CENTER FOR ENERGY STUDIES

BOSSIER - HAYNESVILLE SHALE: NORTH LOUISIANA SALT BASIN

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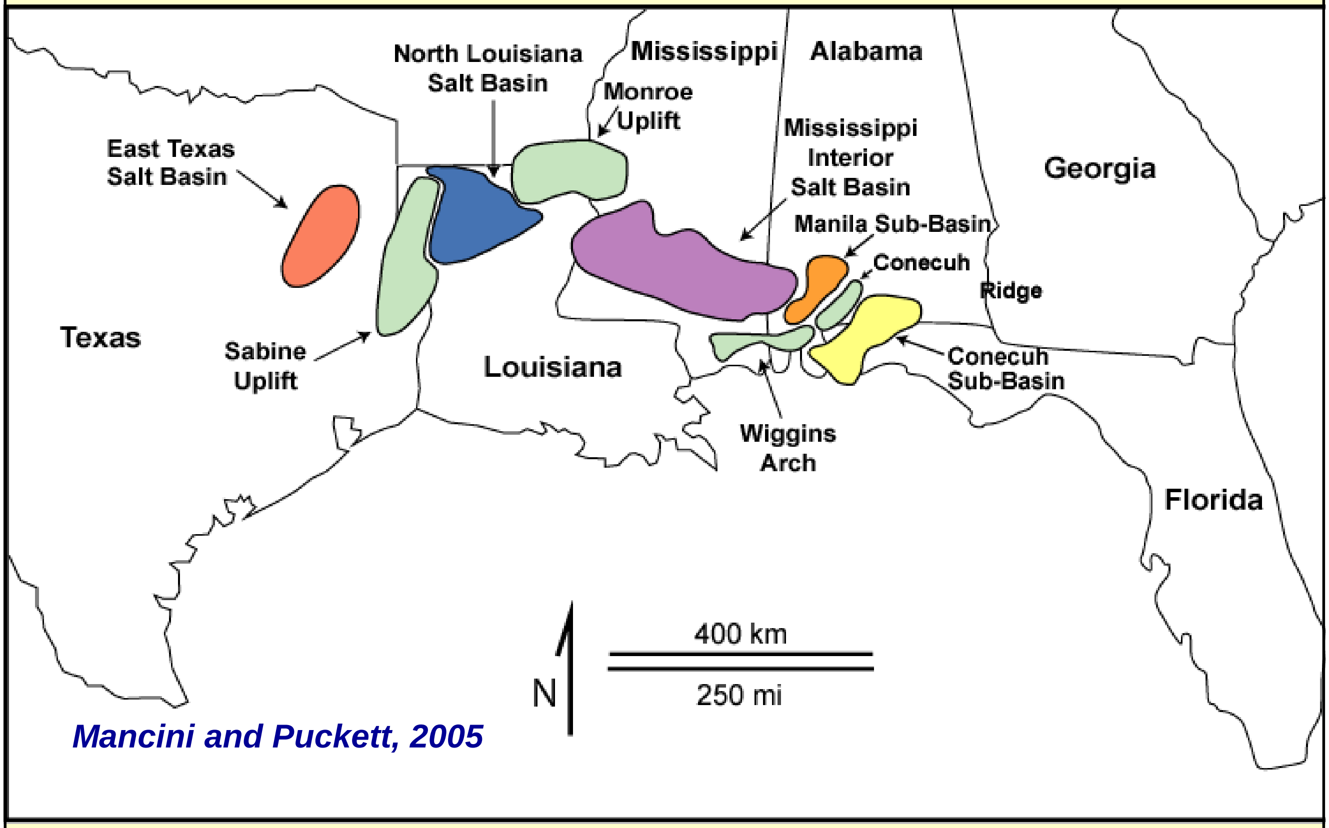
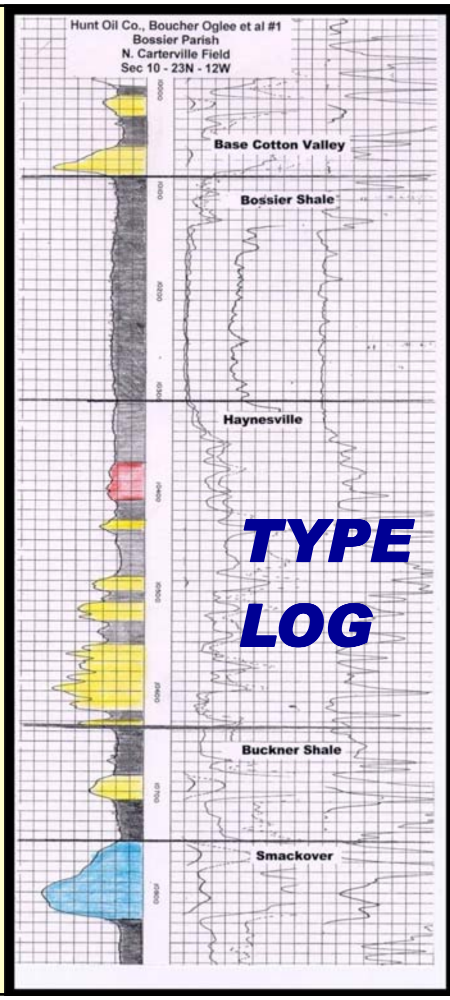
OVERVIEW

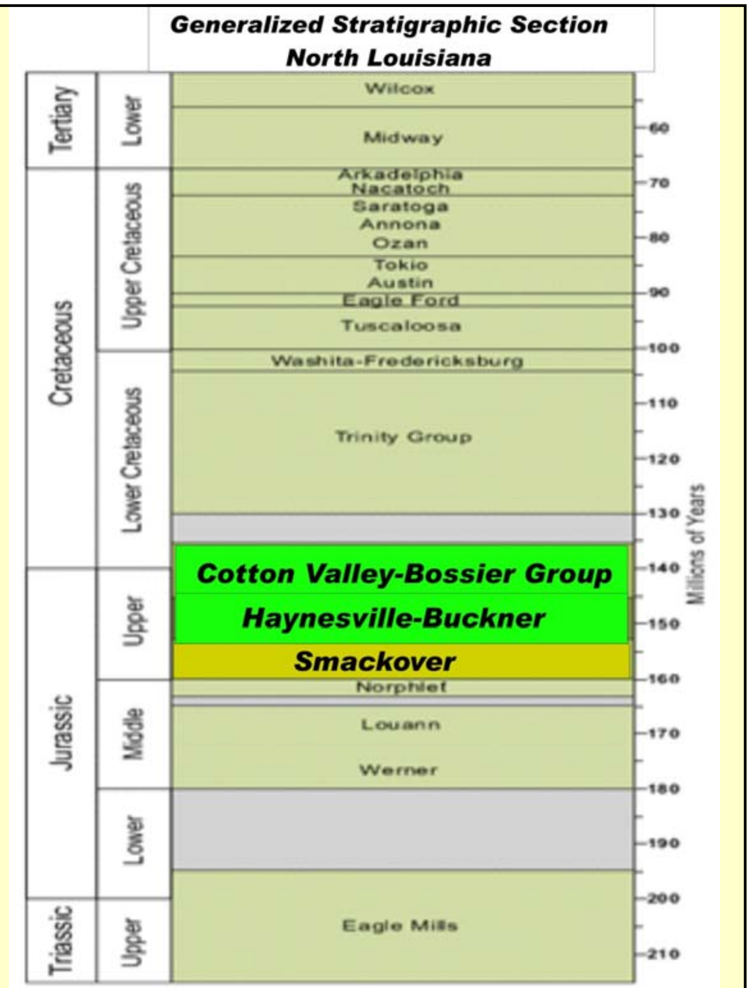
- ***Regional Geological Setting***
- ***Total Organic Carbon & Rock-Eval Pyrolisis***
- ***Kerogen Petrography***
- ***Thin Section Petrography***
- ***Naturally Fractured Shale Reservoirs***
- ***Conclusions***

