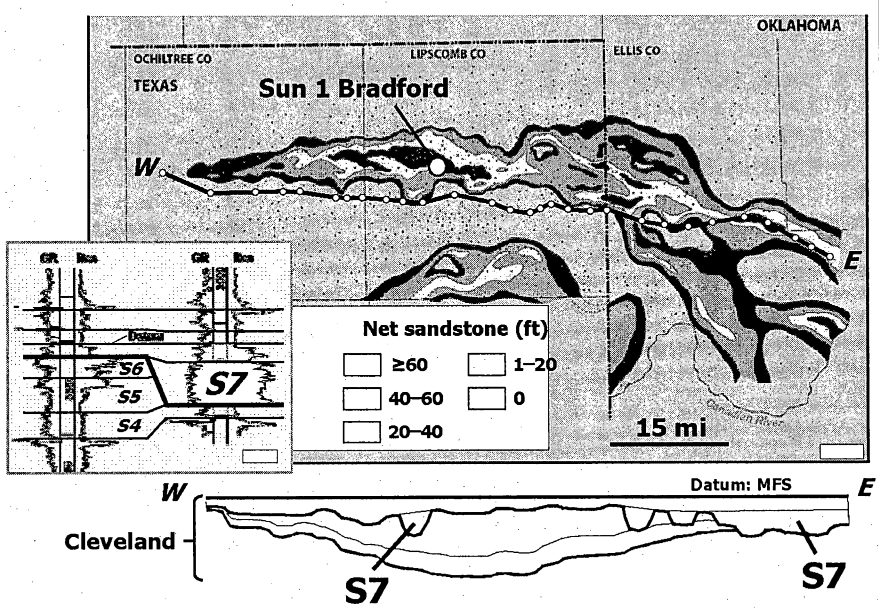


Shallow Shelf Tidal Ridges Offshore Norfolk, UK

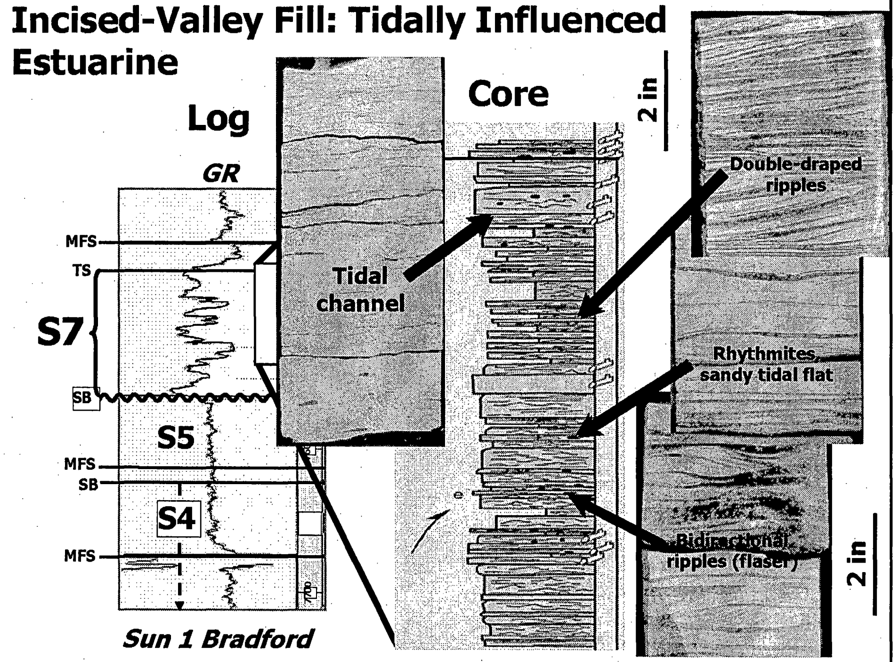


From Swift (1975)
after Houbolt (1968)

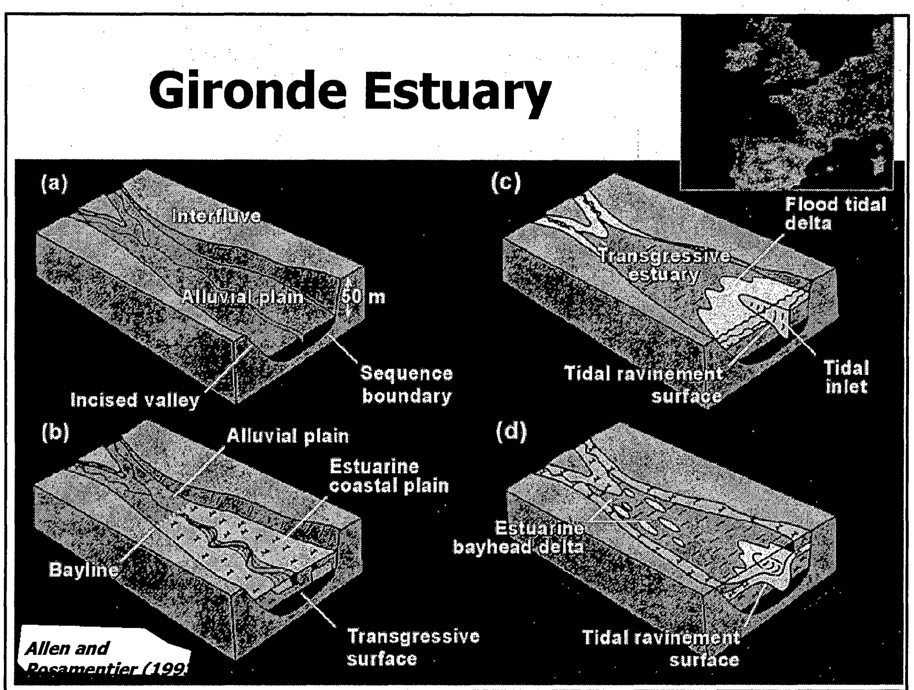
Cleveland: Sequence 7 LST Incised-Valley Fill

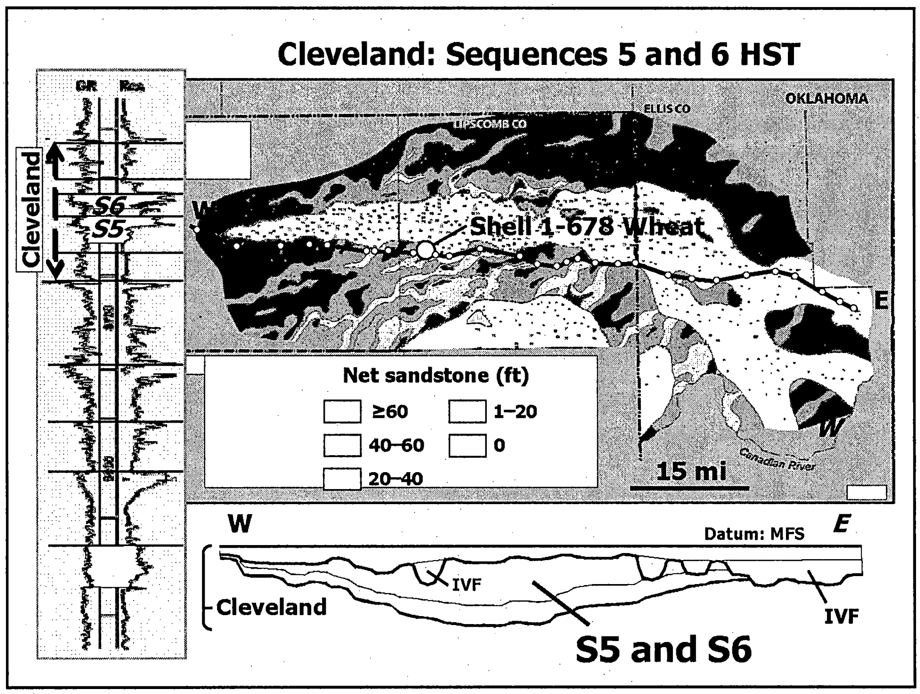


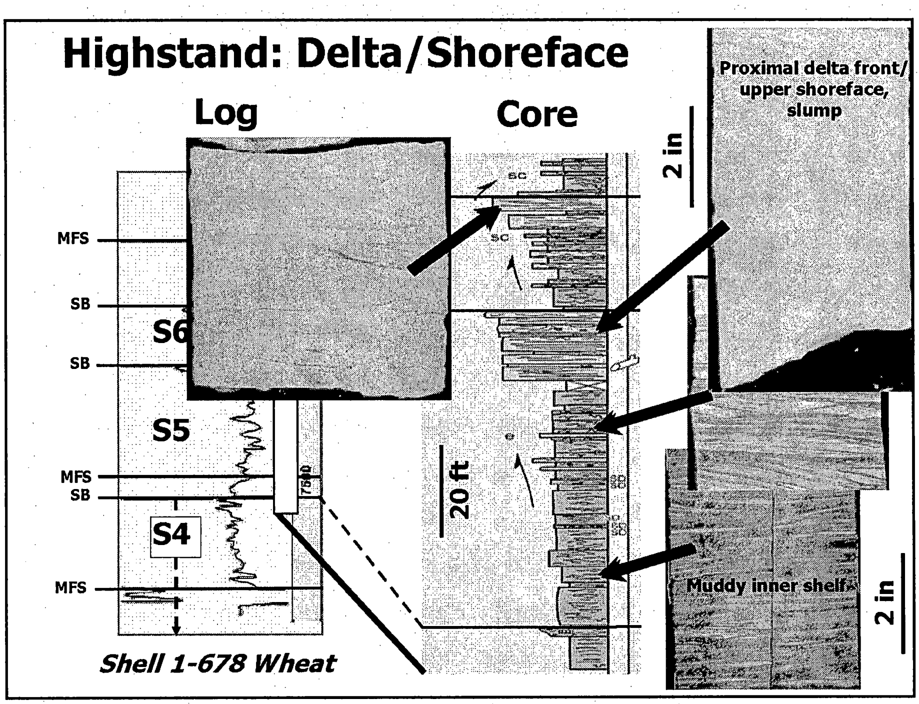
Incised-Valley Fill: Tidally Influenced Estuarine

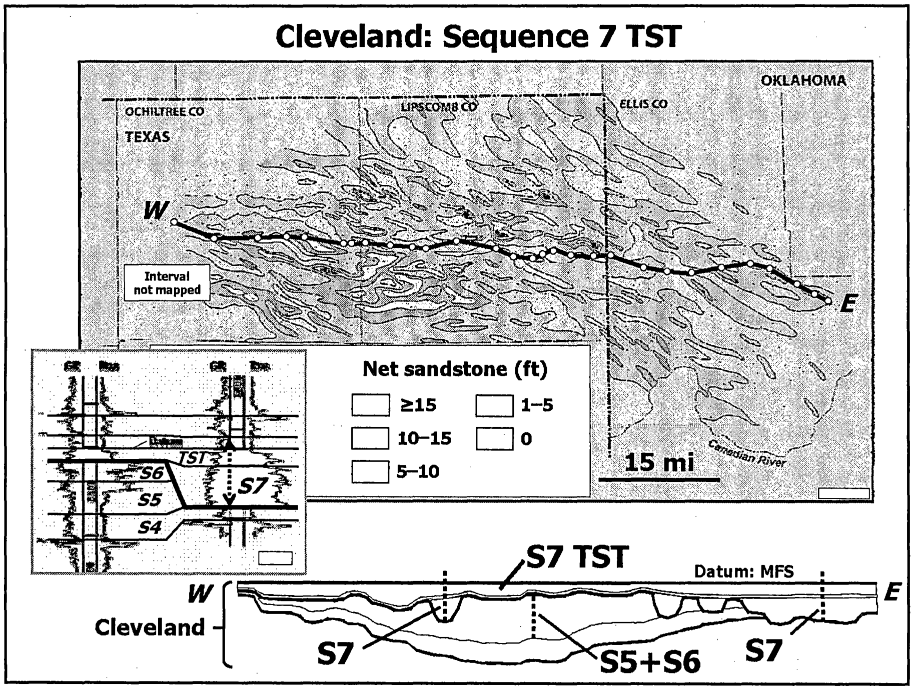


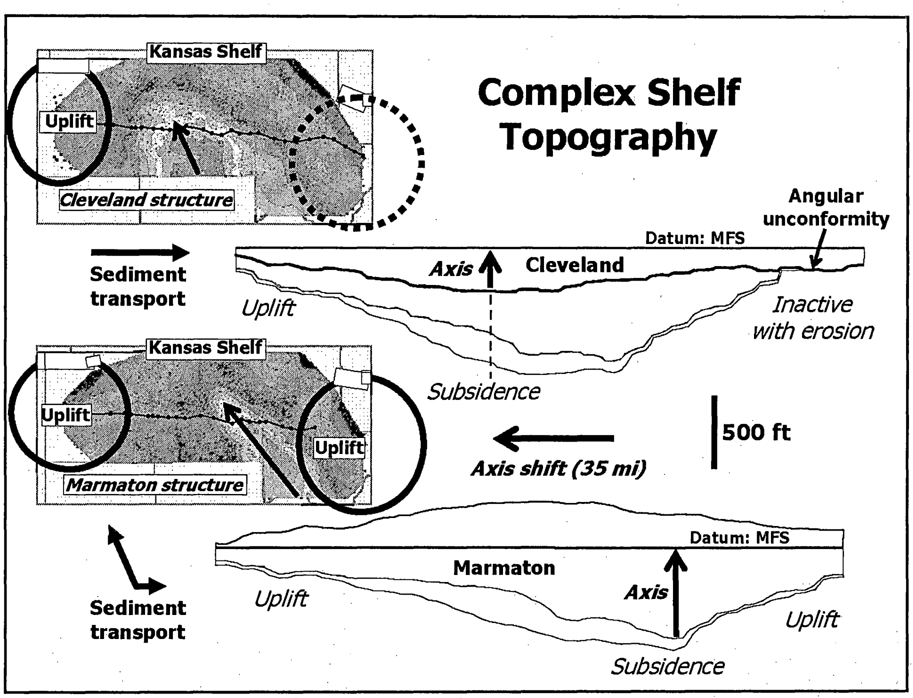
Gironde Estuary




Cleveland: Sequences 5 and 6 HST
GR
Cleveland
S6
S5
OKLAHOMA
LIPSCOMB CO
ELLIS CO
W
Shell 1-678 Wheat
E
Net sandstone (ft)
≥60
1–20
40–60
0
20–40
15 mi
Canadian River
W
W
Datum: MFS
E
IVF
Cleveland
IVF
S5 and S6

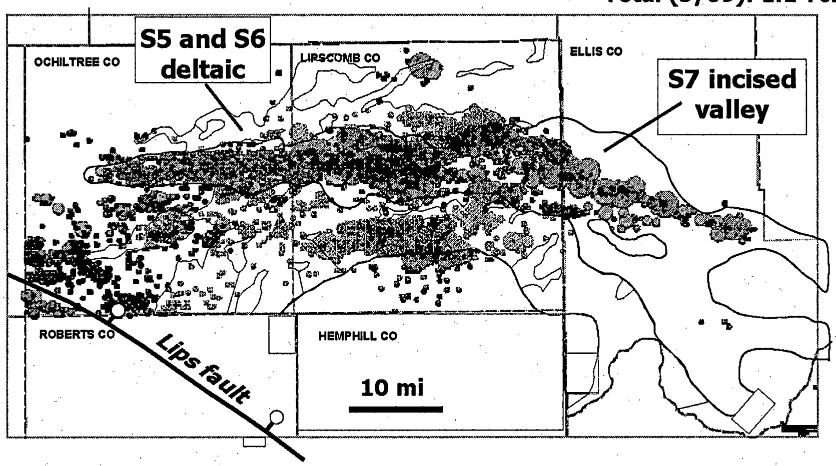

Highstand: Delta/Shoreface
Log
Core
Proximal delta front/ upper shoreface, slump
2 in
MFS
SB
S6
SB
S5
MFS
SB
S4
MFS
20 ft
Muddy inner shelf
2 in
Shell 1-678 Wheat


Cleveland: Sequence 7 TST
OKLAHOMA
OCHILTREE CO
LIPSCOMB CO
ELLIS CO
TEXAS
W
E
Interval not mapped
Net sandstone (ft)
≥15
1–5
10–15
0
5–10
15 mi
Canadian River
TST
S6
S5
S4
S7
S7 TST
Datum: MFS
W
E
Cleveland
S7
S5+S6
S7


Complex Shelf Topography
Kansas Shelf
Uplift
Cleveland structure
Sediment transport
Angular unconformity
Datum: MFS
Axis
Cleveland
Uplift
Inactive with erosion
Subsidence
Kansas Shelf
Uplift
Uplift
Marmaton structure
500 ft
Axis shift (35 mi)
Datum: MFS
Marmaton
Axis
Uplift
Uplift
Sediment transport
Subsidence

Average Daily Maximum Cleveland Gas Production (per well)