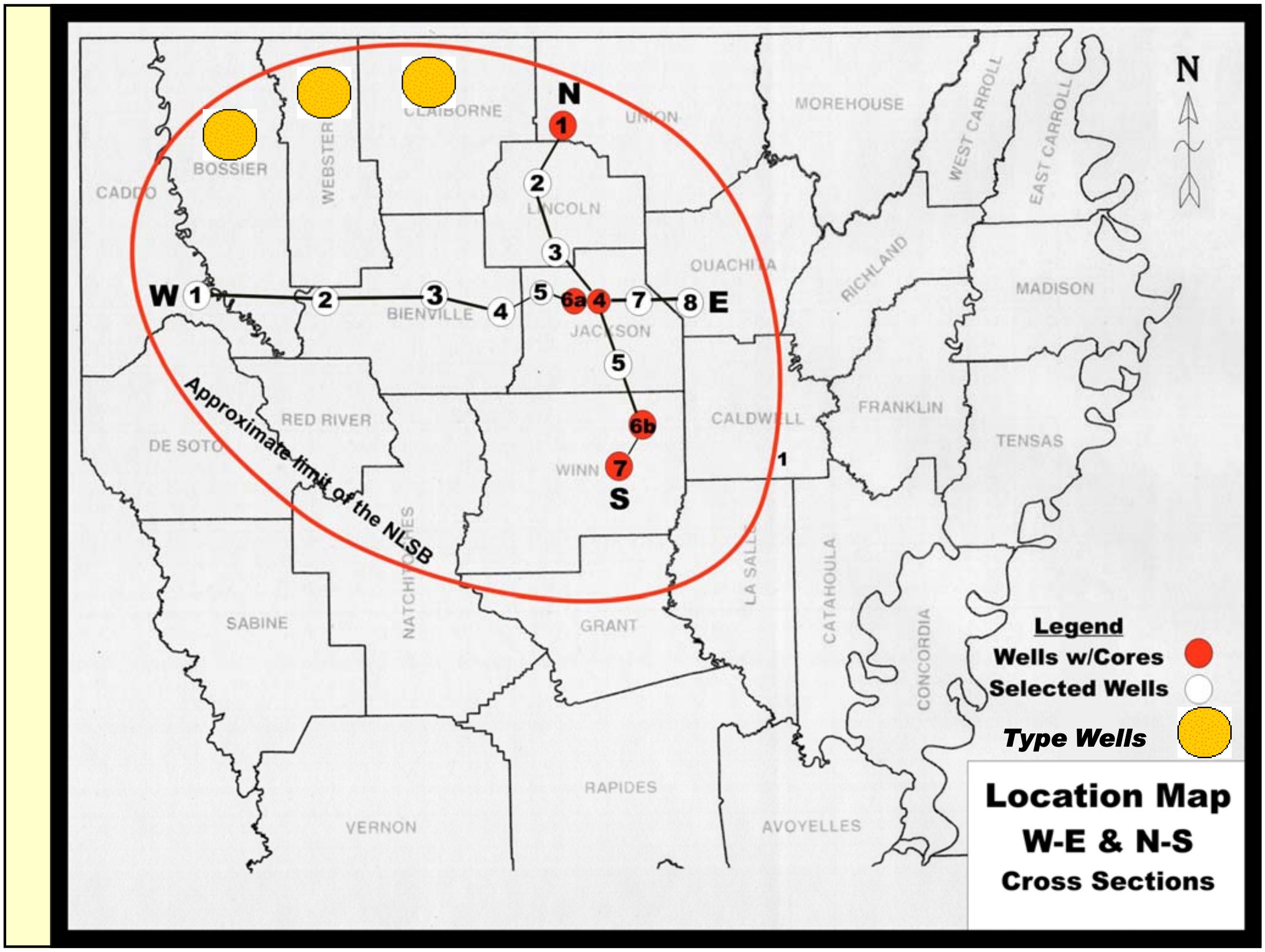
Gulf Coast Interior Basins



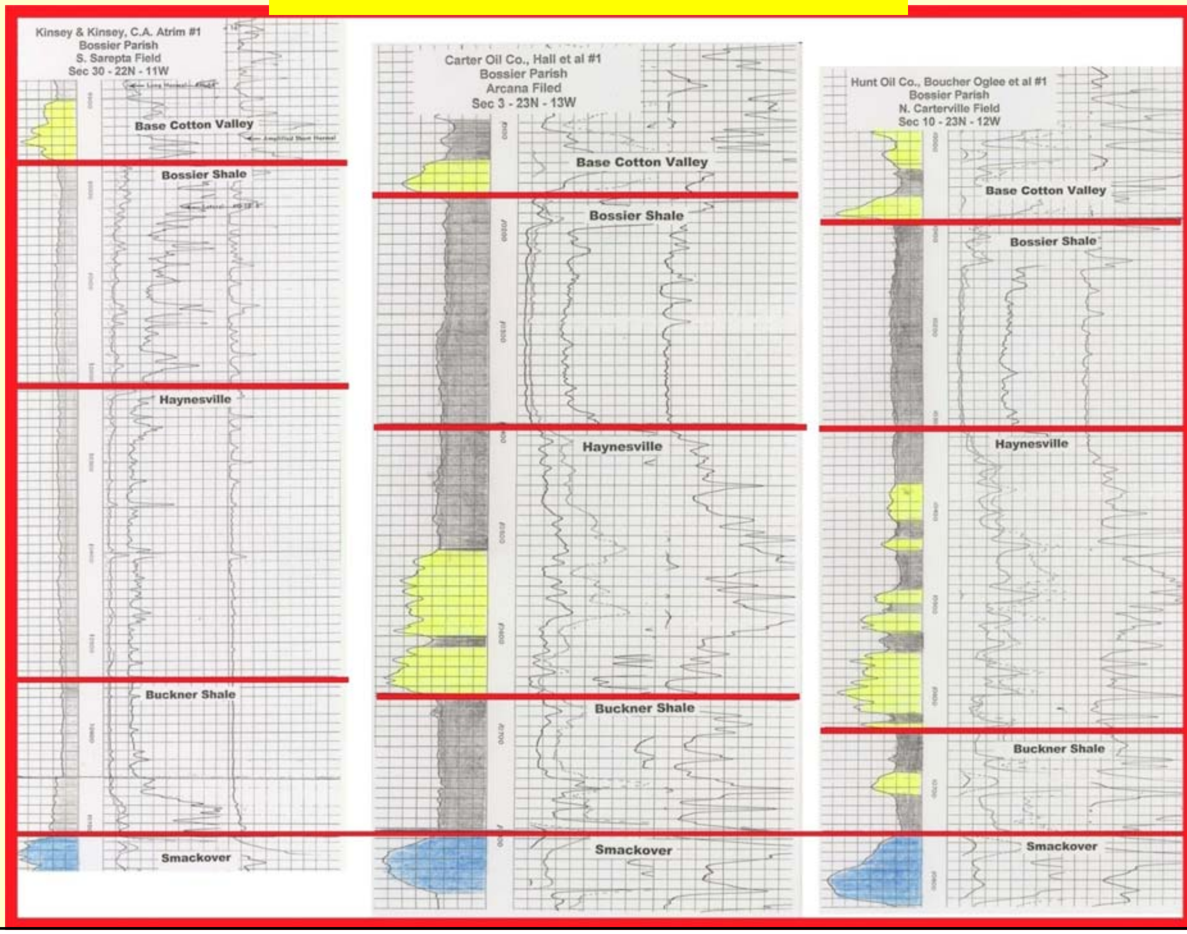
Mancini and Puckett, 2005


Hunt Oil Co., Boucher Oglee et al #1
Bossier Parish
N. Carterville Field
Sec 10 - 23N - 12W
Base Cotton Valley
Bossier Shale
Haynesville
Buckner Shale
Smackover
TYPE LOG


Generalized Stratigraphic Section
North Louisiana
Tertiary
Lower
Cretaceous
Upper Cretaceous
Lower Cretaceous
Jurassic
Upper
Middle
Lower
Triassic
Upper
Wilcox
Midway
Arkadelphia
Nacatoch
Saratoga
Annona
Ozan
Tokio
Austin
Eagle Ford
Tuscaloosa
Washita-Fredericksburg
Trinity Group
Cotton Valley-Bossier Group
Haynesville-Buckner
Smackover
Norphlet
Louann
Werner
Eagle Mills
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
Millions of Years

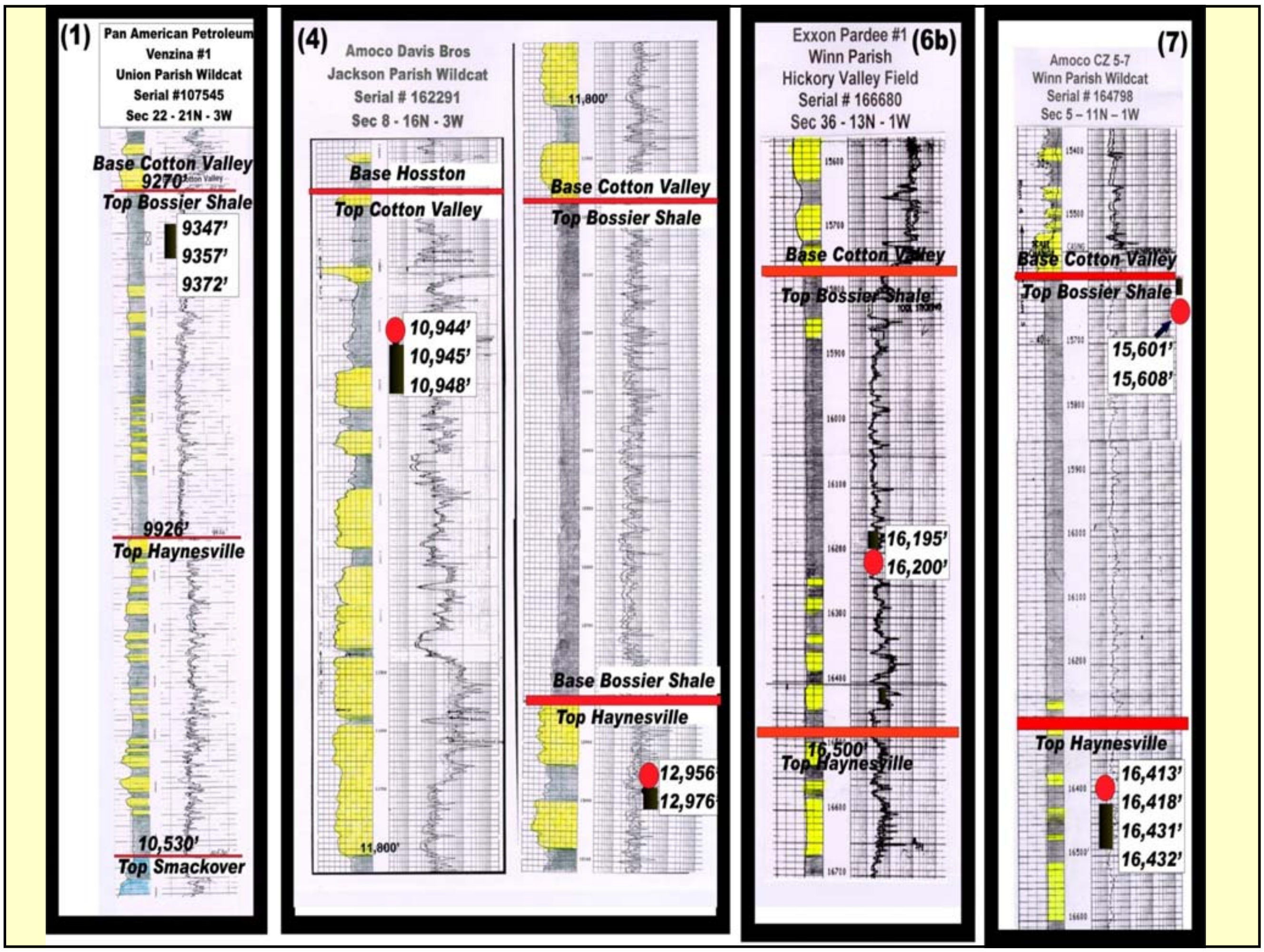

N
N
UNION
MOREHOUSE
WEST CARROLL
EAST CARROLL
CLAIBORNE
BOSSIER
WEBSTER
CADDO
LINCOLN
OUACHITA
RICHLAND
MADISON
W
E
BIENVILLE
JACKSON
Approximate limit of the NLSB
RED RIVER
DE SOTO
CALDWELL
FRANKLIN
TENSAS
WINN
S
NATCHITOCHES
LA SALLE
CATAHOULA
SABINE
GRANT
CONCORDIA
RAPIDES
VERNON
AVOYELLES
Legend
Wells w/Cores
Selected Wells
Type Wells
Location Map
W-E & N-S
Cross Sections

Bossier Parish Wells



Bossier-Haynesville samples in NLSB .

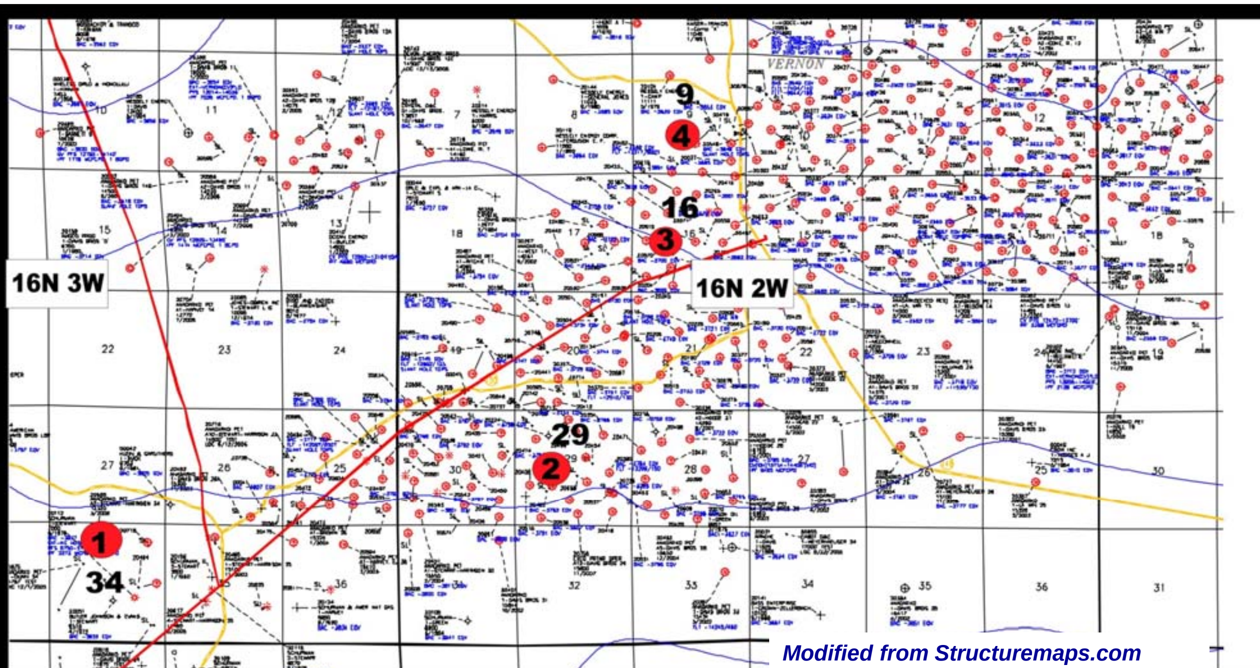
(Serial #)	OP/Well Name	(LA Parish) Core Interval	Sample Depth-Ft
		(Jackson)	10,944
(162291)	AMOCO Davis Bros.	Bossier Fm.	10,945
			10,948
		Haynesville Fm.	12,804
			12,956
			12,976
(164798)	AMOCO CZ 5-7	(Winn)	15,601
		Bossier Fm.	15,608
		Haynesville Fm.	16,413
			16,418
			16,431
			16,432
(166680)	EXXON Pardee	(Winn)	16195
		Bossier Fm.	16,200
			16,400
(107545)	Venzina Green #1	(Union)	9,347
		Bossier Fm.	9,357
			9,372