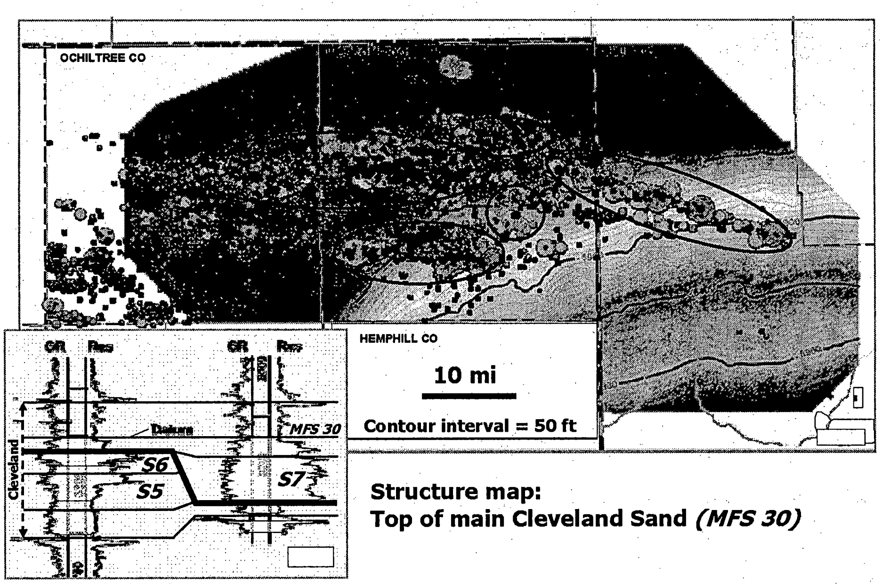
Total (5/09): 1.1 Tcf



Mcf

≥7 | 6–7 | 5–6 | 4–5 | 3–4 | 2–3 | <2

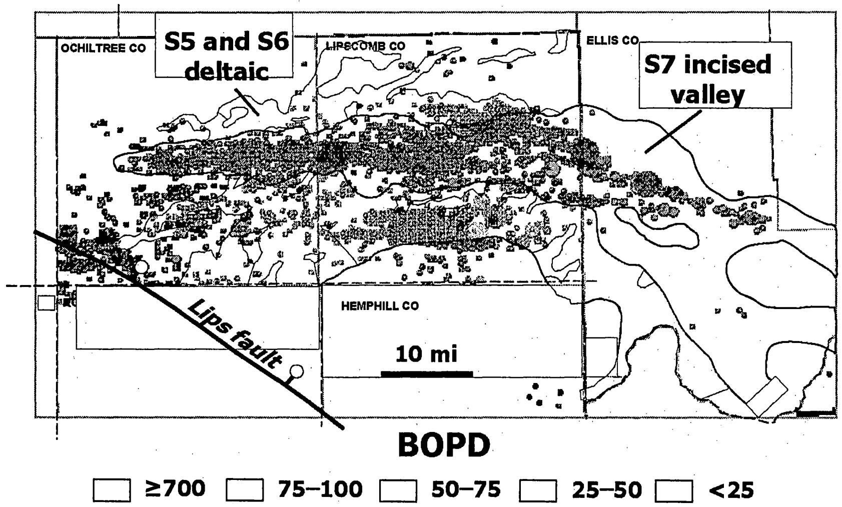
Structural Control on Cleveland Gas Production



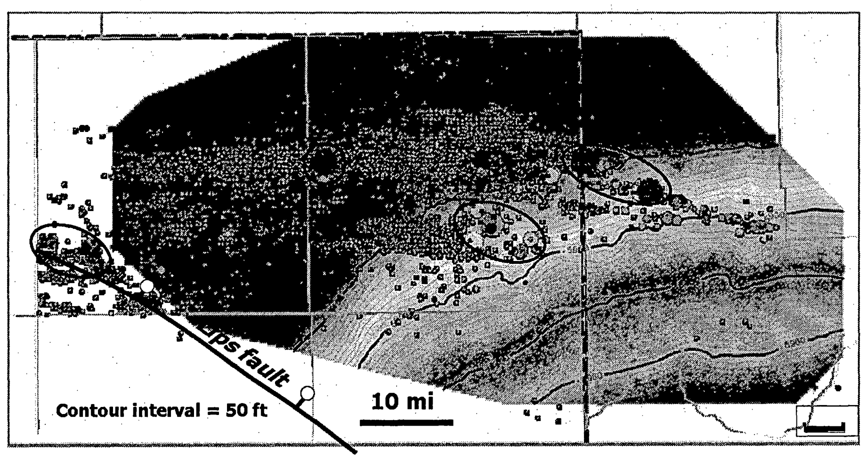
Structure map:
Top of main Cleveland Sand *(MFS 30)*

Average Daily Maximum Cleveland Oil Production (per well)

Total (5/09): 32.4 MMbbl



Structural Control on Cleveland Oil Production



Structure map:
Top of main Cleveland Sand *(MFS 30)*

Summary

- Cleveland/Marmaton: highstand, prominent lowstand IVF
- Irregular shelf (or ramp) topography
- Tidally influenced delta/shoreface and IVF systems dominate
- Controls on hydrocarbons accumulation:
  (1) incised-valley-fill deposits
  (2) upstructure pinch out, subtle anticlines

Acknowledgments

Jones Energy, Ltd.

State of Texas Advanced Resource Recovery

Publication was authorized by the Director, Bureau of Economic Geology,
The University of Texas at Austin

Tidal Depositional Systems: Cleveland and Marmaton Examples

William A. Ambrose
November 10, 2009

Bureau of Economic Geology

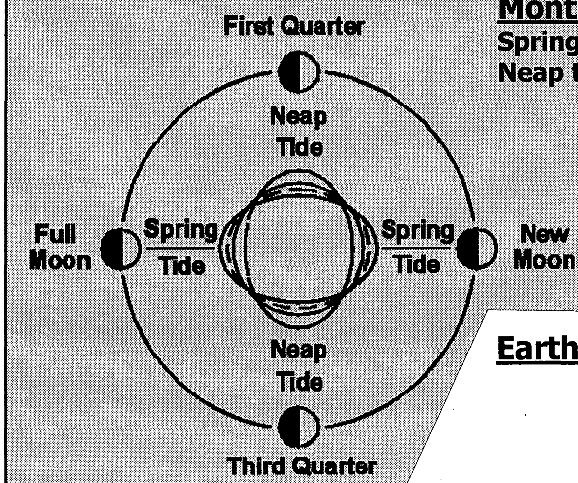
Outline

- **Tidal Origins and Processes**
  - *-Tidal Cycles*
  - *-Tidal Signatures in the Rock Record*
  - *-Tidal Regimes (Micro-, Meso-, Macrotidal)*

- **Modern Tide-Dominated Deltas and Estuaries**
  - *-Colorado, Papua, Gironde and others*

- **Tidal-Shelf and Distal-Delta-Front Deposits**
  - *-Modern and Ancient Examples*

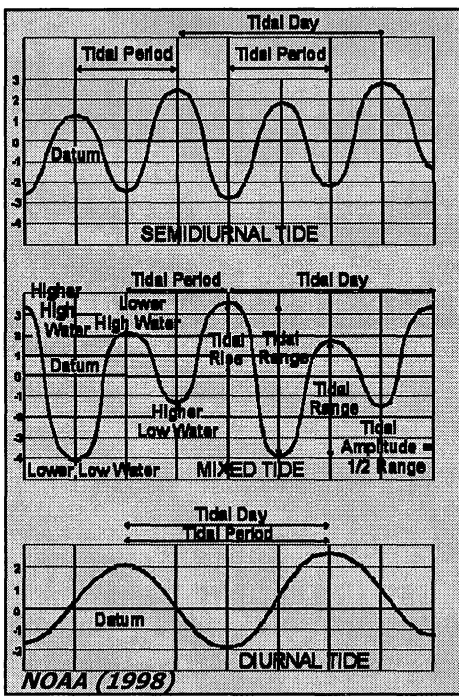
Earth-Sun-Moon Tidal Interactions



Monthly cycle: 29.53 days
Spring tides: greater amplitude
Neap tides: diminished range

Earth-Moon distance (mi):
225-252 x 10^3

NOAA (1998)



Main Tidal Cycles

Semidiurnal

2 per tidal day
(12hr, 25min): siderial/2

Mixed

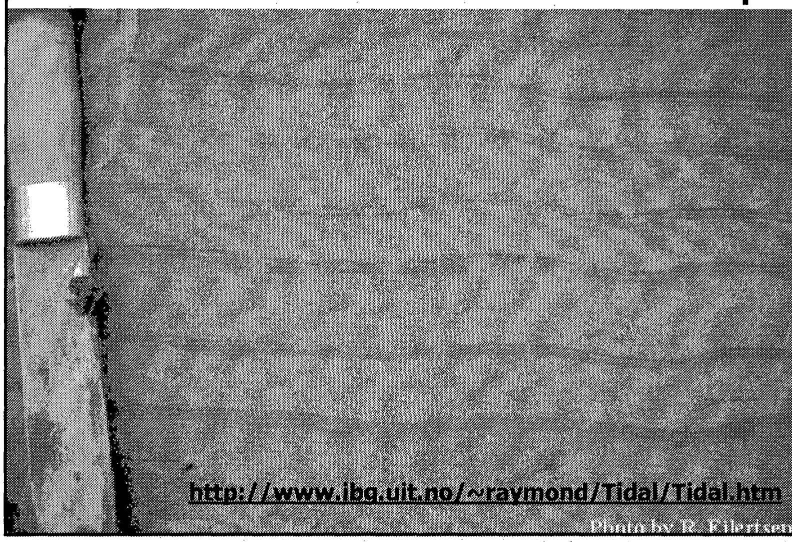
High, low tides vary
Diurnal/Semidiurnal

Diurnal

1 per tidal day
(24hr, 50 min): siderial

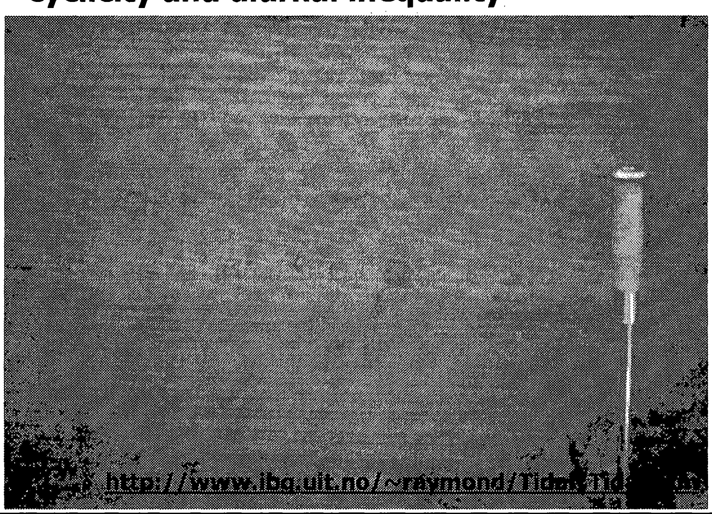
Tidal Cycles in the Rock Record

Double Mud Drapes

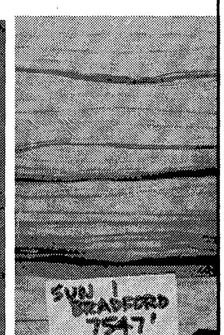


Tidal Cycles in the Rock Record

Tidal rhythmites: neap-spring cyclicity and diurnal inequality



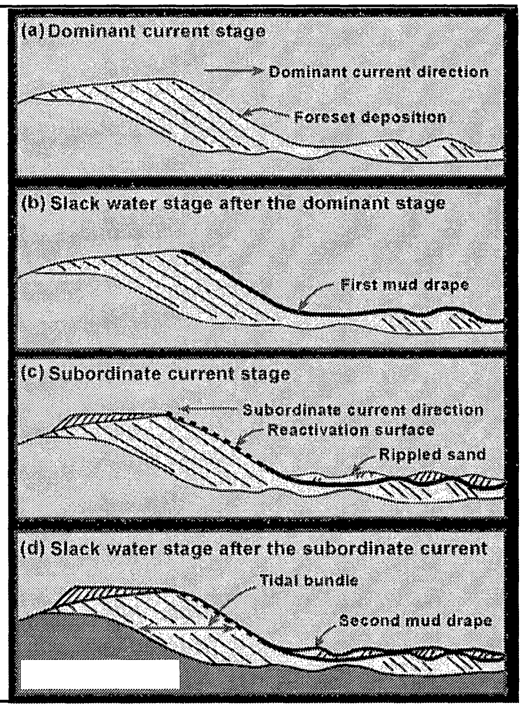
Cleveland Fm.



2 inches

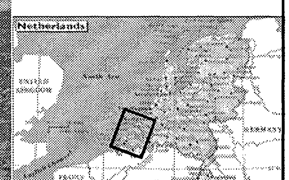
Tidal Currents: Ripple Bedding

From Dalrymple (1992) after Visser (1980)



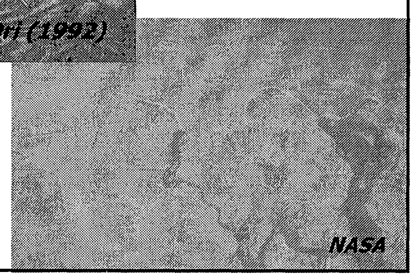
Tidal Flats

Oosterschelde, The Netherlands



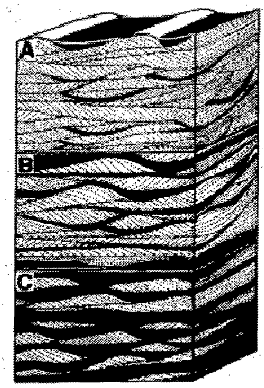
mapquest.com

- **High tide: completely submerged**
- **Asymmetrical dunes and ripples**



Tidal Currents: Ripple Bedding

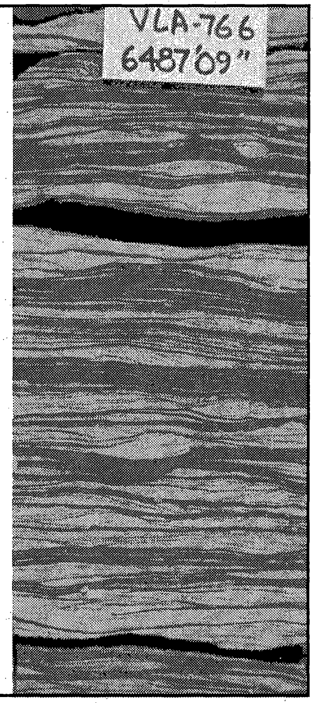
Flaser Bedding



Reineck and Singh (1975)

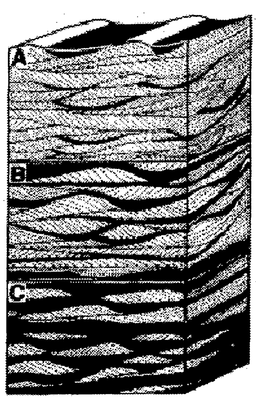
Lake Maracaibo
Lower Eocene

2 in



Tidal Currents: Ripple Bedding

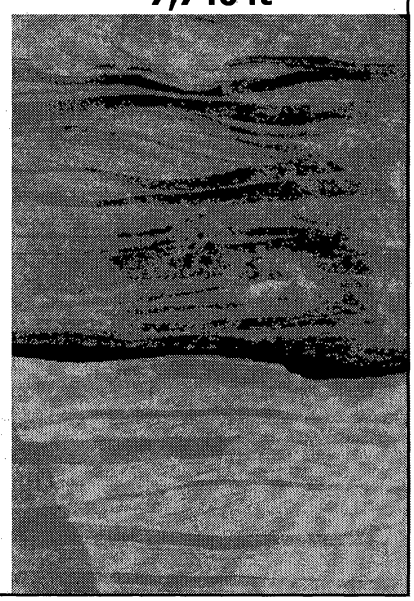
Flaser Bedding



Reineck and Singh (1975)

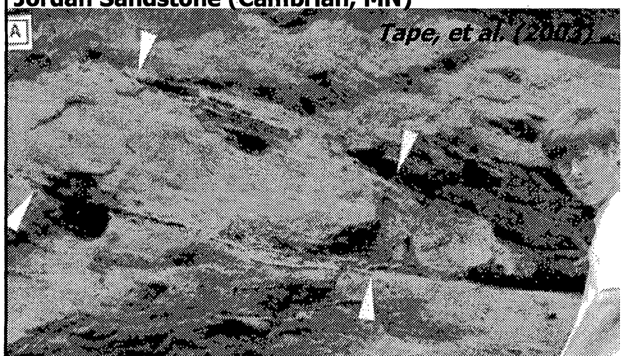
Cleveland Formation
Jones Energy #6 Tyson
7,746 ft