(1)
Pan American Petroleum
Venzina #1
Union Parish Wildcat
Serial #107545
Sec 22 - 21N - 3W
Base Cotton Valley
9270'
Top Bossier Shale
9347'
9357'
9372'
9926'
Top Haynesville
10,530'
Top Smackover
(4)
Amoco Davis Bros
Jackson Parish Wildcat
Serial # 162291
Sec 8 - 16N - 3W
Base Hosston
Top Cotton Valley
10,944'
10,945'
10,948'
11,800'
Base Cotton Valley
Top Bossier Shale
Base Bossier Shale
Top Haynesville
12,956'
12,976'
Exxon Pardee #1
Winn Parish
Hickory Valley Field
Serial # 166680
Sec 36 - 13N - 1W
(6b)
Base Cotton Valley
Top Bossier Shale
16,195'
16,200'
16,500'
Top Haynesville
(7)
Amoco CZ 5-7
Winn Parish Wildcat
Serial # 164798
Sec 5 – 11N – 1W
Base Cotton Valley
Top Bossier Shale
15,601'
15,608'
Top Haynesville
16,413'
16,418'
16,431'
16,432'

Bossier -Haynesville samples in Vernon Field

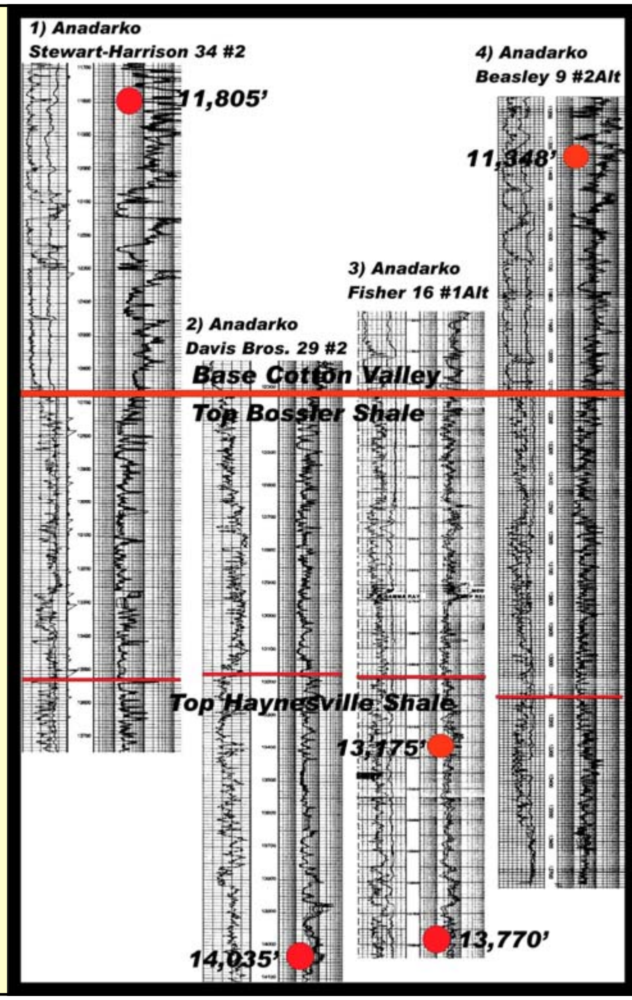
Serial. #	Operator	Well	Field	Sec	TWP	RGE	Parish	Sample Depth-Ft
224274	Anadarko	Fisher 16 #1	Vernon	16	16N	02W	Jackson	13,175
								13,770
226742	Anadarko	Davis Bros 29	Vernon	29	16N	02W	Jackson	14,035
								15,120
231813	Anadarko	Beasley 9 #2	Vernon	9	16N	02W	Jackson	11,348
232316	Anadarko	StewtHarrison 34 #2	Vernon	34	16N	03W	Jackson	11,805



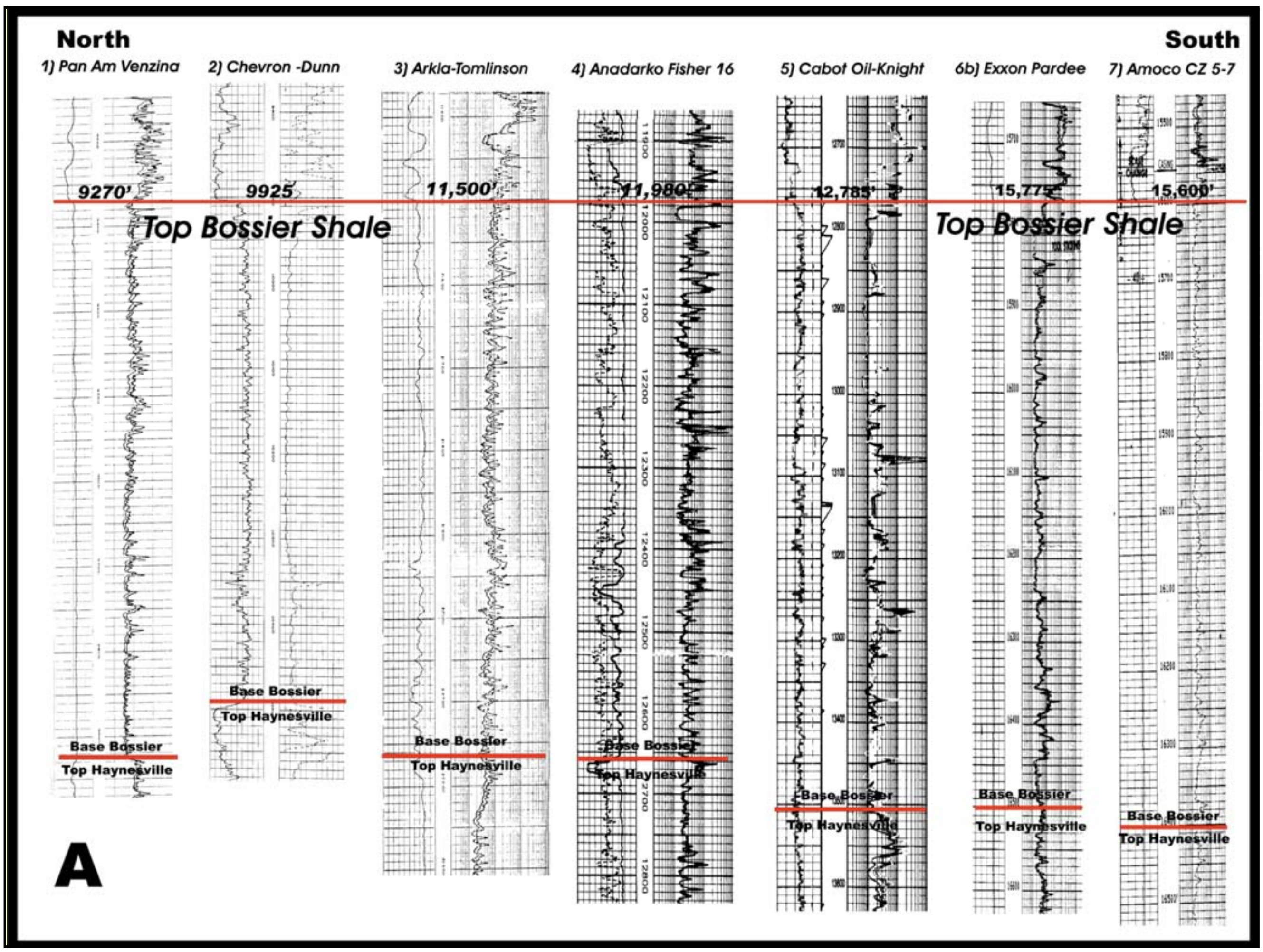
Cored Wells in Vernon Field Selected for Analysis

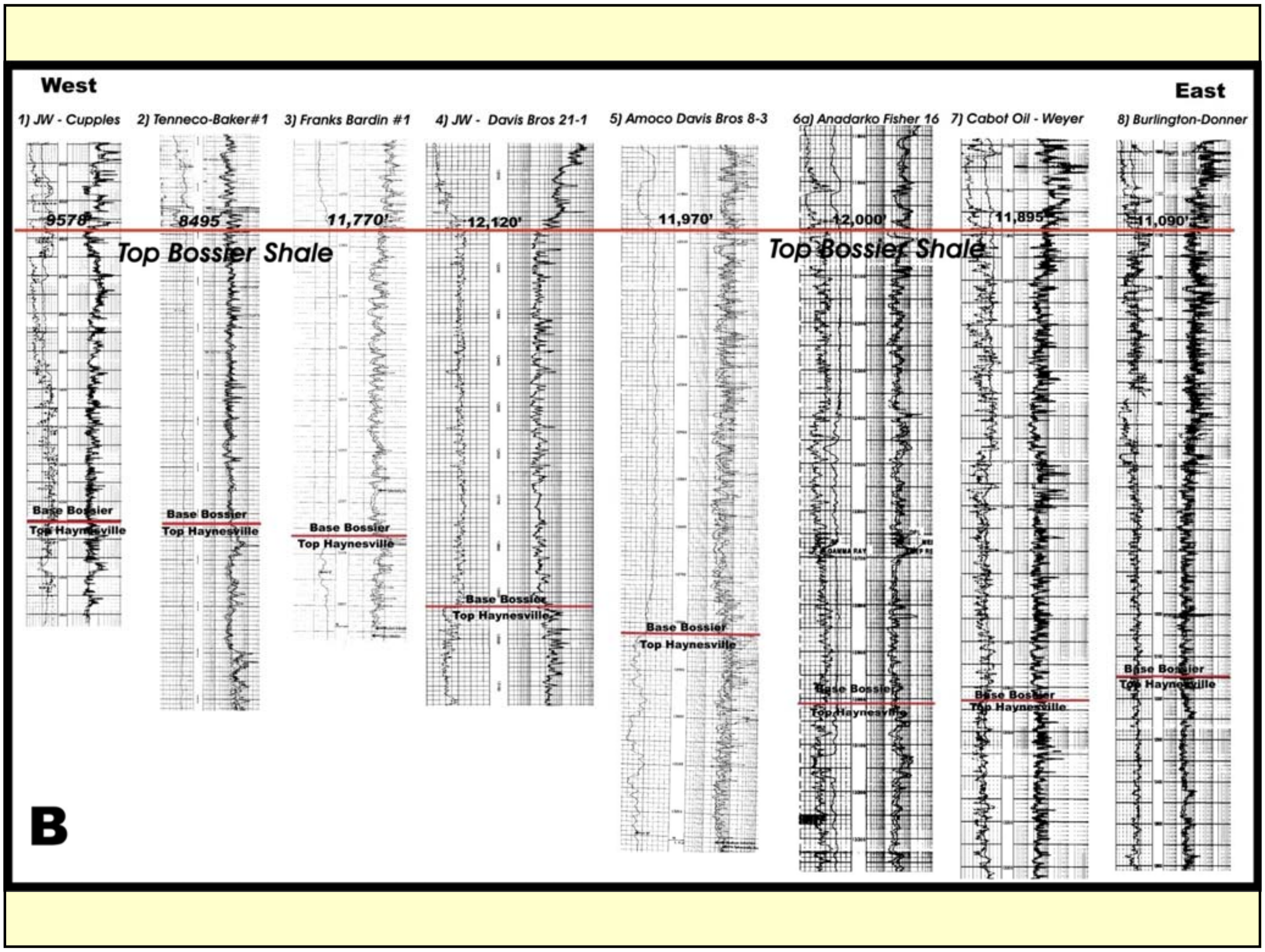
1) Anadarko Stewart Harrison 34 #2; Sec 34 16N 03W
2) Anadarko Davis Bros. 29 #2Alt; Sec 29 16N 02W
3) Anadarko Fisher 16 #1Alt; Sec 16 16N o2W
4) Anadarko Beasley 9 #2Alt; Sec 9 16N 02W

Location Map
Vernon Field
Jackson Parish
Sampled Wells



1) Anadarko
Stewart-Harrison 34 #2
11,805'
4) Anadarko
Beasley 9 #2Alt
11,348'
3) Anadarko
Fisher 16 #1Alt
2) Anadarko
Davis Bros. 29 #2
Base Cotton Valley
Top Bossier Shale
Top Haynesville Shale
13,175'
14,035'
13,770'

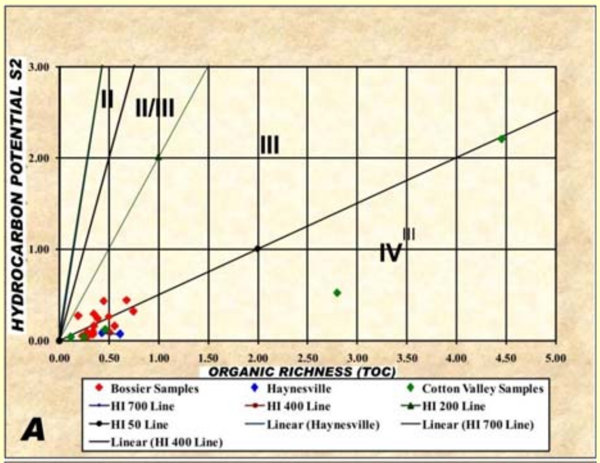

North
South
1) Pan Am Venzina
2) Chevron -Dunn
3) Arkla-Tomlinson
4) Anadarko Fisher 16
5) Cabot Oil-Knight
6b) Exxon Pardee
7) Amoco CZ 5-7
9270'
9925
11,500'
11,980'
12,785'
15,775'
15,600'
Top Bossier Shale
Top Bossier Shale
Base Bossier
Top Haynesville
A

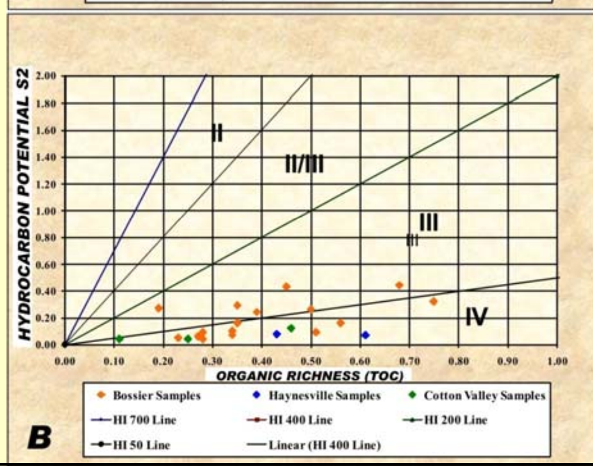

West
East
1) JW - Cupples
2) Tenneco-Baker#1
3) Franks Bardin #1
4) JW - Davis Bros 21-1
5) Amoco Davis Bros 8-3
6a) Anadarko Fisher 16
7) Cabot Oil - Weyer
8) Burlington-Donner
9578'
8495'
11,770'
12,120'
11,970'
12,000'
11,895'
11,090'
Top Bossier Shale
Top Bossier Shale
Base Bossier
Top Haynesville
B

Analytical results of Total Organic Carbon, Rock-Eval Pyrolysis, and Vitrinite Reflectance (Ro) in the NLSB.

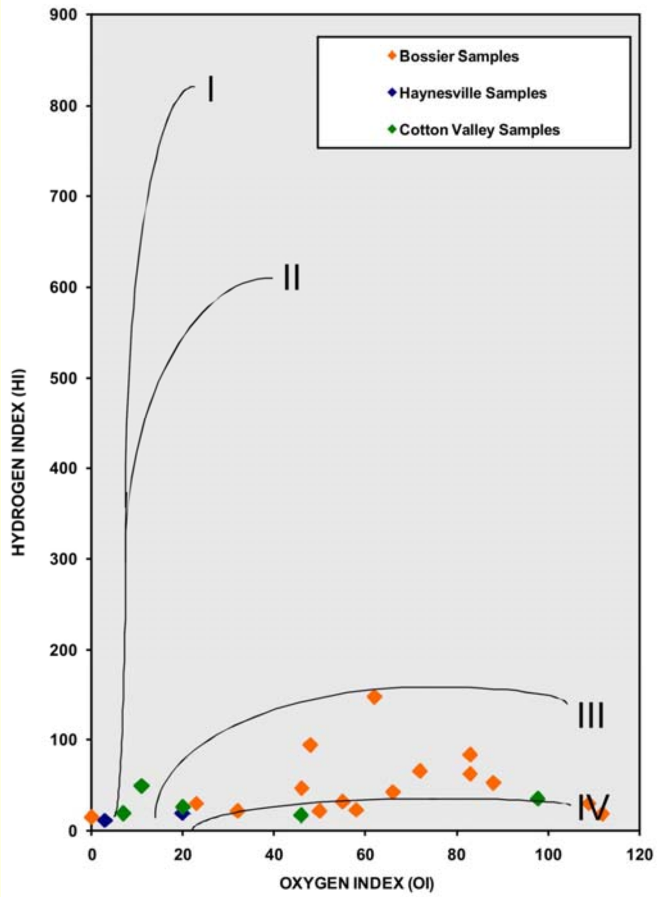
Well	Sample	Depth (Ft)	TOC Wt %	S1 mg/g	S2 mg/g	S3 mg/g	Tmax	HI	OI	S1/TOC	PI	TAI	% Ro
AMOCO DAVIS	Cotton V.	10,944	0.46	0.14	0.12	0.09	331	26	20	30	0.54		
AMOCO DAVIS	Cotton V.	10,945	0.25	0.04	0.04	0.12	442	17	46	17	0.49		
AMOCO DAVIS	Cotton V.	10,948	0.11	0.02	0.04	0.11	424	35	98	18	0.33		
AMOCO DAVIS	Haynesville	12,956	0.43	0.1	0.08	0.22	304	19	20	43	0.56	3.5-3.7	1.73
AMOCO DAVIS	Haynesville	12,976	0.61	0.11	0.07	0.02	313	11	3	18	0.61	3.5-3.7	1.77
AMOCO CZ 5-7	Bossier	15,601	0.27	0.04	0.06	0.13	375	21	50	15	0.42		
AMOCO CZ 5-7	Bossier	15,608	0.28	0.02	0.04	0	307	14	0	7	0.33		
AMOCO CZ 5-7	Haynesville	16,413	0.23	0.04	0.05	0.14	379	22	58	18	0.45		
AMOCO CZ 5-7	Haynesville	16,418	0.34	0.05	0.07	0.11	355	21	32	15	0.42		
AMOCO CZ 5-7	Haynesville	16,431	0.34	0.06	0.1	0.37	329	29	109	18	0.38	3.7-3.8	2.62
AMOCO CZ 5-7	Haynesville	16,432	0.28	0.05	0.09	0.15	375	31	55	18	0.37		
EXXON PARDEE	Bossier	16,195	0.19	0.18	0.27	0.12	370	147	62	96	0.39		
EXXON PARDEE	Bossier	16,200	0.35	0.21	0.29	0.29	322	83	83	60	0.42		
EXXON PARDEE	Bossier	16,400	0.35	0.19	0.16	0.16	328	46	46	54	0.54	3.7-3.8	2.06
PAN AM VENZINA	Bossier	9347	0.50	0.06	0.26	0.44	442	52	88	12	0.19	2.8-3.0	0.91
PAN AM VENZINA	Bossier	9357	0.45	0.19	0.43	0.22	451	94	48	41	0.30	2.8-3.0	0.96
PAN AM VENZINA	Bossier	9372	0.39	0.10	0.24	0.32	449	62	83	26	0.29	2.8-3.0	0.96
STWEHARRISON	Cotton V.	11,805	2.80	0.26	0.52	0.19	491	19	7	9	0.33	3.0-3.2	1.07
FISHER 16-1	Haynesville	13,175	0.51	0.17	0.09	0.57	406	18	112	33	0.65	3.3-3.5	1.72
FISHER 16-1	Haynesville	13,770	0.56	0.16	0.16	0.13	436	29	23	29	0.50	3.3-3.5	1.89
DAVIS Bros 29-2	Haynesville	14,035	0.68	0.87	0.44	0.49	359	65	72	128	0.66	3.5-3.7	1.94
DAVIS Bros 29-2	Haynesville	15,120	0.75	0.53	0.32	0.50	360	42	66	70	0.62	3.7-3.9	2.28
BEASLEY 9-#2	Cotton V.	11,348	4.46	1.31	2.20	0.47	464	49	11	29	0.37	3.3-3.5	1.43