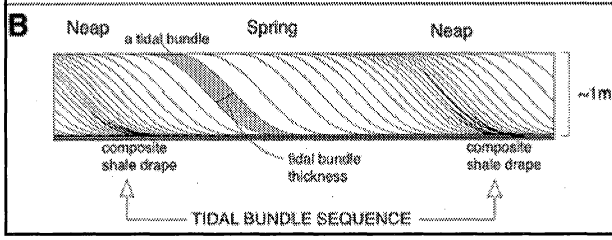
2 in



Tidal Cycles in the Rock Record

Jordan Sandstone (Cambrian, MN)



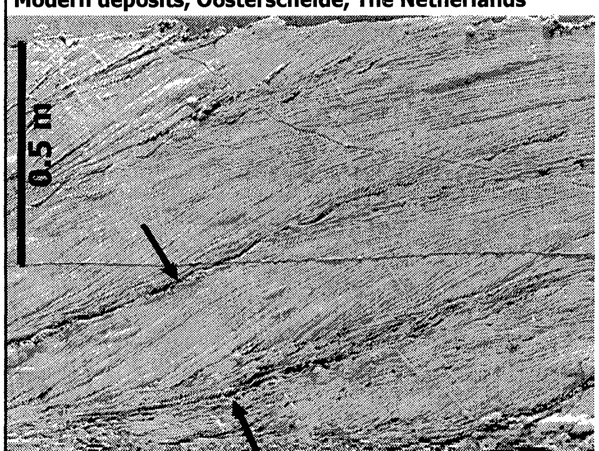


Tidal Bundles

- **Bundle sequence (between arrows)**
- **Bundle sequence (14 days: complete neap-spring-neap cycle)**
- **Individual bundle (Sediment deposited during single ebb stage)**

Tidal Cycles in the Rock Record

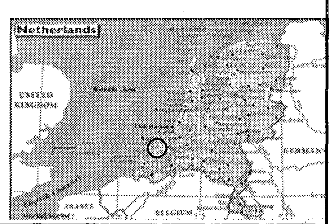
Modern deposits, Oosterschelde, The Netherlands



Terwindt (1981)

Tidal Bundles

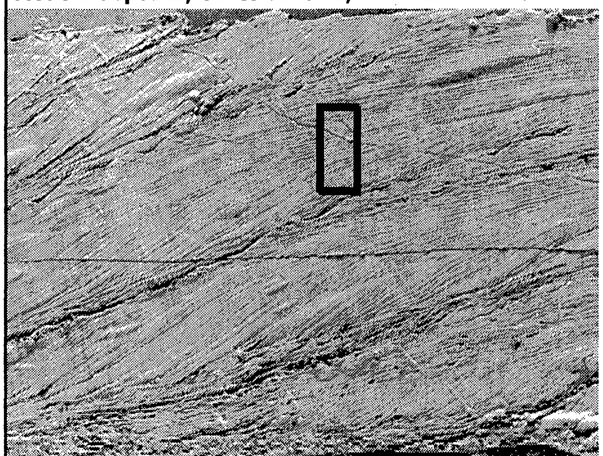
- **Bundle sequence (between arrows)**
- **Tidal fluctuations indicated by cyclically spaced mud drapes**

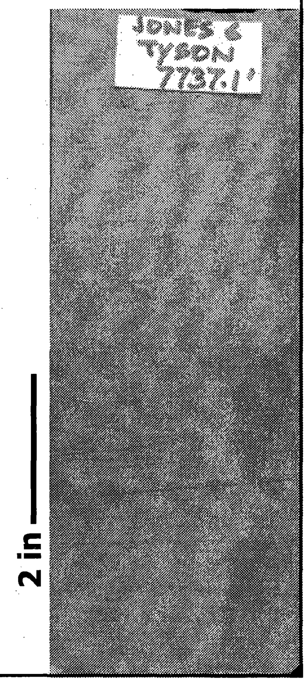


mapquest.com

Cleveland Tidal Bundle

Modern deposits, Oosterschelde, The Netherlands





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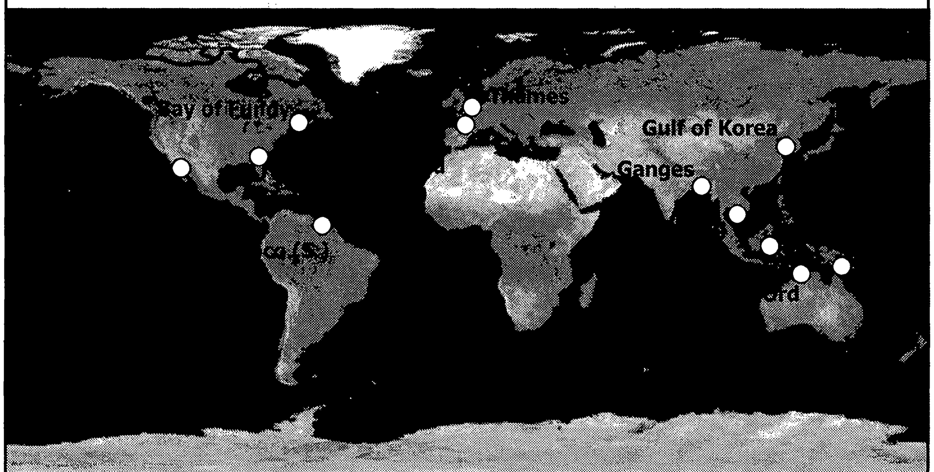
Global Distribution of Tidal Regimes



Microtidal (0-2 m)
Mesotidal (2-4 m)
Macrotidal (>4 m)

○ Macrotidal Embayments and Deltas

From Davies (1964)

Shoreline Curvature and Tidal Regime

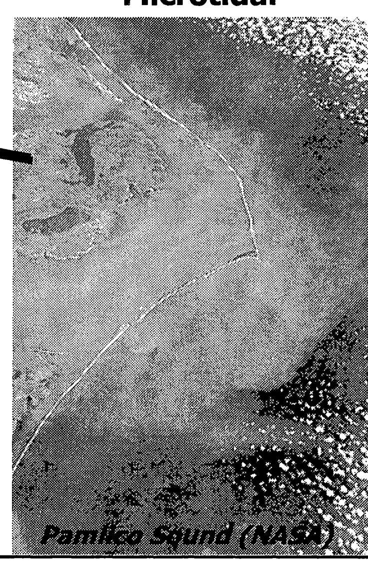
SE US Atlantic Coast

Tidal Regime

Diurnal Range (m)

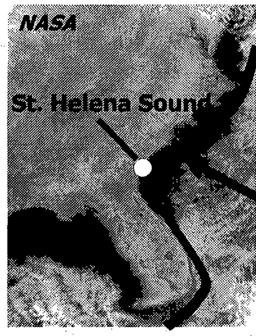
Microtidal (0-2 m)
Mesotidal (2-4 m)
Macrotidal (>4 m)

Microtidal

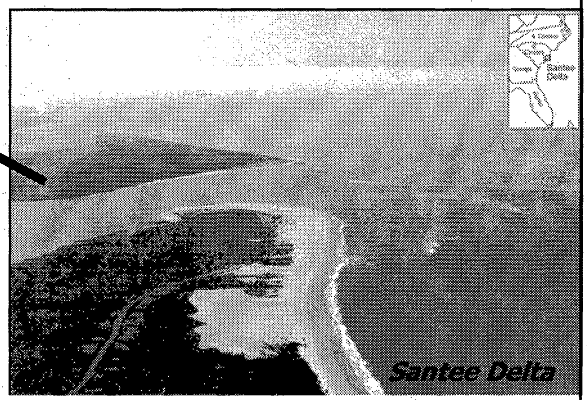


Shoreline Curvature and Tidal Regime

SE US Atlantic Coast



Mesotidal



Ambrose (1985)

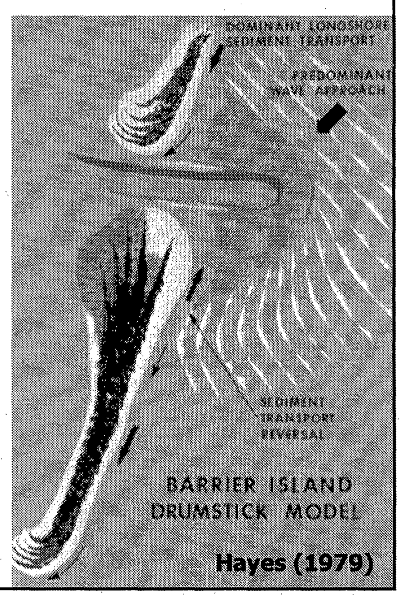
Tidal Regime

Diurnal Range (m)

Microtidal (0-2 m)
Mesotidal (2-4 m)
Macrotidal (>4 m)

Mesotidal Barrier Morphology

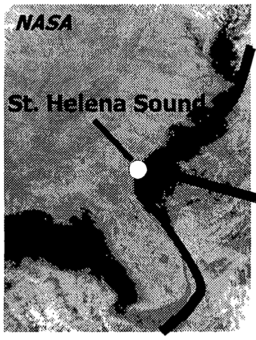
Charleston Bay, SC



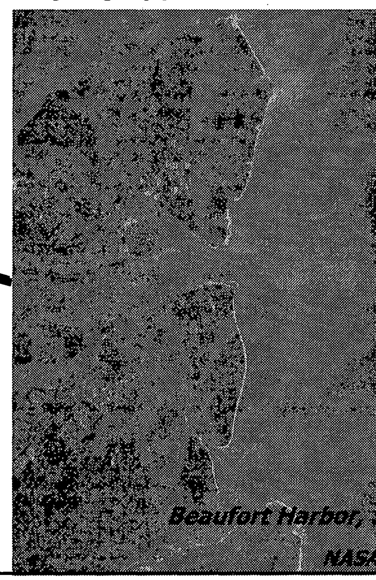
Hayes (1979)

Shoreline Curvature and Tidal Regime

SE US Atlantic Coast



Macrotidal

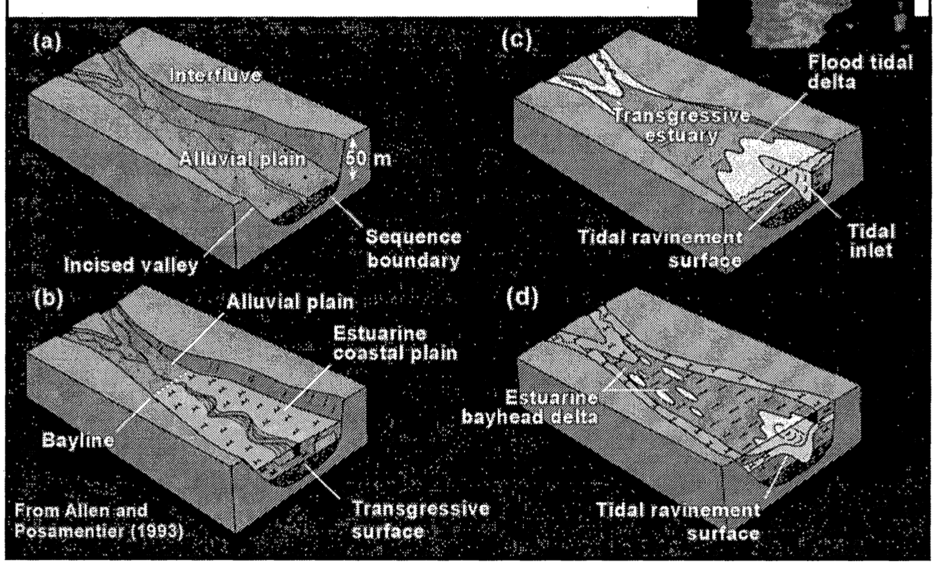


Tidal Regime

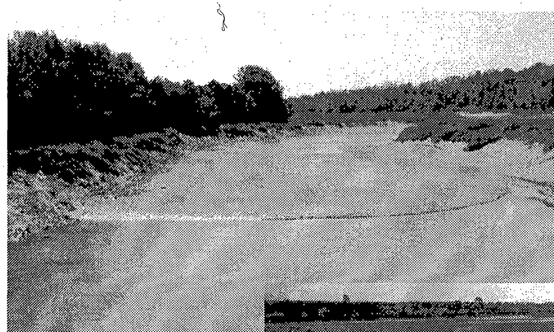
Diurnal Range (m)

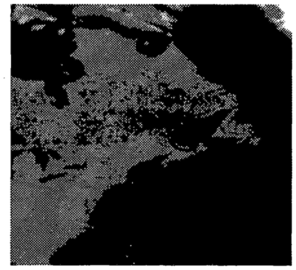
Microtidal (0-2 m)
Mesotidal (2-4 m)
Macrotidal (>4 m)