Hydrocarbon Potential S2 vs TOC Diagram

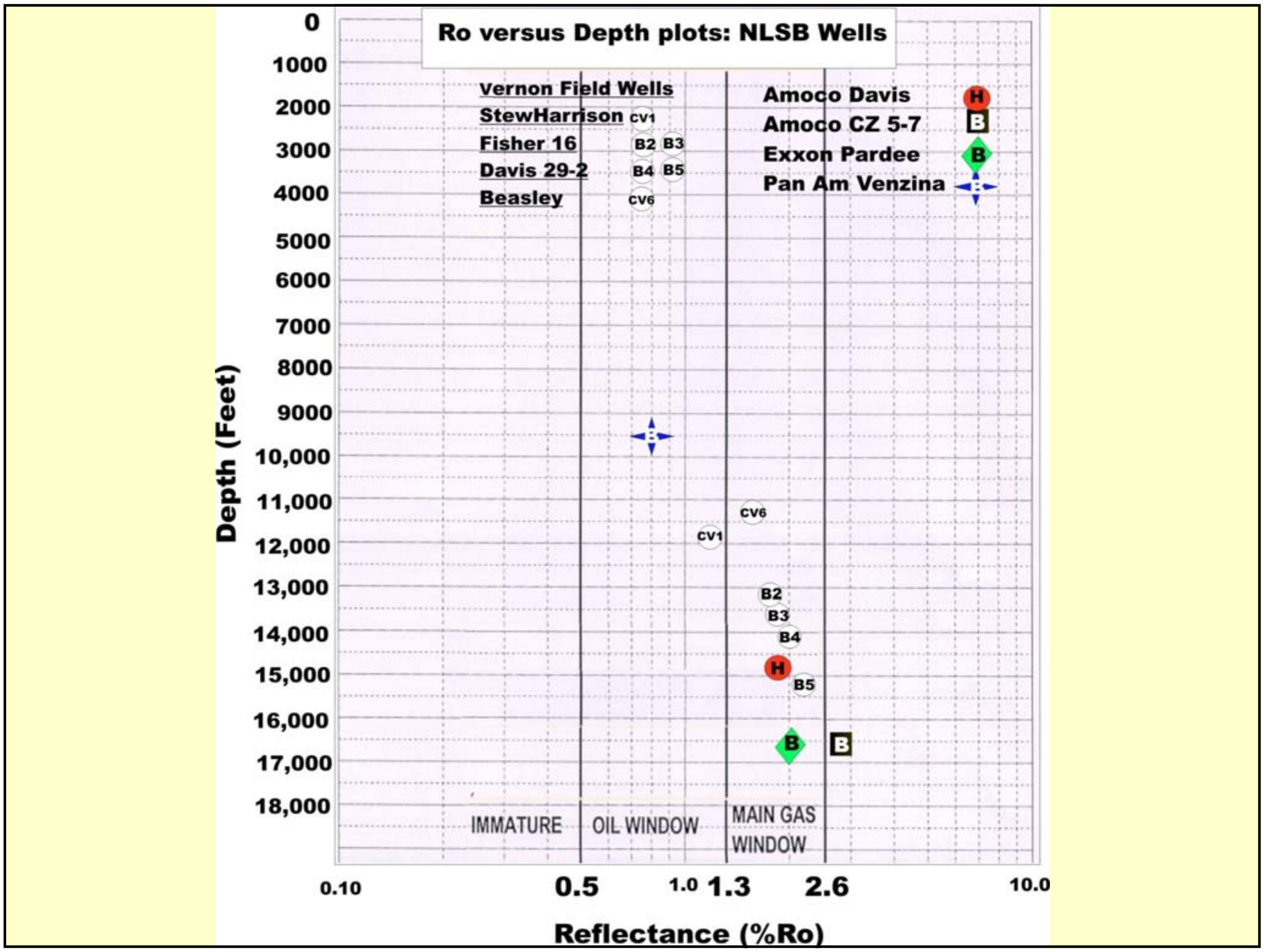




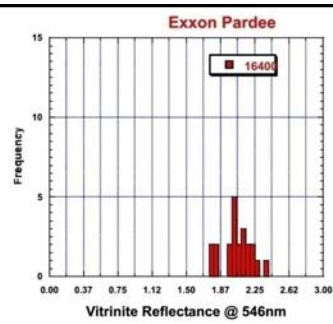
Hydrogen Index vs. Oxygen Index Diagram

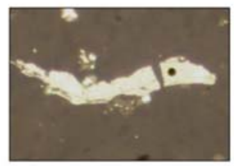


Mostly gas generative, typical of those with type III kerogen



Ro versus Depth plots: NLSB Wells
Vernon Field Wells
StewHarrison CV1
Fisher 16 B2 B3
Davis 29-2 B4 B5
Beasley CV6
Amoco Davis H
Amoco CZ 5-7 B
Exxon Pardee B
Pan Am Venzina
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
Depth (Feet)
IMMATURE
OIL WINDOW
MAIN GAS WINDOW
0.10
0.5
1.0
1.3
2.6
10.0
Reflectance (%Ro)





Pardee	16400
Minimum	1.77
Maximum	2.38
Points	22
Std Deviation	0.16
Mean	**2.06**

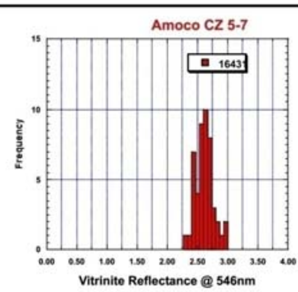
Ordered Ro Values

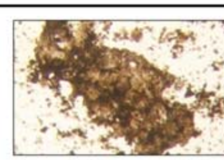
1.77	1.80	1.82	1.83	1.95	1.96	2.00	2.00	2.01	2.02	2.05	2.06
2.10	2.12	2.13	2.14	2.16	2.17	2.23	2.24	2.28	2.38		

Visual Kerogen Analysis

Client ID	Sample ID	Depth	%Alg.	%Lip.	% Vit.	%Inert.	Liptinite Fluores.	% Oil Prone	% Gas Prone	TAI	Spore Color
Pardee	LS000385	16,400		60	30	10	none	60	30	3.7-3.8	brown-black

A





Amoco CZ 5-7	16431
Minimum	2.32
Maximum	2.99
Points	48
Std Deviation	0.15
Mean	**2.62**

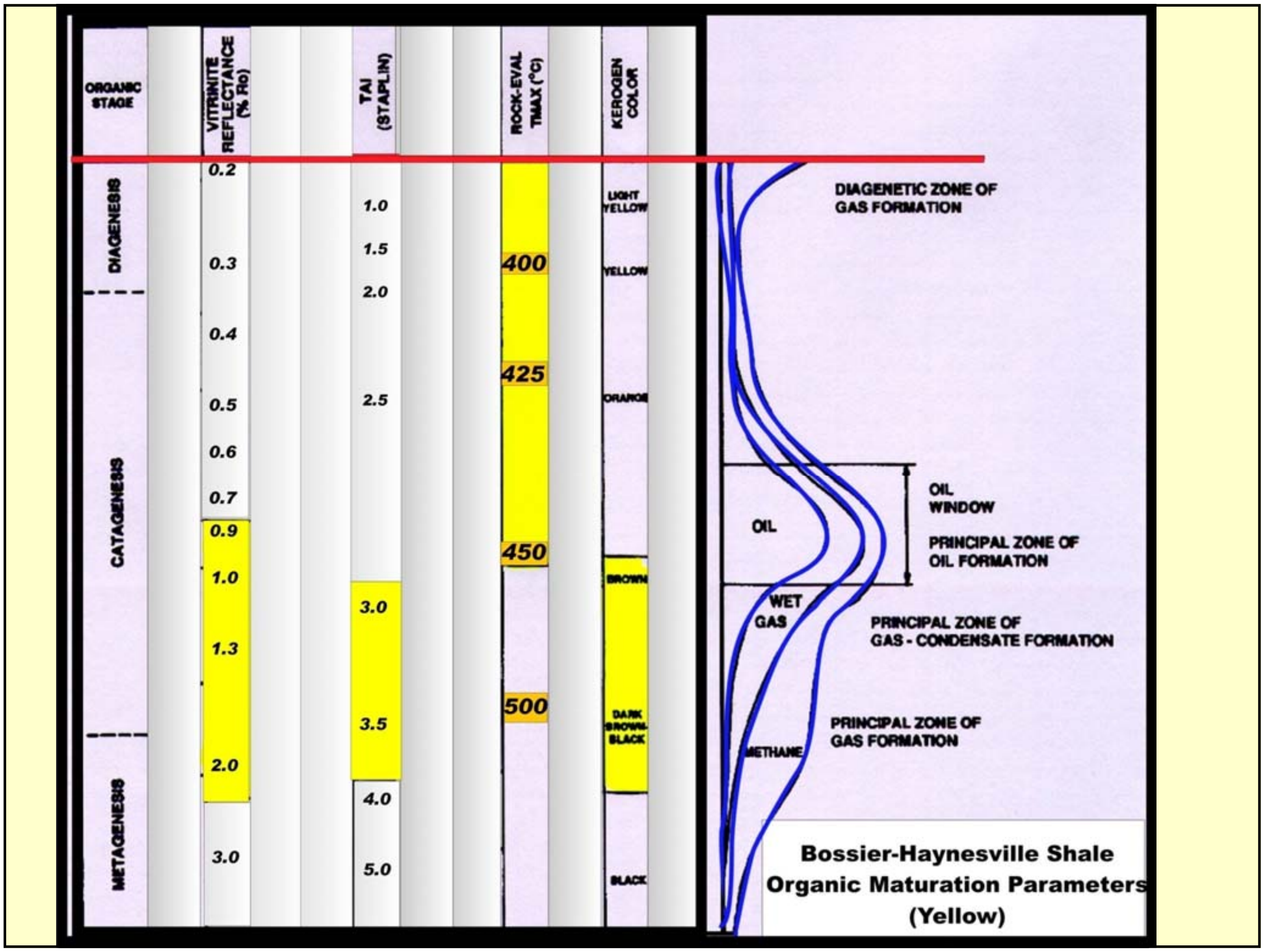
Ordered Ro Values

2.32	2.39	2.42	2.42	2.42	2.44	2.44	2.45	2.45	2.47	2.49	2.52
2.52	2.54	2.54	2.56	2.56	2.57	2.58	2.58	2.60	2.60	2.61	2.61
2.62	2.62	2.64	2.64	2.64	2.65	2.65	2.66	2.67	2.68	2.68	2.69
2.69	2.69	2.70	2.73	2.74	2.74	2.80	2.81	2.84	2.89	2.98	2.99

Visual Kerogen Analysis

Client ID	Sample ID	Depth	%Alg.	%Lip.	% Vit.	%Inert.	Liptinite Fluores.	% Oil Prone	% Gas Prone	TAI	Spore Color
CZ	LS000386	16,431		30	60	10	none	30	60	3.7-3.8	brown-black

B



ORGANIC STAGE
VITRINITE REFLECTANCE (% Ro)
TAI (STAPLIN)
ROCK-EVAL TMAX (°C)
KEROGEN COLOR
DIAGENESIS
CATAGENESIS
METAGENESIS
0.2
0.3
0.4
0.5
0.6
0.7
0.9
1.0
1.3
2.0
3.0
1.0
1.5
2.0
2.5
3.0
3.5
4.0
5.0
400
425
450
500
LIGHT YELLOW
YELLOW
ORANGE
BROWN
DARK BROWN-BLACK
BLACK
DIAGENETIC ZONE OF GAS FORMATION
OIL
OIL WINDOW
PRINCIPAL ZONE OF OIL FORMATION
WET GAS
PRINCIPAL ZONE OF GAS - CONDENSATE FORMATION
METHANE
PRINCIPAL ZONE OF GAS FORMATION
Bossier-Haynesville Shale Organic Maturation Parameters (Yellow)

Results of the Geochemical Analyses

Total Organic Carbon (TOC): 0.19 – 0.75 wt. %
The S2-TOC plot indicates type III-IV gas prone kerogen.

Rock- Eval Tmax: 304 – 464
(Diagenetic zone of gas formation – oil window)

Thermal Alteration Index (TAI): 2.8 - 3.9
(Gas- Gas Condensate)

Reflectance (% Ro): 0.91 - 2.62
(Oil - Gas Condensate – Gas)

Kerogen Color: Brown to Dark Brown Black
(Base Oil Window- Gas Condensate – Gas)

Mudstone consisting of clay, silt and smaller size (0.06 mm) quartz, and white mica.

Larger clasts of plant tissue occupy less than about 1% volume.

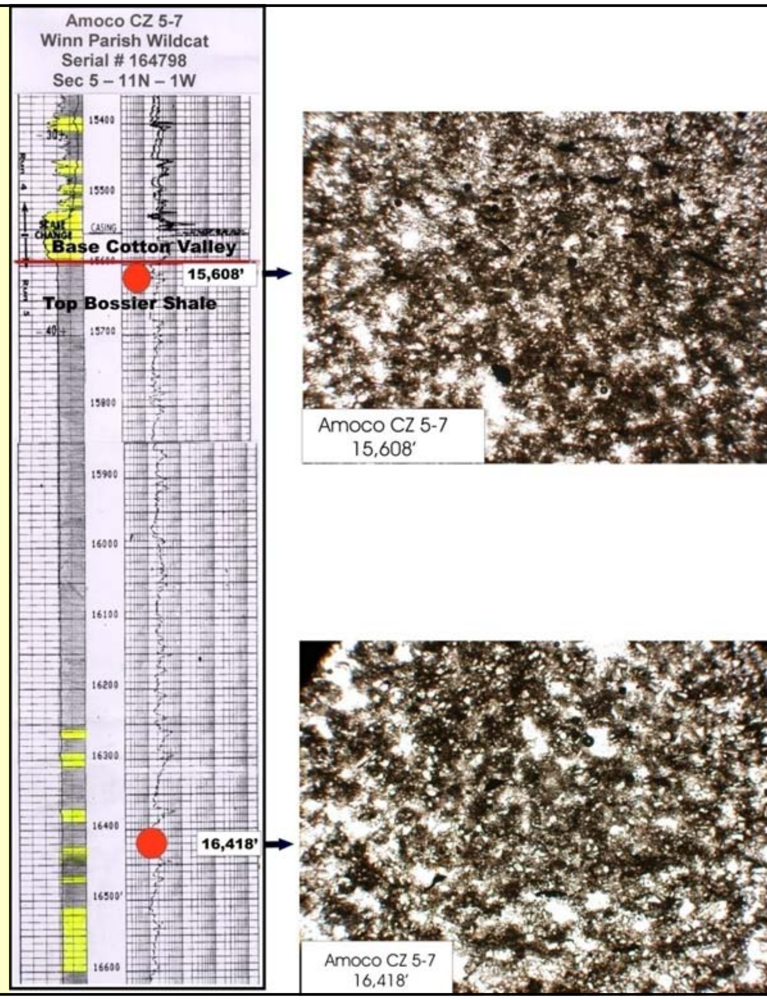
The secondary component is mostly pyrite.

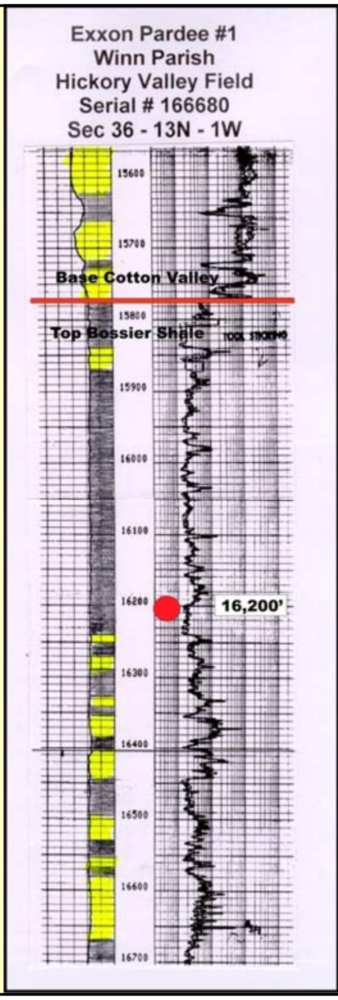
Fine sandy mudstone with 1% fine quartz sand in a brown mudstone matrix.

Accessory minerals are mica and trace amount zircon.

Fossil fragments, including textularid-type foraminifera, and plant fragments occur in trace amounts (< 0.1%).

Secondary phases are pyrite and carbonate.

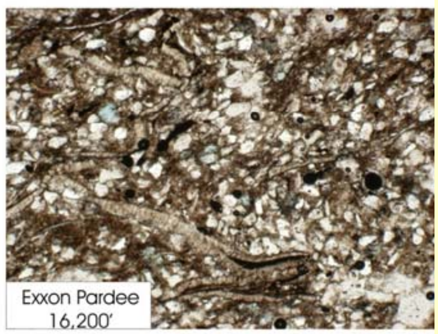


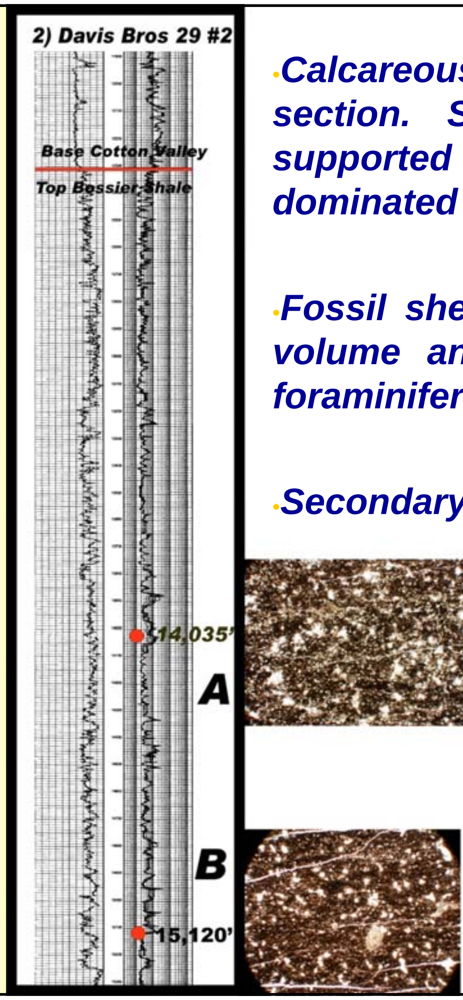


Laminated fine quartz sandstone, muddy fine sandstone, and fine sand mudstone. Accessory clasts include trace colorless mica flakes and zircon grains.

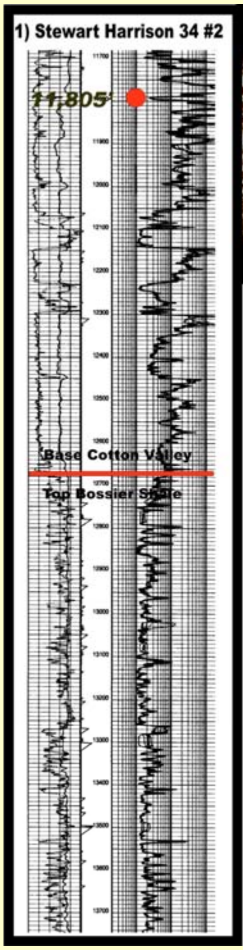
Large fossil fragments tend to be clustered occupying about 3% to 5% of the rock volume.

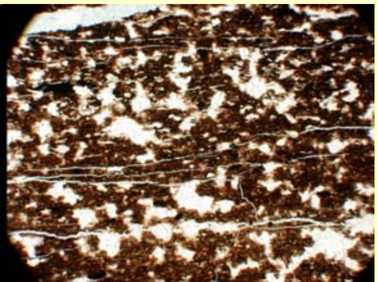
Secondary components are calcite and pyrite.





- *Calcareous black shale, dark brown in thin section. Silt and very fine sand size quartz supported by matrix of dark brown clay dominated mud.*
- *Fossil shell fragments occupy about 2% by volume and include tests of bivalves and foraminifera.*
- *Secondary components are calcite and pyrite.*





E

- Black shale with fine sand, dark brown, mostly fine mud with <1% silt size (0.05 mm) quartz, and supported by muddy fine sand consisting of quartz with interstitial clay-rich mud.

- Approximately 10% of the volume is occupied by filaments of organic tissue.

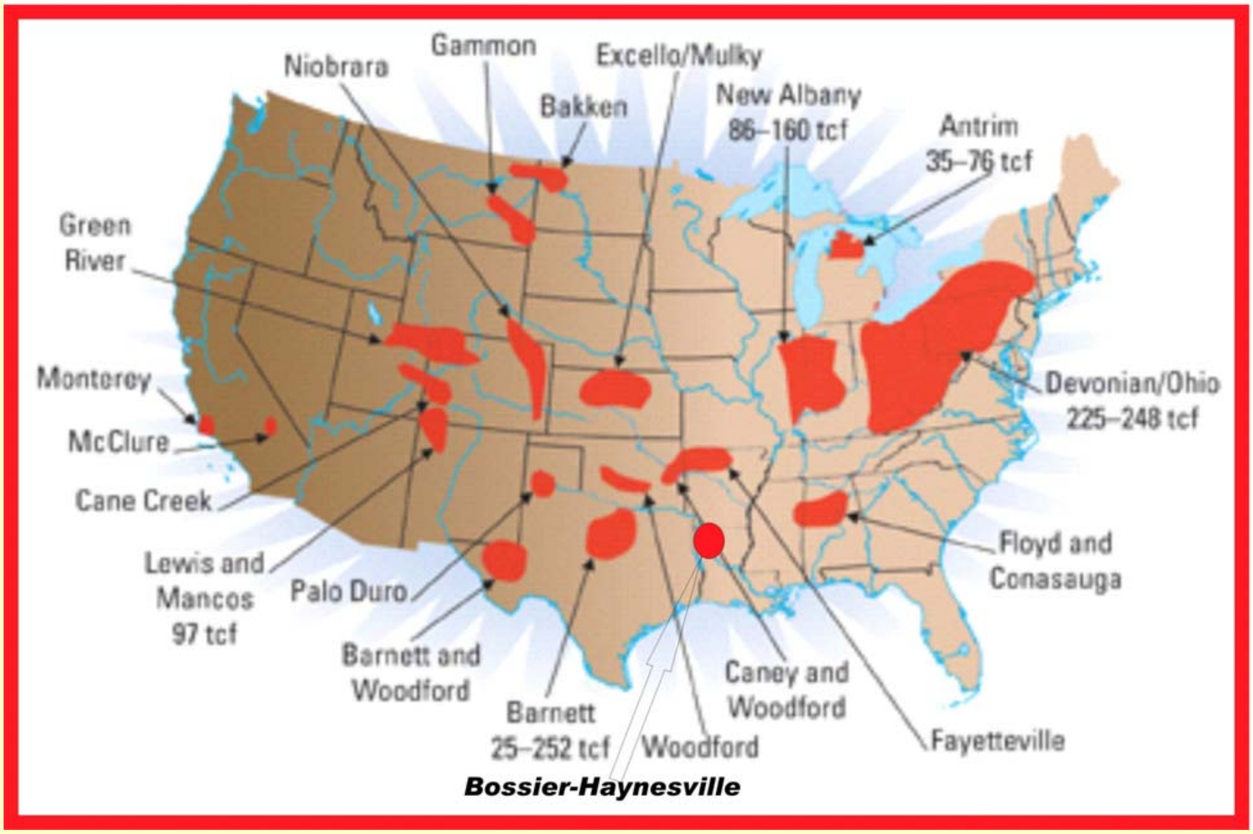
- The secondary component is primarily pyrite