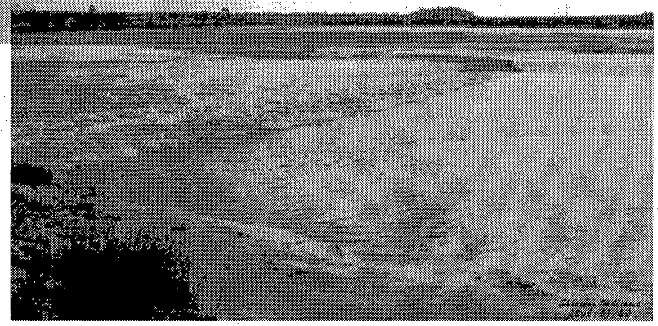
Gironde Estuary: Macrotidal



Macrotidal Tidal Bores: Bay of Fundy







S. Williams (2005)

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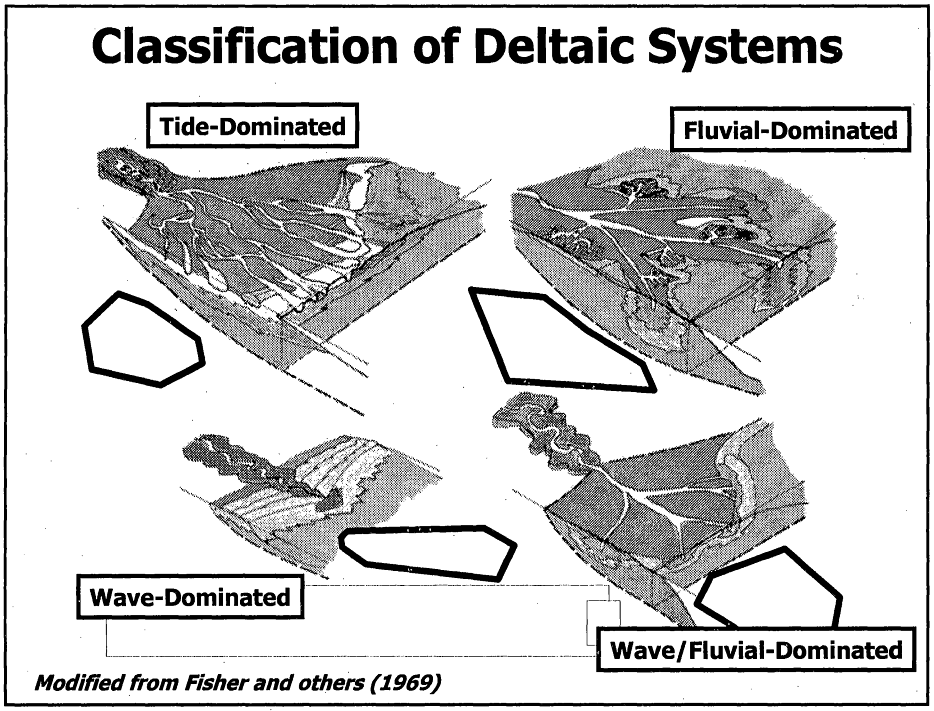
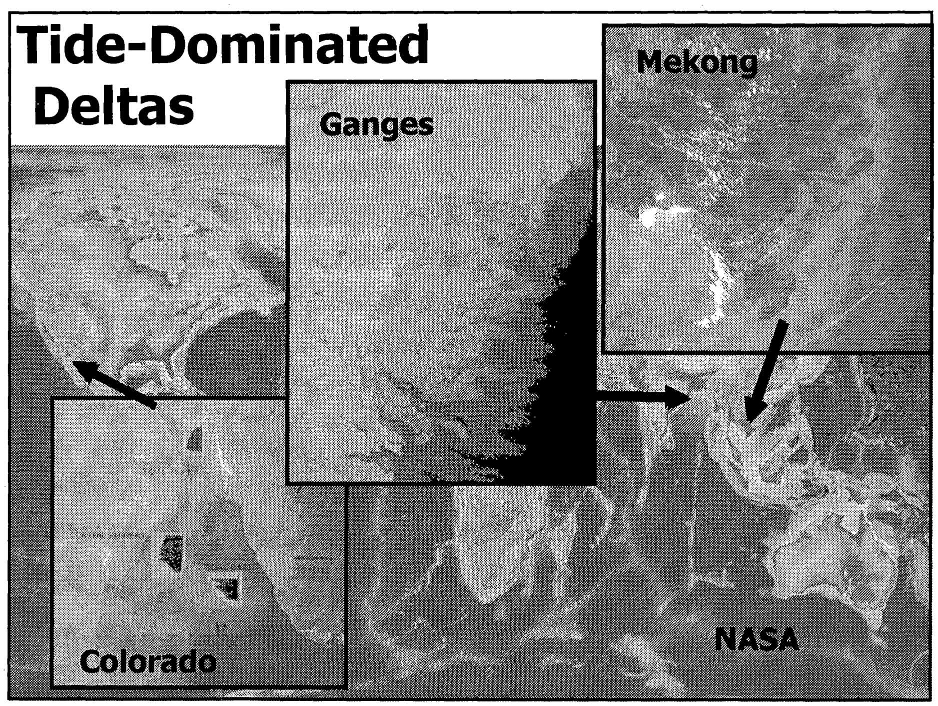
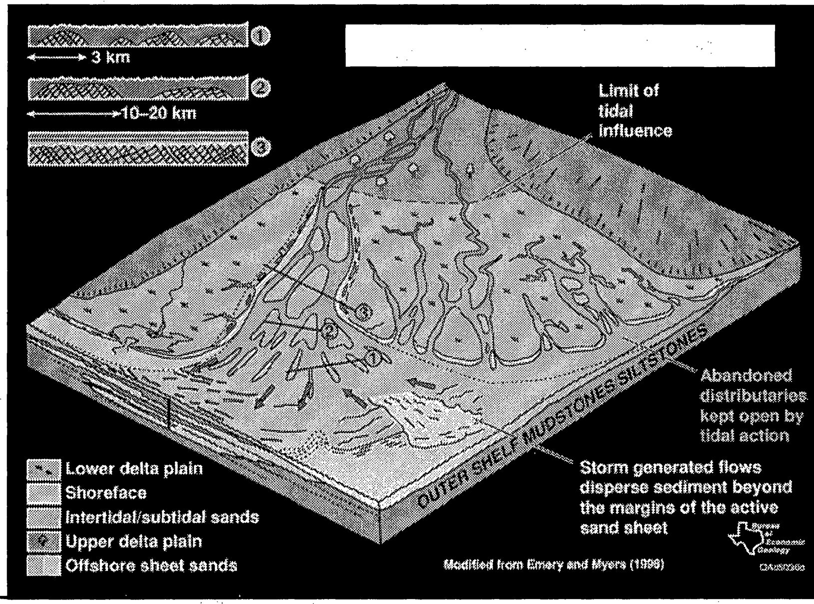
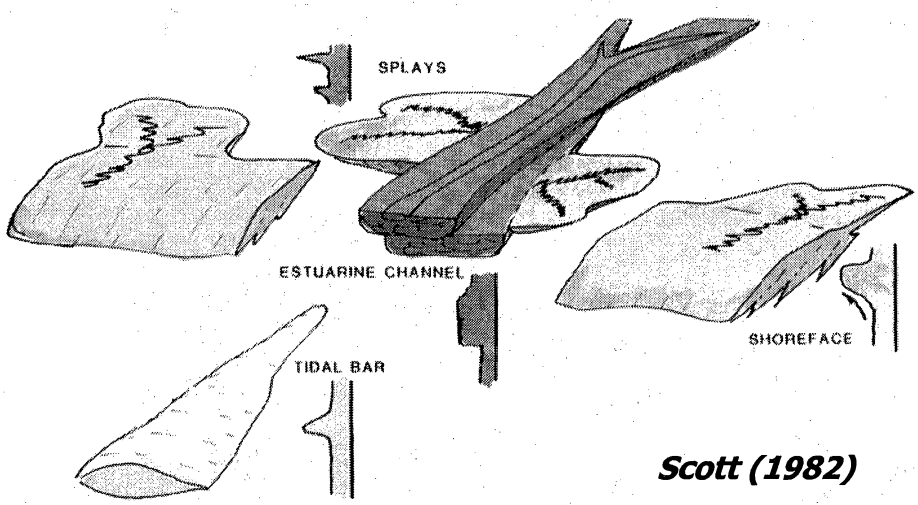

Classification of Deltaic Systems
Tide-Dominated
Fluvial-Dominated
Wave-Dominated
Wave/Fluvial-Dominated
Modified from Fisher and others (1969)


Tide-Dominated
Deltas
Mekong
Ganges
Colorado
NASA

Tide-Dominated Delta and Estuarine Model



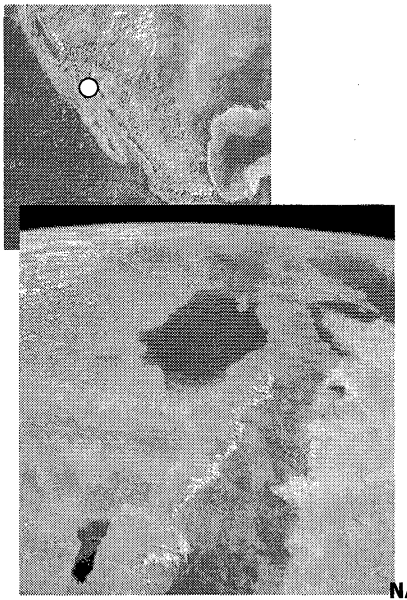
Tide-Dominated Delta Framework Facies

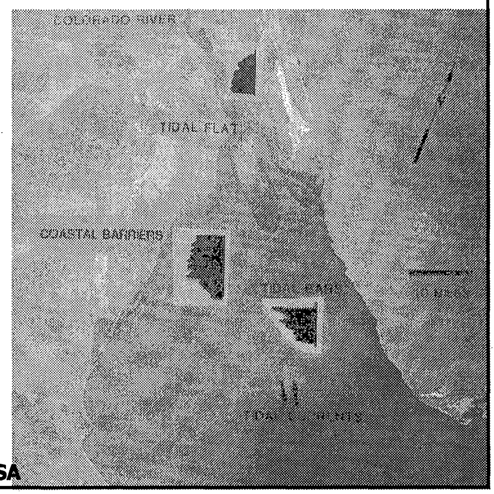


Scott (1982)

Colorado Delta

- Tide Dominated
- Occupies Salton Trough
- Arid Tidal Flats, Coastal Barriers

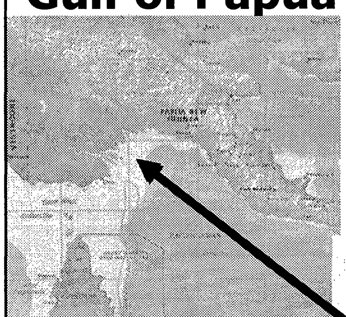


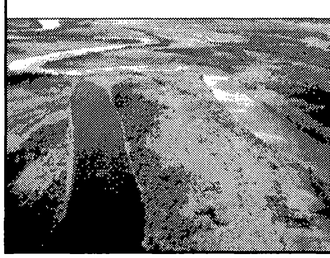


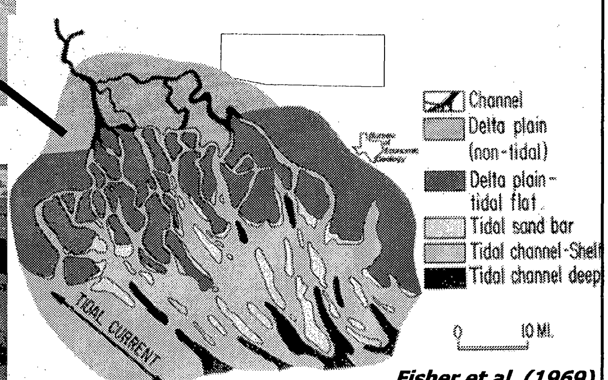
NASA

Gulf of Papua

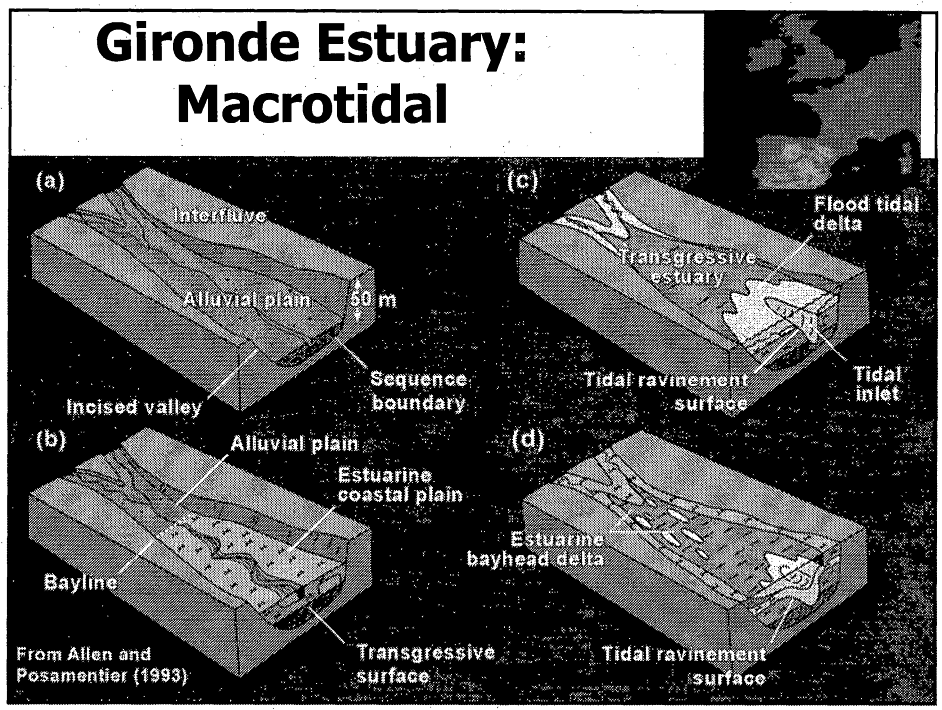
- Tide Dominated (3.5-5 m range)
- Mixed load, tropical setting (>10 m rainfall)

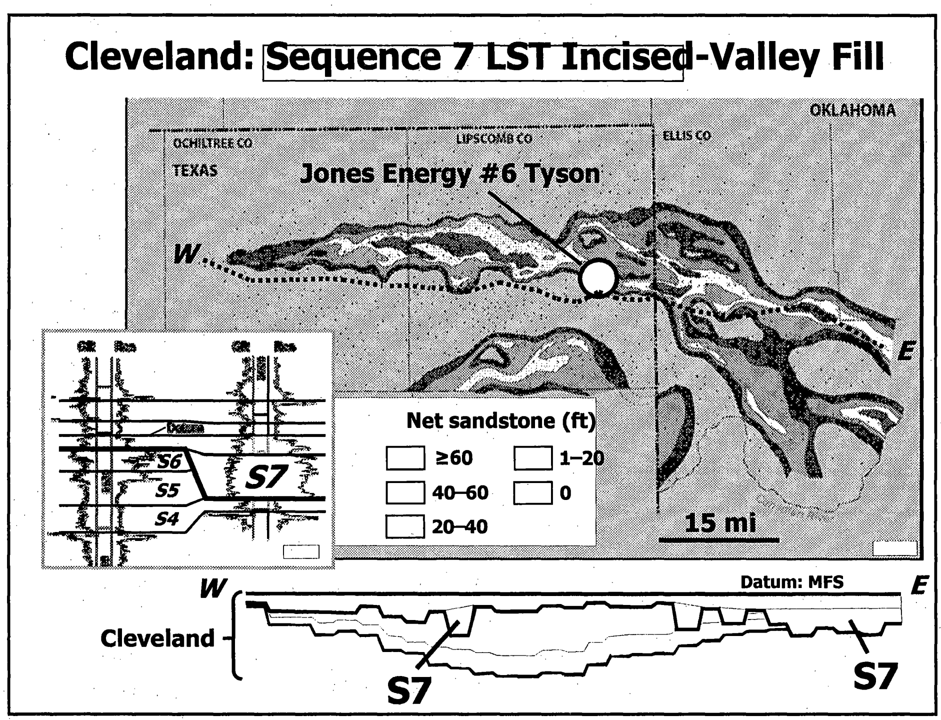




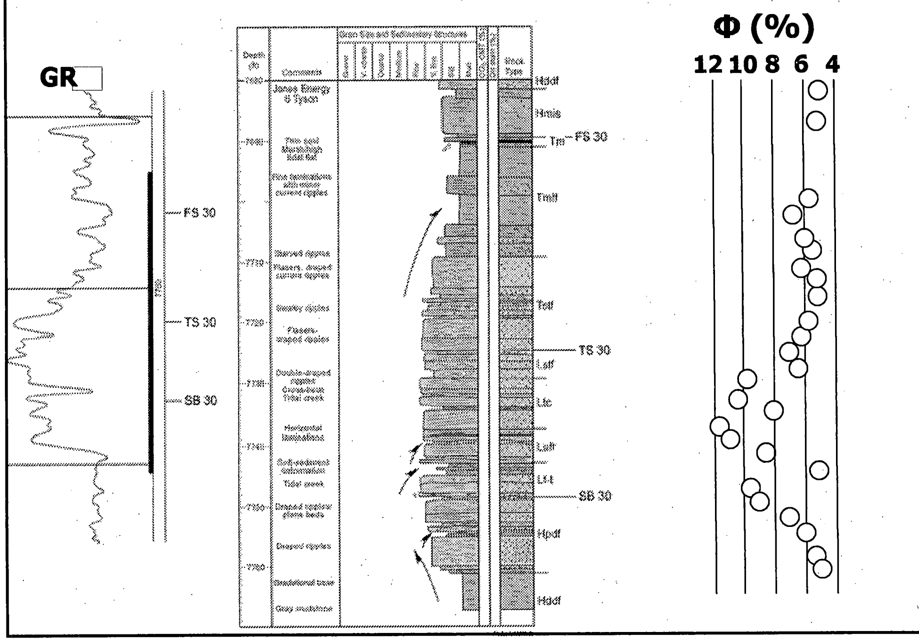


Fisher et al. (1969)

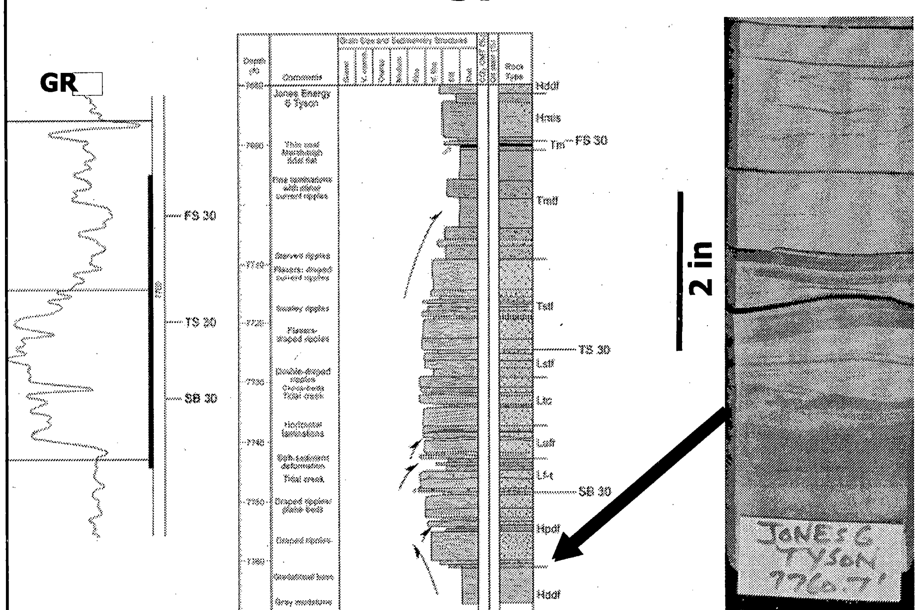

Gironde Estuary:
Macrotidal
(a)
Interfluve
Alluvial plain
50 m
Sequence boundary
Incised valley
(b)
Alluvial plain
Estuarine coastal plain
Bayline
Transgressive surface
(c)
Flood tidal delta
Transgressive estuary
Tidal ravinement surface
Tidal inlet
(d)
Estuarine bayhead delta
Tidal ravinement surface
From Allen and Posamentier (1993)


Cleveland: Sequence 7 LST Incised-Valley Fill
OKLAHOMA
OCHILTREE CO
LIPSCOMB CO
ELLIS CO
TEXAS
Jones Energy #6 Tyson
W
E
S6
S5
S4
S7
Net sandstone (ft)
≥60
1–20
40–60
0
20–40
15 mi
W
Datum: MFS
E
Cleveland
S7
S7

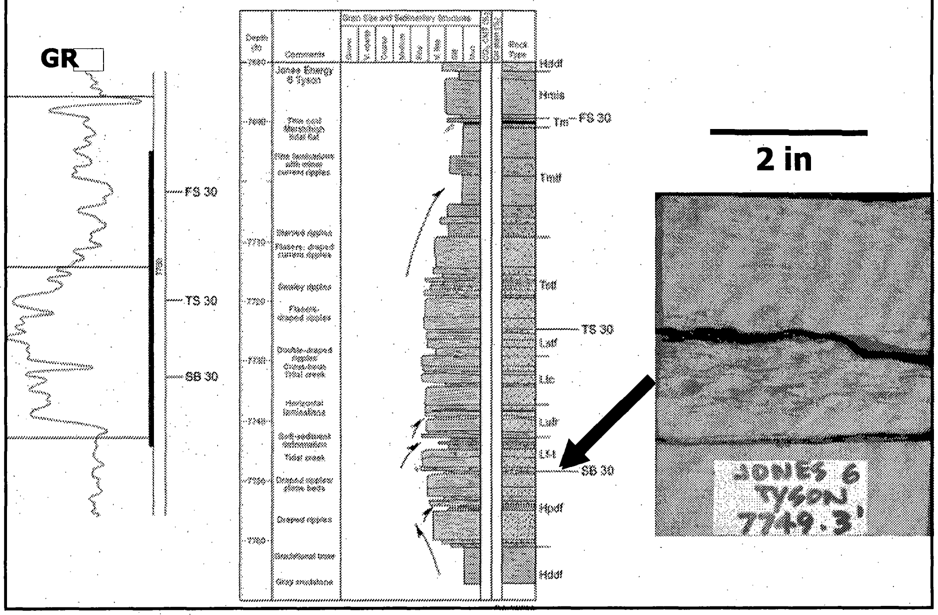
Jones Energy #6 Tyson



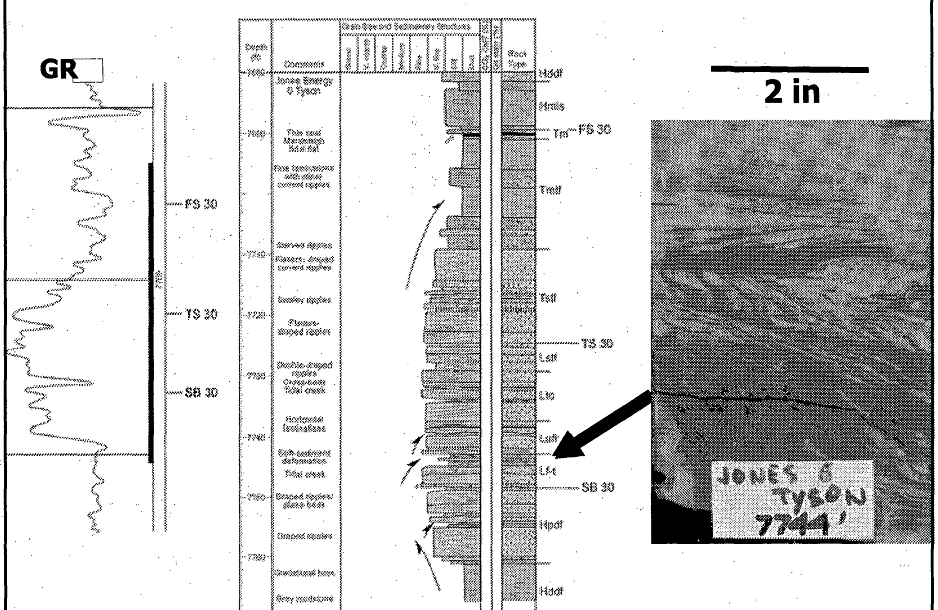
Jones Energy #6 Tyson



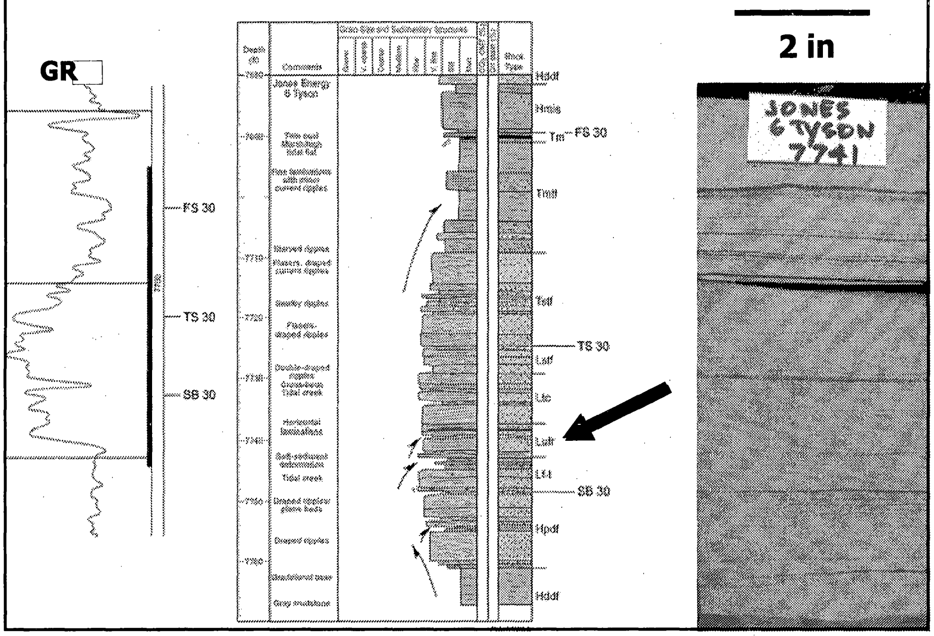
Jones Energy #6 Tyson



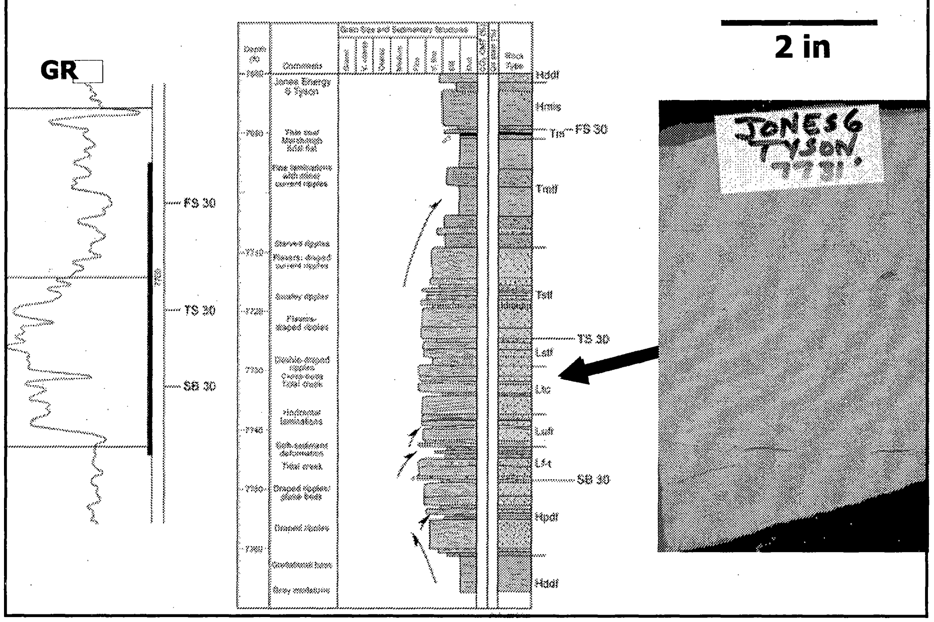
Jones Energy #6 Tyson



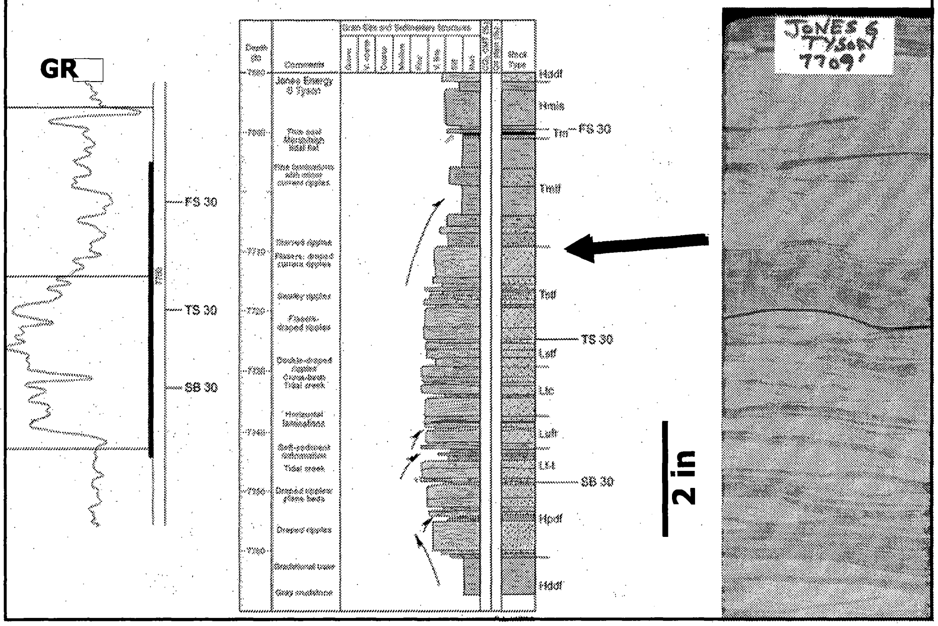
Jones Energy #6 Tyson



Jones Energy #6 Tyson

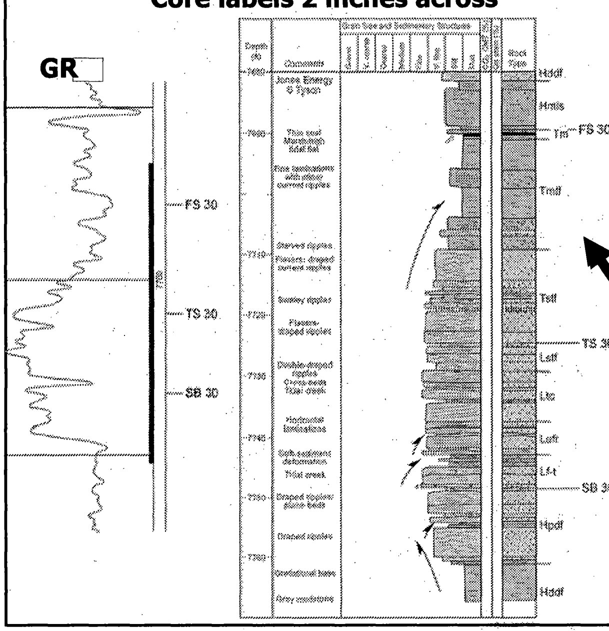


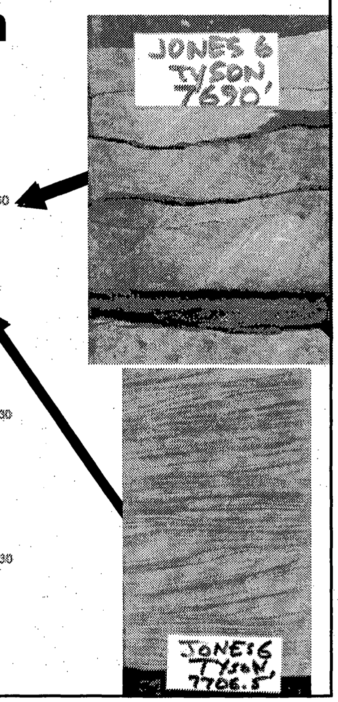
Jones Energy #6 Tyson



Jones Energy #6 Tyson

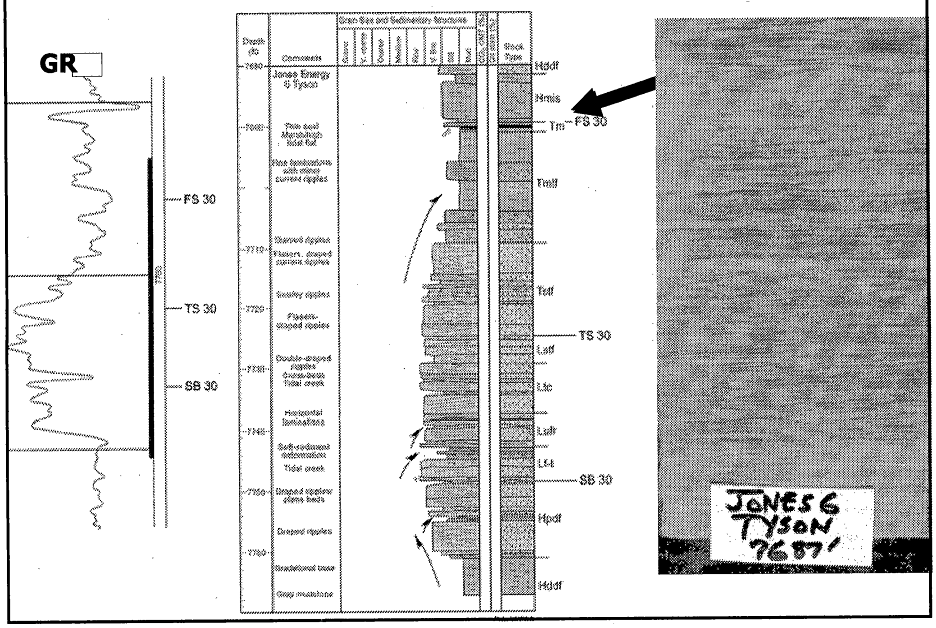
Core labels 2 inches across





Jones Energy #6 Tyson

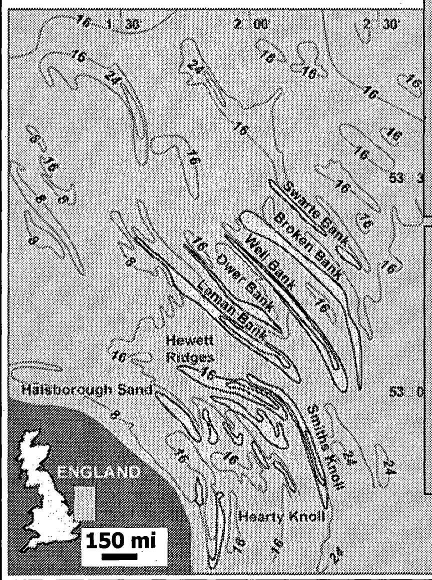
2 in

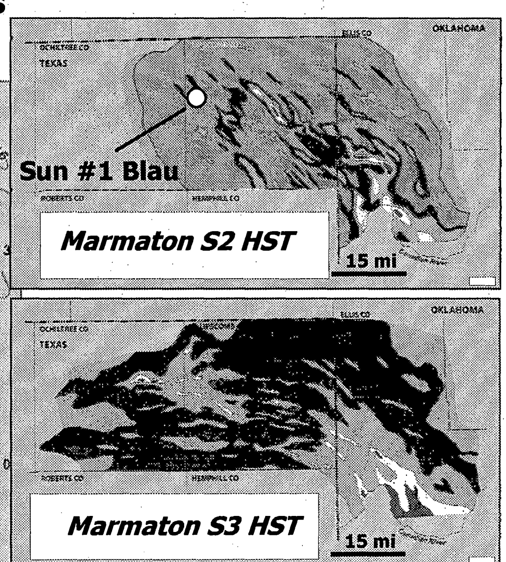


Outline

- **Tidal Origins and Processes**
  - ***-Tidal Cycles***
  - ***-Tidal Signatures in the Rock Record***
  - ***-Tidal Regimes (Micro-, Meso-, Macrotidal)***
- **Modern Tide-Dominated Deltas and Estuaries**
  - ***-Colorado, Papua, Irrawaddy, Gironde, and others***
- **Tidal-Shelf/Distal-Delta-Front Deposits**
  - ***-Modern and Ancient Examples***

Shallow Shelf Tidal Ridges Offshore Norfolk, UK

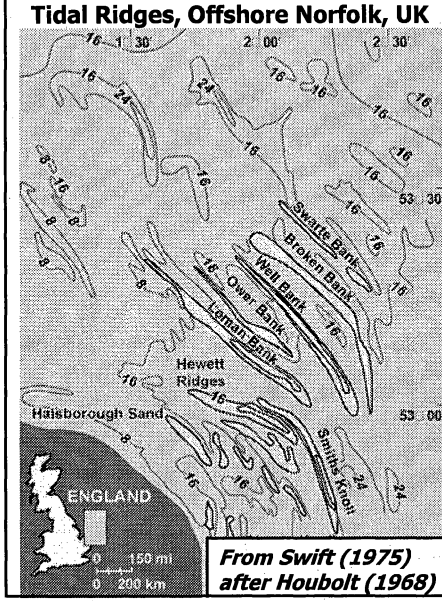




From Swift (1975) after Houbolt (1968)