NATURALLY FRACTURED SHALE RESERVOIRS

Natural Fractures

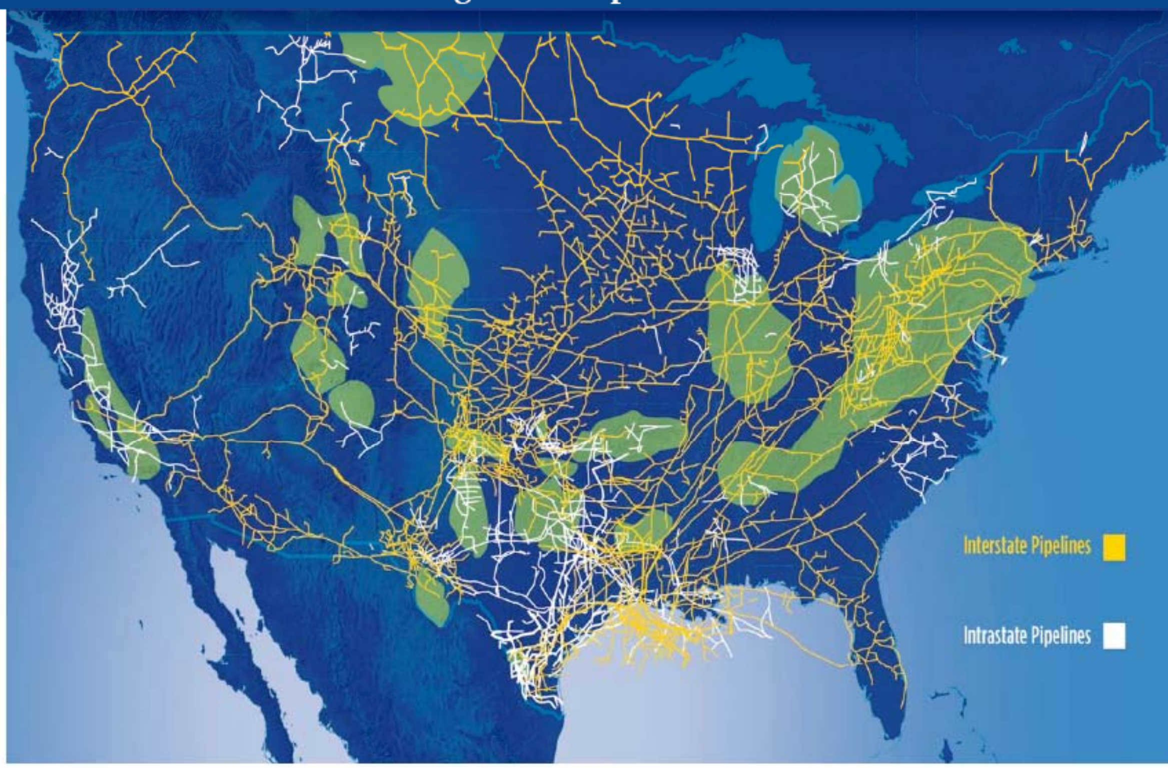
Anadarko Fisher 16-1
Depth 13,770'
Haynesville Shale
Jackson Parish, Louisiana

USA SHALE GAS MAP



from Hart Energy Publishing

U.S. Natural Gas Shale Basins Align with Pipeline Grid



Sources: EIA, US Natural Gas Pipeline

Est. Shale Gas Production (MMcf/day)				
Date	Fort Worth Barnett	Fayetteville	***Haynesville***	Arkoma Woodford
2007	3,014	230	17	109
Est. 1Q08	3,645	517	25	271

Source: US Energy Information Administration (EIA)

COMPARISON OF SOME SHALE GAS PLAYS

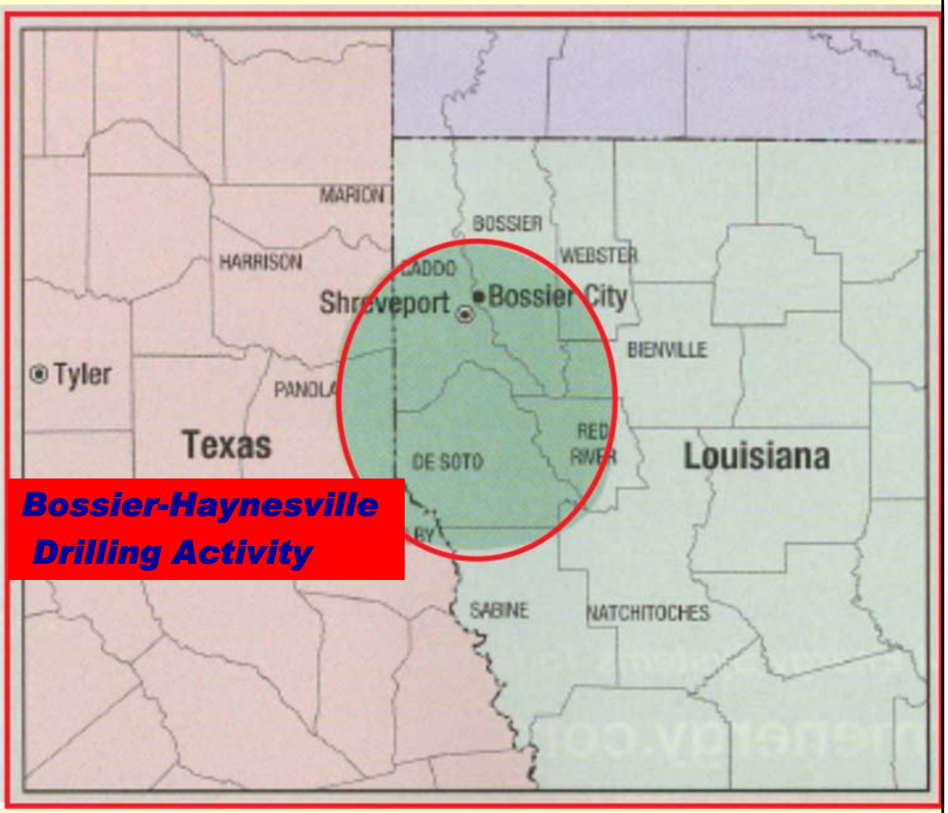
SHALE PLAY (STATE)	DEPTH (Ft)	DAILY PROD (mmcf/d)	CUM PROD	NO. WELLS	ROCK	TOC Wt. %	Ro %
Antrim (Michigan) (1970) Rec. Res. 16 TCF $300,000 / (V.well)	750-3,000	363	2.5 TCF	9,000	Devonian Shale	0.3 - 8	0.6
Barnett (Texas) (1981) Rec. Res. 26 TCF $2 - $3 million/ (H. Well)	6,500-8,000	3,645	3.7 TCF	8,500	Mississippian Mudrock-Shale	3 - 5	0.6-2.1
Woodford (Oklahoma) (1961) Rec. Res. 60 TCF $3 - $4 million/(H. Well)	6,000-12,000	271	64 BCF	1500	Miss/Devonian Shale	1 - 14	0.8 -4.7
Fayetteville (Arkansas) (2004) Rec. Res. 11-15 TCF $2 - $2.5 million/ (H. Well)	2000-6,500	517	106 BCF	500	Mississippian Shale	1 - 5	1-3
Bossier-Haynesville (Texas-LA) (2007) Rec. Res. 34 TCF $ 5 - $8 million/ (H. Well)	10,000-16,000	40		10	Jurassic Shale-Mudstone	0.3 - 4.5	0.9-2.6

BOSSIER –HAYNESVILLE SHALE INTEREST IN NORTH LOUISIANA

Gas in Place
250 – 320 TCF

Recoverable Gas
34 TCF
(RF :15% to 30%)

Players:
- **Chesapeake**
- **Encana**
- **Shell**
- **Petrohawk**
- **Plains**
- **Goodrich**
- **EXCO**
- **Devon**



BASIC CONCEPTS

***(Saturation)* Hydrocarbon reservoirs are typically saturated with oil and/or gas and water (oil/gas > 70% & water < 30%).**

***Porosity (%)* Reservoirs need to have pore space for storing oil and/or gas.**

***Permeability (md)* Reservoirs must be permeable to allow the fluids to flow through them.**

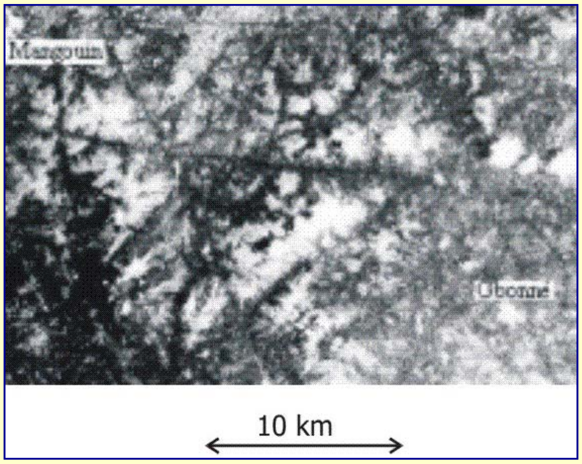
Naturally fractured reservoirs (sandstone, limestone, shale) have very low porosity (< 7 %) & very low permeability (< 0.5 md).

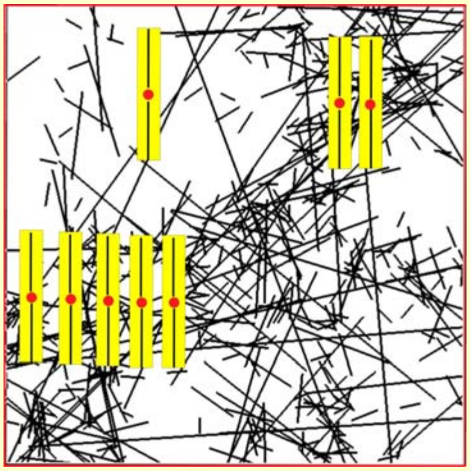
BOSSIER – HAYNESVILLE SHALE GAS

- Gas is sourced in the shale & produced through fracture stimulation of the shale. Porosity & permeability is fracture related. Need to know :

1)Where major regional uplifts/arches & faults are located.

2) Fracture length, orientation, density, position, aperture.





BOSSIER-HAYNESVILLE RESERVOIR PARAMETERS:

Net pay thickness (ft): 100 - 200

Porosity average (%): 7 - 12

Permeability average (md): 0.015 - 0.043

Water saturation average (%): 25 - 30

Temperature 250° to 300° F.