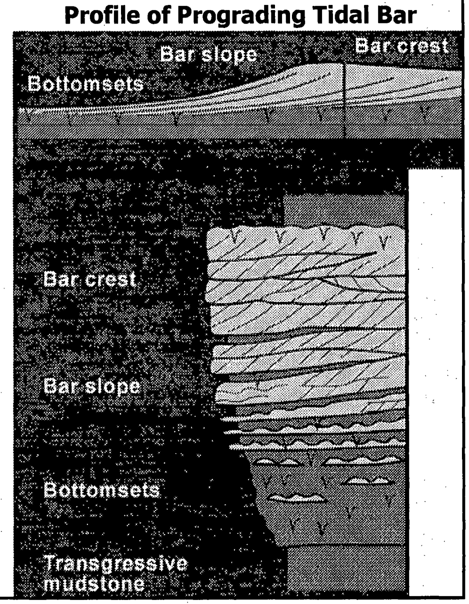
Shallow Shelf Tidal Systems

Tidal Ridges, Offshore Norfolk, UK

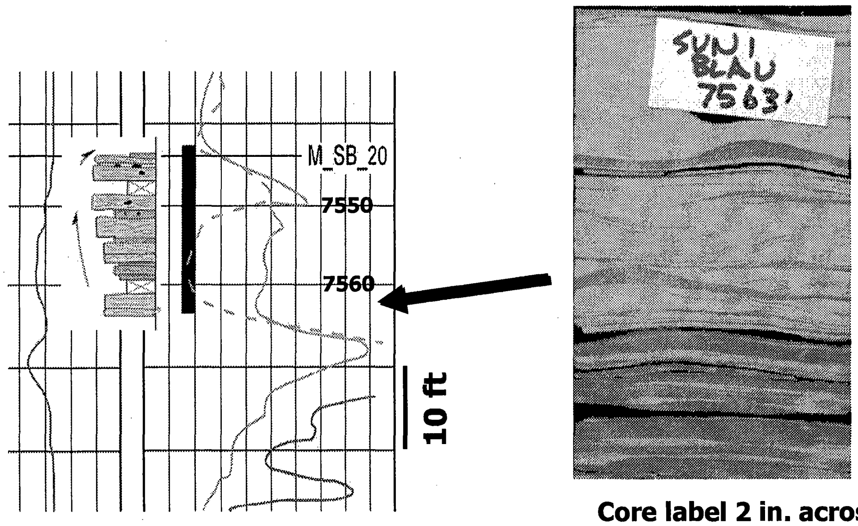


From Swift (1975) after Houbolt (1968)

Profile of Prograding Tidal Bar

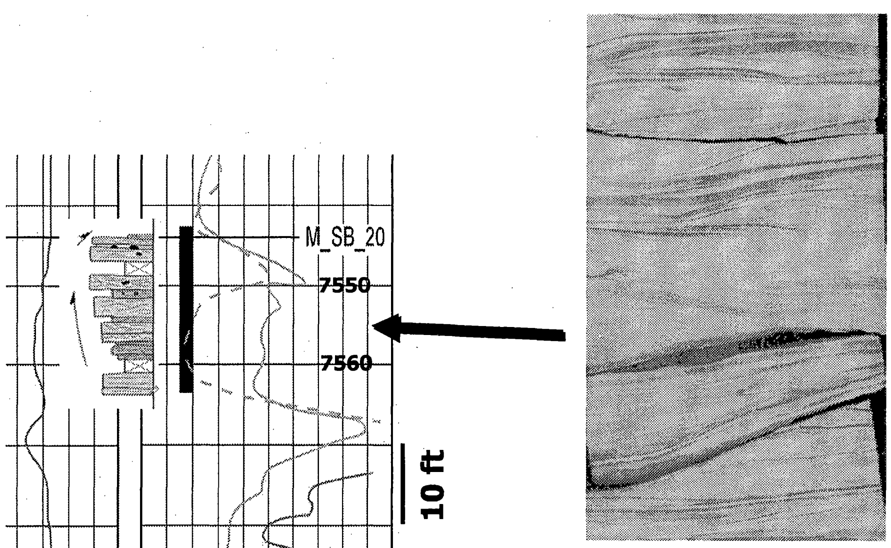


Sun #1 Blau



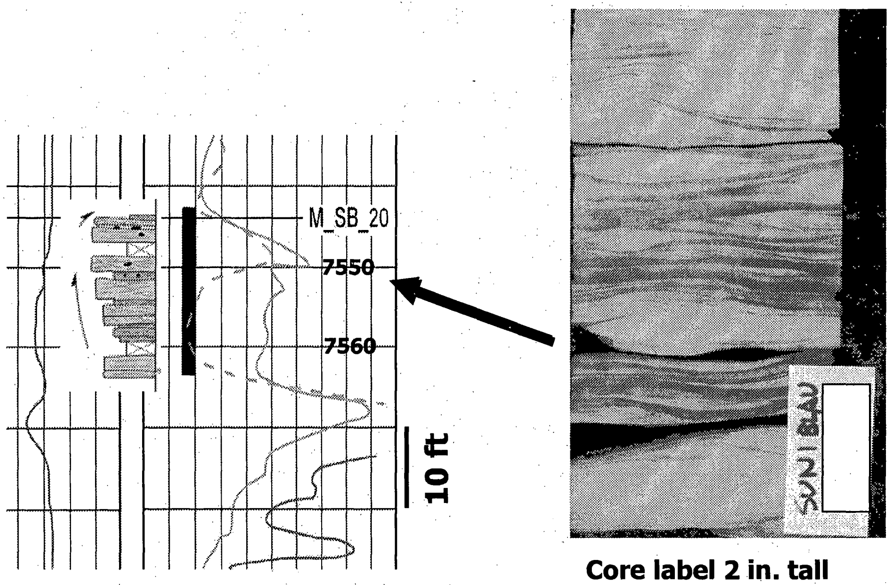
Core label 2 in. across

Sun #1 Blau



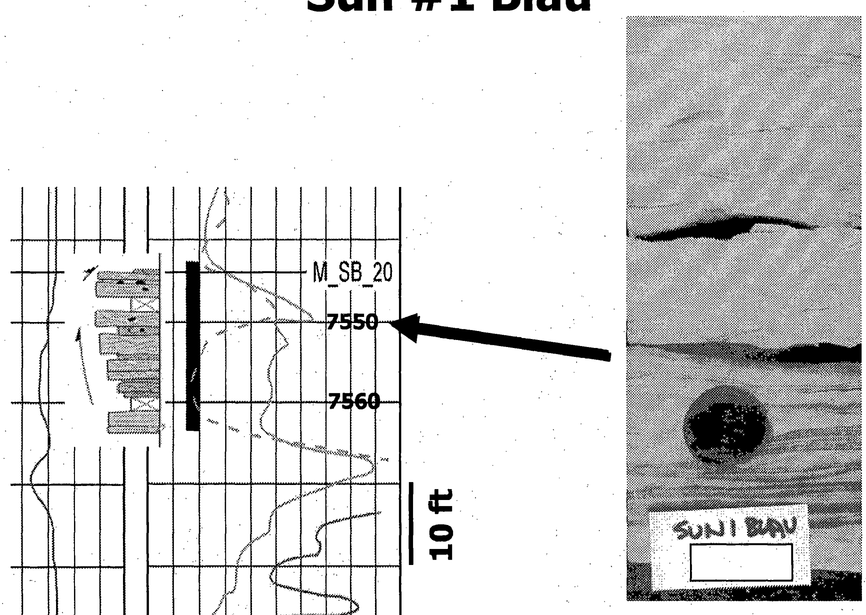
2 inches

Sun #1 Blau



Core label 2 in. tall

Sun #1 Blau



Core label 2 in. across

Summary

- **Tidal Origins and Processes**
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- **Tidal-Shelf and Distal-Delta-Front Deposits**
  - *-Modern and Ancient Examples*

Core Workshop
Cleveland Formation and Marmaton Group
Anadarko Basin

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John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, TX

November 10, 2009

Introduction

Cores in the Cleveland Formation and Marmaton Group in the Anadarko Basin display a variety of facies in tidally dominated depositional settings. This workshop presents cores that illustrate contrasting sequence tracts in the Cleveland Formation that include the Jones Energy #6 Tyson (lowstand-valley-fill and transgressive-estuarine deposits) and the Shell #1-678 Wheat (tide- and wave-modified, highstand-shelf, and delta-front facies). In addition, a short cored section from the Sun #1 Blau well features inner-shelf and delta-front highstand deposits from the Marmaton Group (Fig. 1). Another core from the Atoka Series, the Shell #1 Molesworth in Ochiltree County (located in Fig. 1) demonstrates variable carbonate and shale lithology and is described in a separate document in this guidebook.

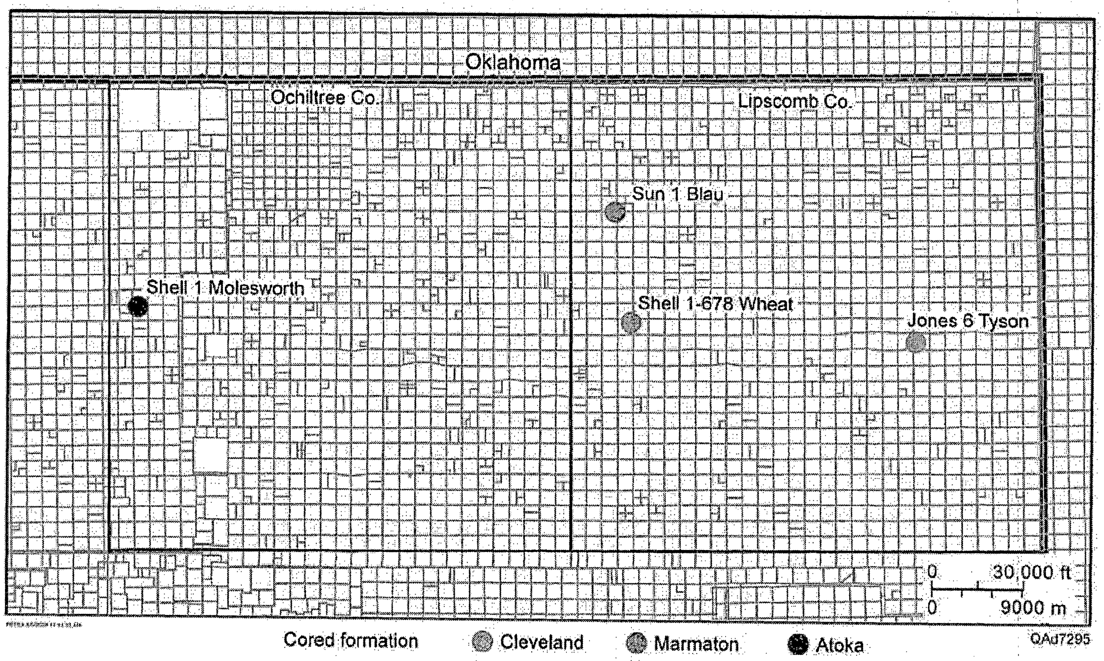

Figure 1. Location of cored wells presented in this workshop.

Cores are vital to an understanding of reservoir architecture because they display a vertical profile of the rock fabric, contacts between beds, and sedimentary structures from which one can infer sedimentary processes and depositional facies. Vertical trends in lithology, grain size, and stratification are the result of changes in depositional environments through time. Workshop participants will have the opportunity to observe numerous examples of vertically superimposed sedimentary facies in the Cleveland Formation and Marmaton Group in a variety of depositional settings that include incised valley, estuary, delta, and highstand shelf.

Recognition criteria for tidal deposits in the Cleveland Formation and Marmaton Group include distinctive stratification and bedforms observed in core, as well as sandstone-body geometry inferred in lithofacies maps of distal-deltaic deposits in the lower Cleveland highstand sequence and shallow-marine deposits in the upper Cleveland transgressive sequence, where the geometry of these sandstone bodies reflects the relative strength of tidal- versus wave-reworking processes. Stratification and bedforms diagnostic of tidal deposits in Cleveland cores include asymmetric, double-draped ripples with bidirectional foresets; abundant reactivation surfaces; rhythmic, laminar stratification; and flaser bedding. These types of features have been described in other studies of both modern and ancient tidally influenced deposits, including Reineck and Wunderlich (1968), Klein (1970), de Mowbray and Visser (1984), Dalrymple and others (1990; 1991), and Allen (1991). Asymmetric current ripples in cores of the Cleveland Formation in particular, interpreted to be tidal in origin, typically exhibit differences in degree of development and size between ripple sets of alternating orientation. These differences in magnitude of the reversal of bedforms reflect the presence of dominant and subordinate tidal currents, which are common in many estuarine settings as a result of the relative strength of flood- and ebb-dominated bedform migration in different reaches of the estuary. For example, in upstream estuarine settings such as in the Ord River Delta in Australia, the velocity of flood-tidal currents commonly exceeds that of ebb-tidal currents, resulting in a weak bidirectional ripple fabric (Wright and others, 1973; 1976). In contrast, at the estuary mouth, flood and ebb currents are approximately equal in strength, and a strong bidirectional ripple orientation is therefore more clearly evident (Hayes, 1976).

Other features in cores of the middle Cleveland lowstand, incised-valley-fill sequence that are consistent with a tidally influenced depositional setting include abundant sections of plane-bedded, laminated sandstone interpreted to represent upper-flow-regime (UFR), sandy tidal-flat deposits (UFR sand-flat facies), similar to that described by Dalrymple and others (1992) and Allen and Posamentier (1993) in the modern Gironde Estuary. Although the presence of plane-bedded, laminated sandstone is not in itself indicative of tidal conditions, its association with strata composed of flaser ripples, double-draped ripples with reactivation surfaces, and rhythmic, laminated bedding is consistent with tidally influenced deposits. Additional evidence of tidally influenced depositional systems is from sandstone-body geometry in lithofacies maps of distal-delta-front and shelf deposits in the lower Cleveland highstand sequence, composed of upward-coarsening, progradational successions exhibiting dip-elongate and subparallel net-sandstone-thickness patterns, consistent with reworking of sandy, delta-front sediments from tidal currents in a shallow-shelf depositional setting. Modern examples include elongate, subaqueous tidal bars in the North Sea (Houbolt, 1968; Swift, 1975), the modern Gulf of Korea (Off, 1963), the Gulf of Papua (Fisher and others, 1969), the Ord River Delta in Australia (Wright and others, 1973), and the Gulf of California (Meckel, 1975). Similar net-sandstone geometries in tide-dominated delta-front depositional settings were documented by Maguregui and Tyler (1991) and Ambrose and others (1995) in Eocene tide-dominated deltas in Lake Maracaibo, Venezuela, as well as tide-dominated shelf and deltaic deposits in the Eocene Baronia deltaic system in northern Spain (Mutti and others, 1985) and Eocene tidal-sand-ridge deposits in Belgium (Houthuys and Gullentops, 1988).

Cleveland Formation: Jones Energy #6 Tyson Core

The Jones Energy #6 Tyson core (located in Fig. 1) offers an excellent example of a continuous, 87-ft (~23-m) section through a tidally influenced, incised-valley-fill system (Fig. 2). The basal 17 ft (5.2 m) of the core consists of upward-coarsening, highstand delta-front deposits inferred to be truncated by a lowstand, incised-valley-fill section that extends from 7,724 to 7,748 ft (2,354 to 2,362 m). This lowstand section represents formation of a paleovalley that was filled with estuarine deposits during subsequent sea-level rise, recorded by an upward-fining section of transgressive deposits that extend from 7,748 to ~7,690 ft (2,362 to 2,344 m). The uppermost 10 ft (3 m) of core is interpreted to be inner-shelf and distal-delta-front deposits in another highstand sequence above a flooding surface (FS_30) that caps the transgressive section at 7,690 ft (2,344 m).

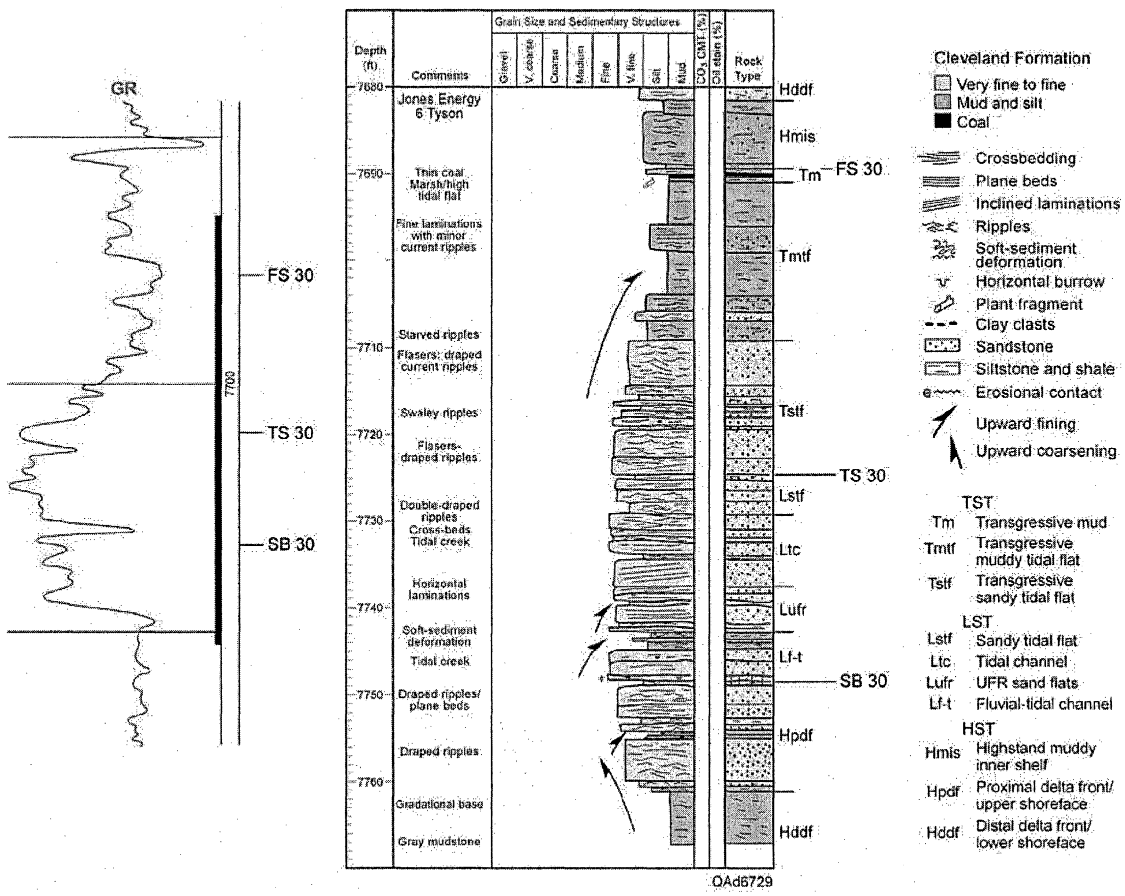

Figure 2. Description and log response of the Cleveland Formation in the Jones Energy #6 Tyson core, located in Fig. 1.

Highstand Systems Tract

The basal 17 ft (5.2 m) of the Jones Energy #6 Tyson core is composed of highstand deposits below the base of the lowstand systems tract that is identified by the SB_30 marker. This section is upward coarsening, ranging from weakly laminated, silty mudstone at the base to fine-grained sandstone at the top. Sedimentary structures in this lower highstand succession are interpreted to be wave- and tidal-reworked delta-front deposits on the basis of net-sandstone distribution maps that indicate dip-elongate sandstone body geometry (Hentz and others, 2009) and the presence of both wavy and asymmetrical, draped ripples. Thin (0.5-inch [~1.3-cm]) zones of plane beds also occur toward the top of the highstand section, possibly recording a transition to upper flow regime and higher-energy conditions. The gamma-ray (GR) response of the highstand systems tract is commonly serrate to upward coarsening, reflecting a progradational origin.

Lowstand Systems Tract

The Cleveland lowstand systems tract, which extends from 7,724 to 7,748 ft (2,354 to 2,362 m) in the Jones Energy #6 Tyson core, is a slightly upward fining section of fine-grained sandstone, with thin (commonly <3-inch [~7.5-cm] beds of siltstone and silty mudstones. The base of the lowstand systems tract is marked by sharp-based, upper fine-grained sandstones that fine upward into siltstones with flaser ripples. The lowstand section is a heterogeneous succession of facies composed from bottom to top of fluvial-tidal (Lf-t), UFR (Lufr), tidal-channel (Ltc), and sandy-tidal-flat (Lstf) facies (Fig. 2).

The Lf-t facies, 6 ft (1.8 m) thick, consists of an upward-fining section of erosion-based, upper fine-grained sandstone with planar stratification and asymmetric mudstone-draped flaser ripples inferred to have been deposited by alternating tidal currents (for example, at 7,746 ft). This basal lowstand section is interpreted to represent tidally reworked fluvial deposits at the base of the incised-valley fill. Analogous Lf-t facies in modern estuarine settings include alluvial-channel deposits composed of gravelly sandstones in the Gironde Estuary (Dalrymple and others, 1992; Allen and Posamentier, 1993); gravelly and shelly sandstones in a channel-fill succession in Ossabow Sound, Georgia (Greer, 1975); and upward-fining, scour-based sandstones in the Cobequid Bay-Salmon River Estuary in the Bay of Fundy (Dalrymple and others, 1990). Alluvial-channel deposits in the basal estuarine fill section in the Gironde Estuary are typically much thicker and compose a greater percentage of the overall estuarine succession than the equivalent Lf-t facies in cores of the Cleveland Formation (Allen and Posamentier, 1993). However, the lowstand alluvial-channel facies occurs at the mouth of the Gironde Estuary, with relatively little or no fluvial aggradation in the upstream part of the estuary. This scenario is consistent with the poorly developed basal fluvial-tidal section in the Jones Energy #6 Tyson core, which occupies an updip part of the overall incised-valley system in the study area (see slide set "Sequence Stratigraphy and Depositional Summary of the Marmaton and Cleveland Formations, Anadarko Basin," this volume).

The section of Lft-facies is overlain by the UFR facies, a 6-ft (1.8-m) section of fine-grained sandstone with planar stratification, with particularly good examples from 7,739 to 7,741 ft (2,359 to 2,359 m). The UFR facies is interpreted to represent shallow (typically <6.5-ft [<2-m] water depths), upper-flow-regime tidal currents exceeding 6.5 ft s^{-1} (2 m s^{-1}) that are associated with fluctuating water levels (Reineck and Singh, 1973; Dalrymple and others, 1990). Parallel-laminated intervals in tidally influenced depositional settings commonly form during maximum tidal flow velocities that occur either at the peaks of flood or ebb tides. In contrast, cross-stratified tidal sediments are commonly developed during accelerating or waning-flow conditions within the tidal cycle (Kreisa and Miolola, 1986). UFR facies are documented in a variety of modern macrotidal estuaries, where the diurnal tidal range is at least 13 ft (4 m) (Davies, 1964). Some examples include the Cobequid Bay-Salmon River estuary in Canada (Dalrymple and others, 1990; 1991) and the Gironde Estuary in southwest France (Allen, 1991). In estuarine systems the UFR facies commonly occurs in the transitional area between the distal tidal-sand-bar facies and the proximal tidal-meanderbelt facies along the axial part of estuaries (Lambiase, 1980; Dalrymple, 1992). The UFR facies can either underlie or overlie the tidal-meander facies. The UFR facies is also recognized in ancient successions of tide-dominated estuarine deposits such as the Eocene Central Basin in Spitsbergen, where individual deposits consist of river-dominated, 3- to 4-ft (0.9- to 1.2-m) sections of sandstone interbedded with bidirectional, ripple-laminated sandstones in abandoned-channel sequences (Plint-Björklund, 2005).

The overlying tidal-channel (Ltc) facies in the Jones Energy #6 Tyson core is an upward-fining section of fine-grained sandstone with crossbeds, inclined stratification, climbing ripples, clay clasts, and organic fragments. Diagnostic features of the Ltc facies include inclined stratification (for example, at 7,737 ft [2,358 m]), crossbeds (7,731 ft [2,356 m]), and numerous internal scour surfaces, with minor planar stratification overlain by ripples with mud drapes. Tidal-channel successions in modern examples of estuarine systems or areas with significant tidal influence, such as the Ossabow Sound in Georgia (Greer, 1975), the Solway Firth in Scotland (Bridges and Leeder, 1976), tidal flats in the Netherlands in the North Sea (van Stratten, 1954; Reineck, 1967), and the Gironde Estuary (Dalrymple and others, 1992; Allen and Posamentier, 1993) display vertical successions similar to those in the Cleveland Formation, with some minor differences. Tidal-channel deposits in the Ossabow Sound are dominated by basal sections of steeply dipping foresets with mud pebbles overlain by muddy, burrowed, and fine-grained sandstone. In contrast, those in the Solway Firth are composed of basal sections of coarse-grained sandstone with mud and shell clasts. Tidal-channel deposits associated with tidal flats in the Netherlands, commonly highly meandering, exhibit characteristics of point bars, with vertical successions consisting of medium- to coarse-grained sandstone with a basal lag, overlain by interbedded, fine-grained sandstone and siltstone with lateral accretion surfaces. These tidal-channel deposits commonly pinch out into and are overlain by sandy tidal-flat deposits (Reineck, 1967). The sandy tidal-flat facies (Lstf), which constitutes the top of the lowstand sequence in the Jones Energy #6 Tyson core, is composed of a 4-ft (1.2-m) section of fine-grained sandstone. The Lstf facies is typically dominated by climbing ripples with thin mudstone drapes, reflecting migration of sandy sediment. The Lstf facies represents deposition from lower-flow-regime tidal currents, with slackwater suspension sedimentation recorded as siltstone drapes over ripples. Most of these ripples are asymmetric, reflecting deposition from low-energy, alternating tidal currents rather than from wave processes.

Transgressive Systems Tract

The upper Cleveland transgressive systems tract (TST) records flooding of the LST estuarine valley-fill system. Numerous examples of transgressive estuarine successions are in the ancient rock record, including the Upper Cretaceous Point Lookout Sandstone in northwestern New Mexico (Devine, 1991); the Albian Paddy Member of the Peace River Formation and lower Shaftesbury Formation in Alberta (Leckie and Singh, 1991); the Lower Triassic in Provence, France (Richards, 1994); the Lower Permian Hueco Formation in south-central New Mexico (Mack and others, 2003); the Lower Cretaceous Woburn Sands in southern England (Yoshida and others, 2004); and the Eocene Central Basin in Spitsbergen (Plint-Björklund, 2005).

The base of the upper Cleveland TST is marked by the TS_30 marker, defined in many cores as the base of an upward-fining section that grades upward into either burrowed or carbonaceous siltstones. In electric logs, the base of the TST is inferred at inflection points in the gamma-ray (GR) curve at the base of upward-fining successions below the FS_30 flooding surface (Fig. 2). In the Shell #1-678 Wheat core, also presented in this workshop, no lowstand facies are preserved, and the transgressive systems tract is represented by a thin (commonly <3-ft [0.9-m]) section of fine-grained sandstone with ripple scours above an upward-coarsening section of highstand proximal-delta-front deposits (Fig. 3). The upper Cleveland TST is well developed in the Jones Energy #6 Tyson well, where it is an upward-fining 30-ft (9-m) section composed of a basal interval of sandy tidal-flat facies (Tstf) that grades upward into muddy tidal-flat (Tmtf) and marsh (Tm) facies.

Sandy and muddy tidal-flat facies (Tstf and Tmtf, respectively) in the upper Cleveland TST are herein described together because they have a similar genetic depositional origin, containing similar bedforms and reflecting similar depositional processes. However, they are distinguished from one another by average grain size and general stratigraphic position, with the Tstf facies occurring lower in the TST succession (Fig. 2). The Tstf facies typically is composed of fine- to very fine grained sandstone with abundant ripples with mud drapes and internal scour surfaces. These ripples are dominantly asymmetric, although symmetrical, wavy ripples are also present. In contrast, the Tmtf facies is composed primarily of muddy siltstone and very fine grained sandstone. Stratification in the Tmtf facies is typified by abundant, small-scale, mud-draped ripples. Minor accessory features in the Tmtf facies include soft-sediment deformation, load structures at the bases of ripples, and carbonaceous fragments.

Upper Cleveland TST marsh facies are inferred from thin (commonly <1-cm) coal beds and carbonaceous shales. The marsh facies in the Jones Energy #6 Tyson well occurs at ~7,691 ft (~2,344.8 m) and overlies an 18-ft (5.5-m), upward-fining interval of Tmtf facies. In the Jones Energy #6 Tyson well it is composed of a 0.3-inch (0.7-cm), bright coal streak bounded below by gray mudstone with abundant plant fragments. It is overlain by muddy siltstone. In other cores from previous studies, marsh deposits are inferred from similarly thin (<4-inch [<10-cm]) coal seams that directly overlie upward-fining successions of crossbedded and ripple-laminated sandstone interpreted to be fluvial channel in origin (Hentz, 1994).

The upward-fining grain size in the tidal-flat and marsh section in the upper Cleveland TST sequence is consistent with overall grain-size profiles in prograding tidal-flat models in the Wash in the United Kingdom (Evans, 1965) and the southwestern coastline in the Netherlands (Van Stratten, 1954), as summarized in Klein (1971). In the prograding tidal-flat model from these modern examples, the upward-fining succession typically consists of a basal section of sandy, bedload-dominant, subtidal, and low-tidal-flat deposits that grade upward into finer-grained, middle- and upper-tidal-flat and marsh silt and mud deposits in which suspended-load sedimentation dominates over bedload sedimentation. Basinward superposition of muddy, upper-tidal-flat, and marsh deposits over lower-tidal-flat and subtidal deposits results in a net upward-fining grain-size profile. However, the upward-fining grain-size profile in transgressive tidal-flat and marsh deposits in the Jones Energy

#6 Tyson core is more a function of retrogradation. Muddy siltstones above the thin coaly zone in this core represent marine drowning (give-up surface) and destruction of marsh-forming environments. The give-up transgressive surface separates the lower peat deposit from the marine sediments above, dividing the two cycles into an upward-deepening cycle below and an upward-shallowing cycle above (Diessel et al., 2000).

Cleveland Formation: Shell #1-678 Wheat Core

Highstand Systems Tract

The Shell #1-678 Wheat core (Fig. 3) contains prominent, well-preserved highstand successions, in contrast to the Jones Energy #6 Tyson core. The lower highstand succession in the Shell #1-678 Wheat well from 7,331 to 7,404 ft (2,234 to 2,257 m) consists of a basal section of muddy inner-inner-shelf deposits (Hmis facies) that grades upward into distal-delta-front and proximal-delta-front sandstones (Hddf and Hpdf facies, respectively). This highstand succession is capped by a thin transgressive sandstone at 7,330 ft (2,234 m), in turn overlain by another upward-coarsening highstand succession.

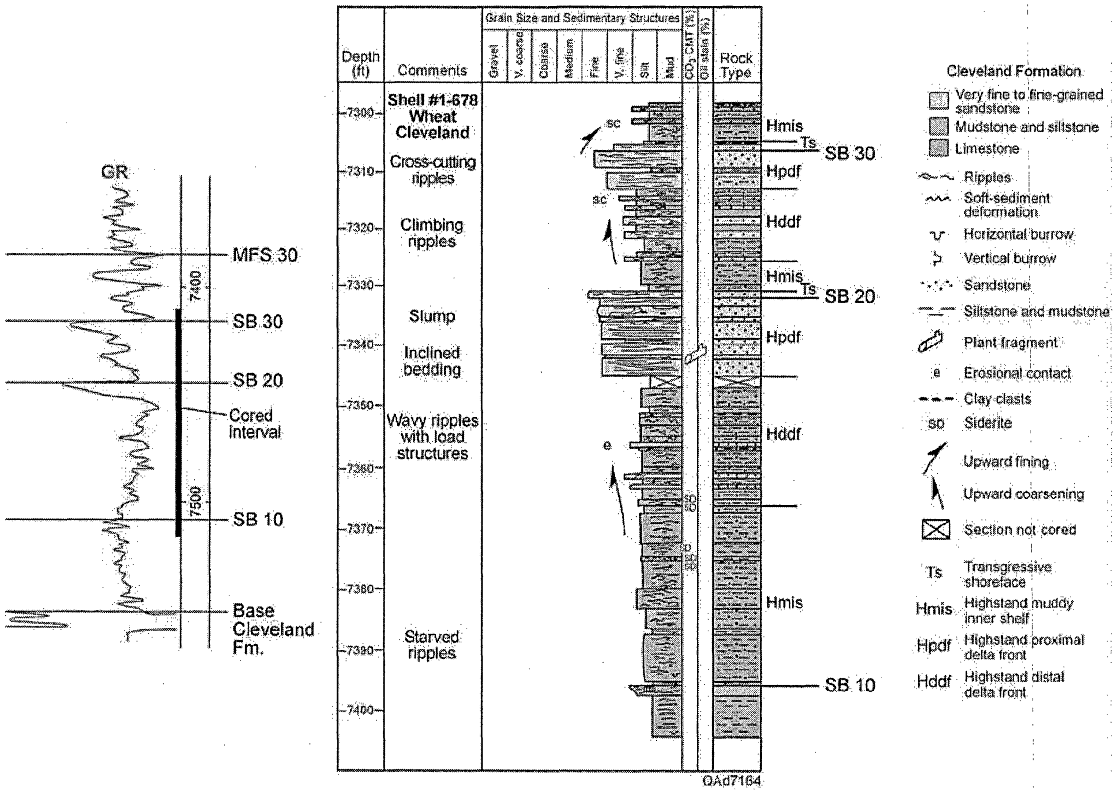

Figure 3. Description and log response of the Cleveland Formation in the Shell #1 Wheat core, located in Fig. 1.

Muddy inner-shelf facies (Hmis) composing the basal part of the highstand systems tract in the Cleveland Formation is overlain by distal-delta-front facies (Hddf). It consists of up to 30 ft (9 m) of sparsely burrowed, silty mudstone, with starved ripples and lenticular beds composed of fine-grained sandstone, as well as discontinuous siltstone laminae. These starved ripples and lenticular beds are typically <1 cm thick. The Hmis facies commonly exhibits no overall grain size, varying from fine- to coarse-grained siltstone, although it locally contains thin (<2-inch [<5.1-cm]) beds of calcareous, fine-grained sandstone.

The predominance of starved and isolated ripples in a muddy matrix in the Hmis facies indicates a low-energy shelf setting typified by suspension sedimentation and periodic sediment transport reflected by starved ripples, consistent with a sparse sand supply periodically transported by weak marine currents on a muddy substrate. The overall bedding is of the form described by Reineck and Wunderlich (1968) as lenticular bedding with single lenses, in which >75% of the ripples (lenses) are discontinuous and encased in mudstone, stratification commonly associated with tidally influenced shelf environments. Weak wave reworking of these shelf deposits is recorded by minor, wavy, and symmetrical ripples, although these are small scale, with ripple heights commonly <0.5 inch (<1.3 cm).

Cleveland highstand delta-front deposits are divided into distal- (Hddf) and proximal-delta-front (Hpdf) facies. Net-sandstone maps of these highstand deltaic facies indicate that they are strongly dip-elongate, subparallel, and linear (see slide set "Sequence Stratigraphy and Depositional Summary of the Marmaton and Cleveland Formations, Anadarko Basin," this volume), consistent with net-sand patterns in modern subaqueous tidal-bar deposits such as those in the Gulf of Korea (Off, 1963), the Gulf of Papua offshore from the mouth of the Fly River (Fisher and others, 1969), and the Gulf of California (Meckel, 1975). A complete delta-front succession with both distal- and proximal-delta-front deposits is present in the Shell #1-678 Wheat well from 7,331 to 7,366 ft (2,234 to 2,245 m). The distal-delta-front section, inferred from 7,345 to 7,366 ft (2,239 to 2,245 m), is composed of sparsely burrowed siltstone and thin (<3-inch [<7.6-cm]) beds of very fine grained sandstone. Sedimentary structures in these distal-delta-front deposits are dominated by asymmetric and wavy, starved ripples. Soft-sediment deformation is common, occurring as slumps and load structures. The proximal-delta-front facies (Hpdf) in the Shell #1-678 Wheat core abruptly overlies the distal-delta-front facies and is composed of upper-fine-grained sandstone. Stratification in the proximal-delta-front facies in the Shell #1-678 Wheat well consists of slightly inclined laminae and crossbeds. Soft-sediment deformation is also present, occurring as slumps with overturned strata. Slumps and soft-sediment deformation, although common in delta-front settings in fluvial-dominated deltas (Coleman and others, 1974; Prior and Coleman, 1978; Elliott, 1989), can also occur in tide-dominated facies, where rapid deposition of material from flood-tidal currents on an unstable substrate can result in rotation and failure of semicoherent material (Rahman and others, 2008; Carmona and others, 2009). The top of the Hpdf facies is capped by a thin, upper, fine-grained sandstone at 7,331 ft (2,234 m), interpreted to represent transgressive deposits, which is in turn overlain by muddy inner-shelf deposits in another highstand cycle. This second highstand succession, which ranges from 7,307 to 7,331 ft (2,227 to 2,234 m), is an upward-coarsening interval that ranges from lenticular, starved ripples in a muddy matrix at the base, grading upward into large-scale, climbing, wavy ripples with significant mud drapes. The section is capped by another thin (<6-inch [<15-cm]) zone of transgressive deposits at 7,307 ft (2,227 m), identified as fine- to very fine grained sandstone with abundant internal scours. This transgressive sandstone is abruptly overlain by burrowed, silty mudstone with thin (millimeter-scale) laminae and starved ripples composed of very fine grained sandstone. This fine-grained section is the lower part of another highstand succession at the top of the cored interval.

Marmaton Group: Sun #1 Blau Core

A small, 22-ft (6.7-m) cored section from the Sun #1 Blau core, located in Fig. 1, is included to show sedimentary structures and facies within a highstand succession in the Marmaton Group for the sake of comparison with similar cored intervals in the Cleveland Formation. This cored interval is from an upward-coarsening Marmaton parasequence that grades upward from horizontally stratified, very fine grained sandstone at the base to fine-grained sandstones with large, wavy ripples with mudstone drapes that are in turn overlain by fine-grained sandstones with internal scour surfaces and flattened clay clasts (Fig. 4). The main part of the cored section from 7,548 to 7,562 ft (2,301 to 2,305 m) is composed of draped, wavy ripples that vary in type from starved ripples/flasers at 7,560 ft (2,304 m) to shale-draped, climbing ripples and large, climbing ripples from 7,552 to 7,560 ft (2,302 to 2,304 m). Many of the shale drapes occur as couplets, especially at 7,554 to 7,555 ft (2,302 to 2,303 m). The upper one-third of the section is dominated by fine-grained sandstone with clay clasts and ripple scours, suggesting relatively high energy deposition and erosional processes consistent with wave or storm scouring. Although the spontaneous potential (SP) curve in the cored section is nonresponsive, the resistivity curve suggests an upward-coarsening grain-size profile. The top of the cored section is near the sequence boundary M_SB_20, inferred in the core at ~7,545 ft (~2,300 m) along the base of the uppermost sandstone bed with internal scour surfaces and clay clasts. The overall upward-coarsening grain-size profile in the cored section is interpreted to record a progradation and offlap of a tidally influenced delta-front succession capped by ravinement scouring during a regional transgression subsequent to a relative-sea-level fall marked by the M_SB_20 sequence boundary.

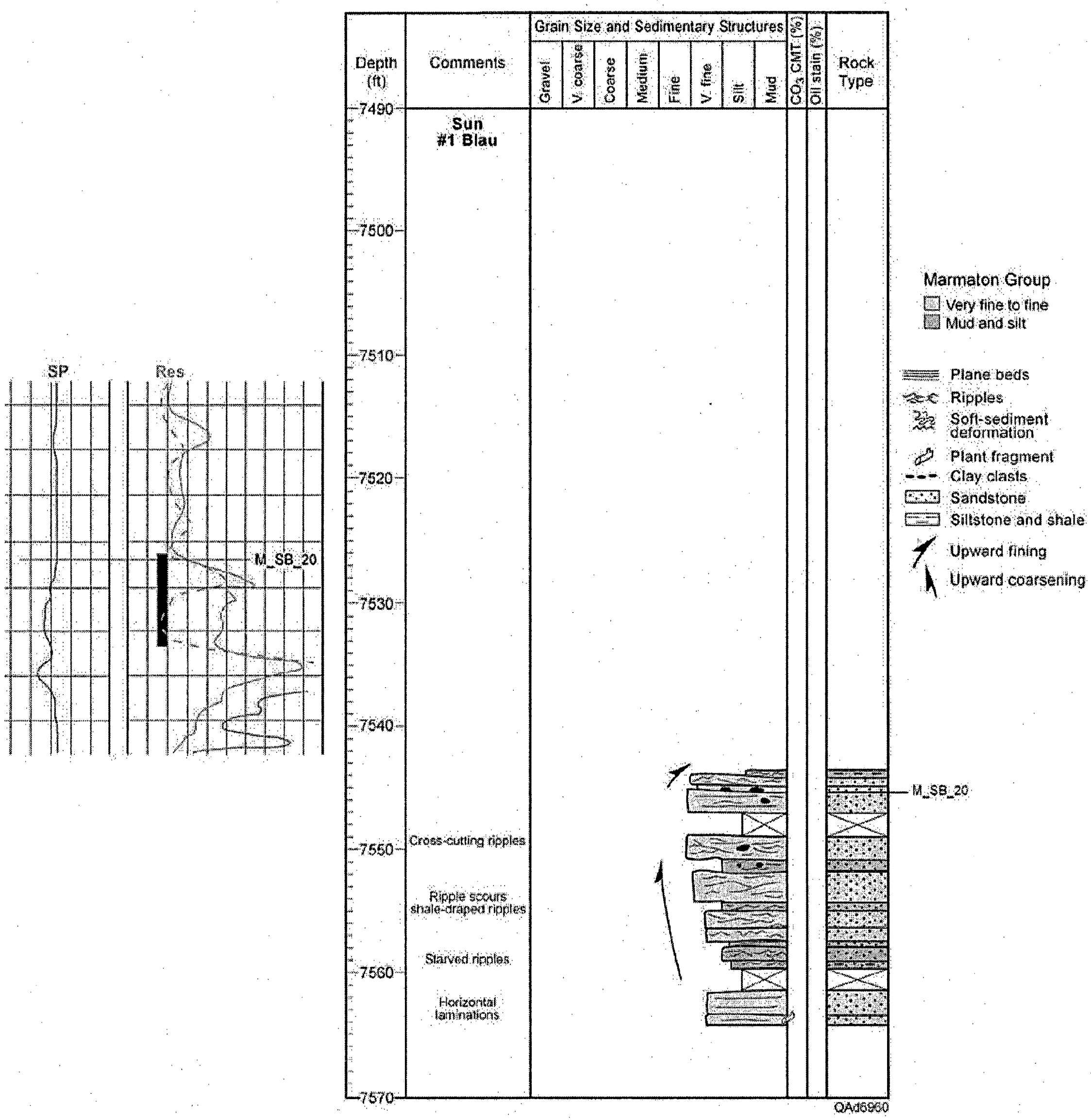

Figure 4. Description and log response of the Marmaton Formation in the Sun #1 Blau core.

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only Dan Jarvie

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Bob	Texas	2007	10/17/07	10/17/2007	Production Data Gathering and Remote Surveillance	Midland	TX
yes	Texas	2007	10/30/07	10/30/2007	Pilot Study of the East Texas Field; Geology, Engineering and Potential Future Exploitation	Kilgore	TX
N	Texas/Central Gulf	1998	12/1/1998	12/1/1998	Fractured Reservoirs (w/DOE & PTTC Central Gulf)	Tyler	TX

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Geological, Petrophysical, and Engineering Aspects of Avoiding Reserves Writedowns: presented to PTTC Texas Region, Farmers Branch, Texas, September 2005.

Stranded Gas, Options for Realizing Value: presented to PTTC Texas Region, Wichita Falls, Texas, September 2005.

Introduction to Mining the Internet: Using Free GIS Data and Low Cost Software for the Oil & Gas Professional: presented to PTTC Texas Region, Midland, Texas, September 2005.

Introduction to Mining the Internet: Using Free GIS Data and Low Cost Software for the Oil & Gas Professional: presented to PTTC Texas Region, Farmington, New Mexico, September 2005.

Barnett Shale Symposium III: presented to PTTC Texas Region, Farmers Branch, Texas, June 2005.

Turning Emissions into Significant Profits: presented to PTTC Texas Region, Corpus Christi, Texas, June 2005.

Material Balance, Modeling, and Simulation: Reservoir Engineering Tools Past, Present, and Future: presented to PTTC Texas Region, Houston, Texas, June 2005.

Drillinginfo.com seminar: presented to PTTC Texas Region, Farmers Branch, Texas, May 2005.

Rocks, Pores, and Capillary Pressure: The Hole Story on How to Understand Reservoirs and Seals by Thinking like Oil and Gas: presented to PTTC Texas Region, Farmers Branch, Texas, March 2005.

Production Data: Collecting It and Using It!: presented to PTTC Texas Region, Midland, Texas, March 2005.

Production Data: Collecting It and Using It!: presented to PTTC Texas Region, Farmington, New Mexico, March 2005.

Sand Control Workshop: presented to PTTC Texas Region, Houston, Texas, March 2005.

Stratigraphic Synthesis of Paleozoic Oil-Bearing Depositional Systems: Data and Models for Recovering Existing and Undiscovered Oil Resources from the Permian Basin: presented to PTTC Texas Region, Houston, Texas, December 2004.

Lunch and Learn: Technology in Well Optimization Utilizing New Technologies: presented to PTTC Texas Region, Houston, Texas, December 2004.

Converting Stranded Gas and Lowering Power/Operating Costs Workshop: presented to PTTC Texas Region, Midland, Texas, December 2004.

Deep Gas Well Simulation Workshop: presented to PTTC Texas Region, Houston, Texas, December 2004.

Lunch and Learn: Technology in Well Optimization Utilizing New Technologies in Field Automation and Remote Monitoring: presented to PTTC Texas Region, Midland, Texas, December 2004.

Essentials of Subsurface Mapping: presented to PTTC Texas Region, San Antonio, Texas, November 2004.

Stratigraphic Synthesis of Paleozoic Oil-Bearing Depositional Systems: Data and Models for Recovering Existing and Undiscovered Oil Resources from the Permian Basin: presented to PTTC Texas Region, Midland, Texas, November 2004.

Unconventional Reservoirs Symposium: presented to PTTC Texas Region, Farmers Branch, Texas, November 2004.

Produced Water and Associated Issues: presented to PTTC Texas Region, Wichita Falls, Texas, November 2004.

Polymer and Polymer-Gel Water Shutoff Treatments: What It Takes To Be Successful and Illustrative Field Applications: PTTC Texas Region, Houston, Texas, August 2004.

Reservoir Fluids: from the Matrix to the Market—What You Don't Know CAN Hurt You: PTTC Texas Region, Houston, Texas, July 2004.

Operators Working in Offshore Texas State Waters Royalty Leases: PTTC Texas Region, Houston, Texas, June 2004.

Soil Remediation: PTTC Texas Region, Hobbs, New Mexico, June 2004.

Barnett Shale and Other Fort Worth Basin Plays: PTTC Texas Region, Farmers Branch, Texas, June 2004.

Low-Cost Rod Pump Control: PTTC Texas Region, Farmers Branch, Texas, March 2004.

Low-Cost Rod Pump Control: PTTC Texas Region, Midland, Texas, March 2004.

Soil Remediation: PTTC Texas Region, Tyler, Texas, January 2004.

Integrated Synthesis of Permian Basin Depositional History and Stratigraphic Architecture: Data and Models for Recovering Existing and Undiscovered Oil Resources: PTTC Texas Region, Midland, Texas, January 2004.

Low-Cost Rod Pump Control: PTTC Texas Region, Houston, Texas, October 2003.

Understanding Paraffin and Asphaltene Problems in Oil and Gas Wells: PTTC Texas Region, San Angelo, Texas, September 2003.

Visualization Seminar: presented at Bureau of Economic Geology, Austin, Texas, September 2003.

Inexpensive, Rapid Cross-Section Generation Utilizing MJ Systems' Raster Log Images and DigiRule's CrossLog Suite™ Software: PTTC Texas Region, Austin, Texas, August 2003.

Produced Water and Associated Issues: PTTC Texas Region, Farmers Branch, Texas, August 2003.

Produced Water and Associated Issues: PTTC Texas Region, Midland, Texas, August 2003.

Reservoir Fluids: PTTC Texas Region, Houston, Texas, June 2003.

New Methods for Locating and Recovering Remaining Hydrocarbons in the Permian Basin: PTTC Texas Region, Midland, Texas, May 2003.

Hydraulic Fracturing: PTTC Texas Region, Shreveport, Louisiana, April 2003.

Well Cuttings: PTTC Texas Region, Houston Research Center, Houston, Texas, April 2003.

SONRIS Database Web Interface: PTTC, Houston, Texas, November 2002.

Inexpensive, Rapid Cross-section Generation Utilizing MJ Systems' Raster Log Images and DigiRule's CrossLog Suite™ Software: PTTC Texas Region, Austin, Texas, October 2002.

New Resources from Old Fields: Revitalizing Gas Exploration and Production in the Gulf of Mexico Shelf Province: PTTC Texas Region, Austin, Texas, September 2002.

Wellbore Management: PTTC Texas Region, Tyler, Texas, September 2002.

Inexpensive, Rapid Cross-section Generation Utilizing MJ Systems' Raster Log Images and DigiRule's CrossLog Suite™ Software: PTTC Texas Region, Austin, Texas, September 2002.

Optimizing Horizontal Well Technology: PTTC Texas Region, Austin, Texas, May 2001.

Predicting Reservoir Quality Using Diagenetic Models: PTTC Texas Region, Austin, Texas, March 2001.

Reservoir Characterization Technologies for the Next Millennium: Virtual Reality, Multicomponent Seismic, Fracture Modeling, and Borehole Imaging: PTTC Texas Region, Austin, Texas, February 2000.