Reservoir pressure (psi): 8,000 - 10,000

Requires hydraulic fracture stimulation

Pre-stimulation (Mcf/d): 500 - 1000

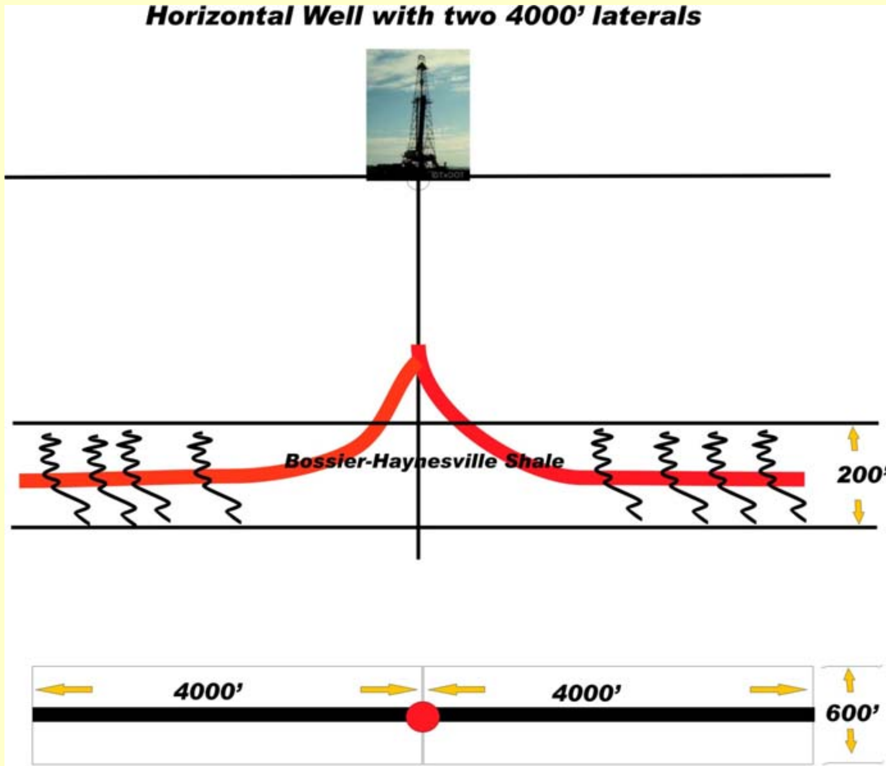
Post-stimulation (MMcf/d): 10 - 25

Expected recovery per completion (BCF): 4.0 - 7.0

Decline rate: 50% - 80% in first year

HOW ABOUT A FEW "WHAT Ifs"

- GR/DLL
- Neutron Density
- Sonic
- Magnetic Resonance
- MDT
  (Modular Formation Dynamic Tester)
- Borehole Imaging Tool



Bossier-Haynesville Shale reservoir characteristics
Porosity = 10%   Thickness = 200'
Drainage area = 8000' x 600' = 4.8 x 10 sq. Ft.
Or 110 acres

GAS VOLUME EVALUATION SHEET

Datum... 10,000 (Feet)
Porosity.. 10 (%)
Average Connate Water(SW)... 30 (%)
1 – Connate Water.. 70 (%)
Initial BHP.. 9000 (psi)
Abandonment Pressure... 100 (psi)
Reservoir Temperature (BHT)... 250 (° F)
Compressibility Factor (Z)... 1
Number of Cubic Feet per acre foot................................... 4,3560
Atmospheric pressure... 14.65 psi

NET GAS RECOVERY (Gas in Place)

(43,560 acre-feet) (Porosity) (1-connate water)
(1 Atmospheric Pressure / Initial BHP– Aban. Pres) (BHT Absolute / 460 ° + 60°) (Compressibility Factor)

(43,560 acre-feet) (0.10) (0.7)
(14.65 / 9000 – 100) (460 ° + 240 / 460 ° + 60°) (1)

(3049)
(0.0016) (1.34) (1) = ... 1,424,766 cu-ft/ac-ft

or GIP of ----- 1425 MCF/ac-ft

Shrinkage Factor (Gas Equiv. Of Condensate/Gross gas at surface)......... 0.98

Recovery Factor (RF) (Drive mechanism=Gas expansion)............... 15 (%)

Recoverable Gas : GIP RF (Shrinkage)................................ 279 MCF/ac-ft
(1425) (0. 15) (0.98)

Recoverable Gas Reserves: (Productive Acres) (Net Pay) (mcf/ac-ft) 4,598,000 MCF
(110) (200) (279)

or Approx: 4.6 BCF

EXPLORATION & PRODUCTION

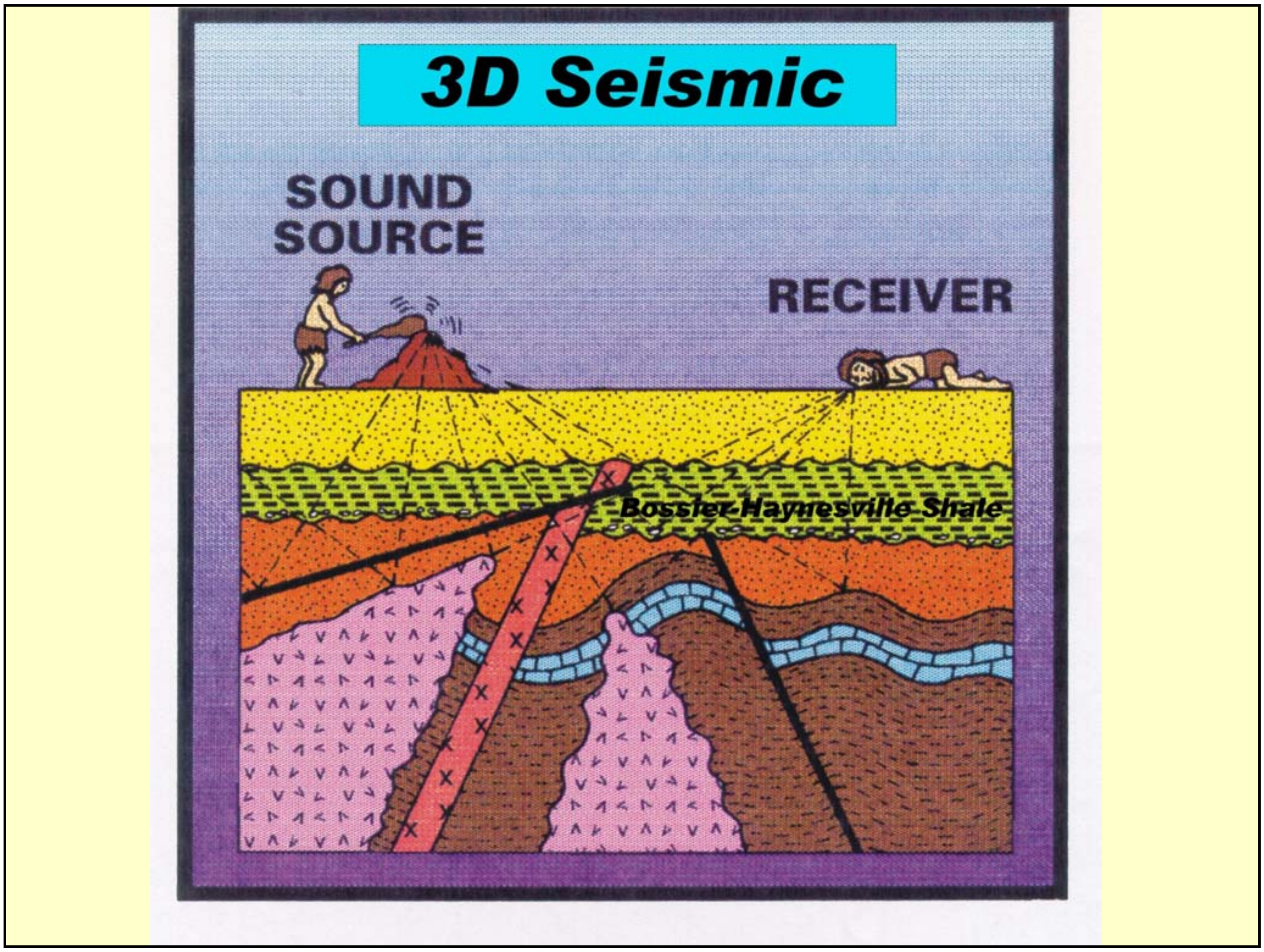
EXPLORATION METHODS

3D seismic technology for locating major structures such as anticlines or faults that are responsible for the fracturing ($85,000/sq.mile).

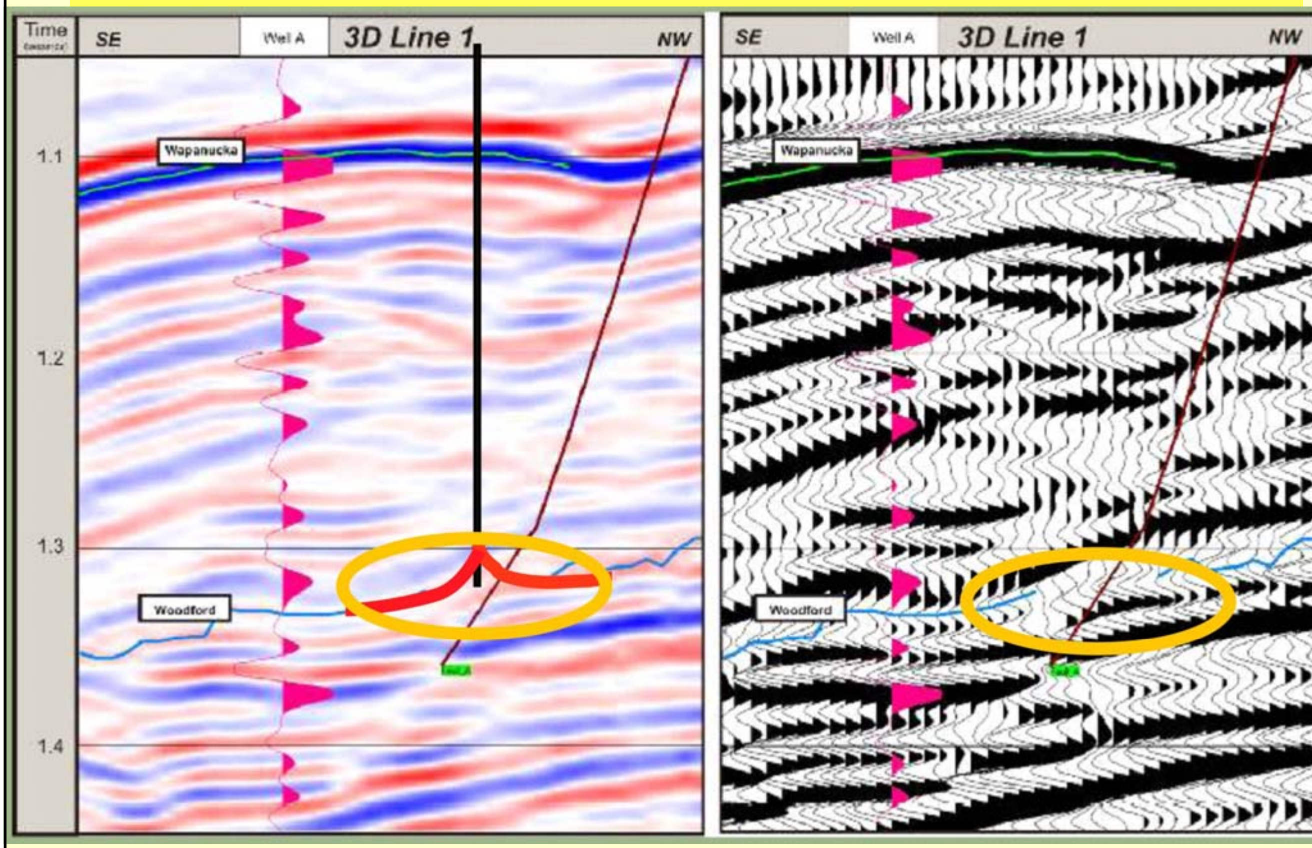
OPTIMUM PRODUCTION METHOD

Drill horizontal wells in order to cut maximum amount of fractures ($5 - $8 million/well)

Perform hydraulic fractures to increase permeability ($600,000 - $900,000/well).

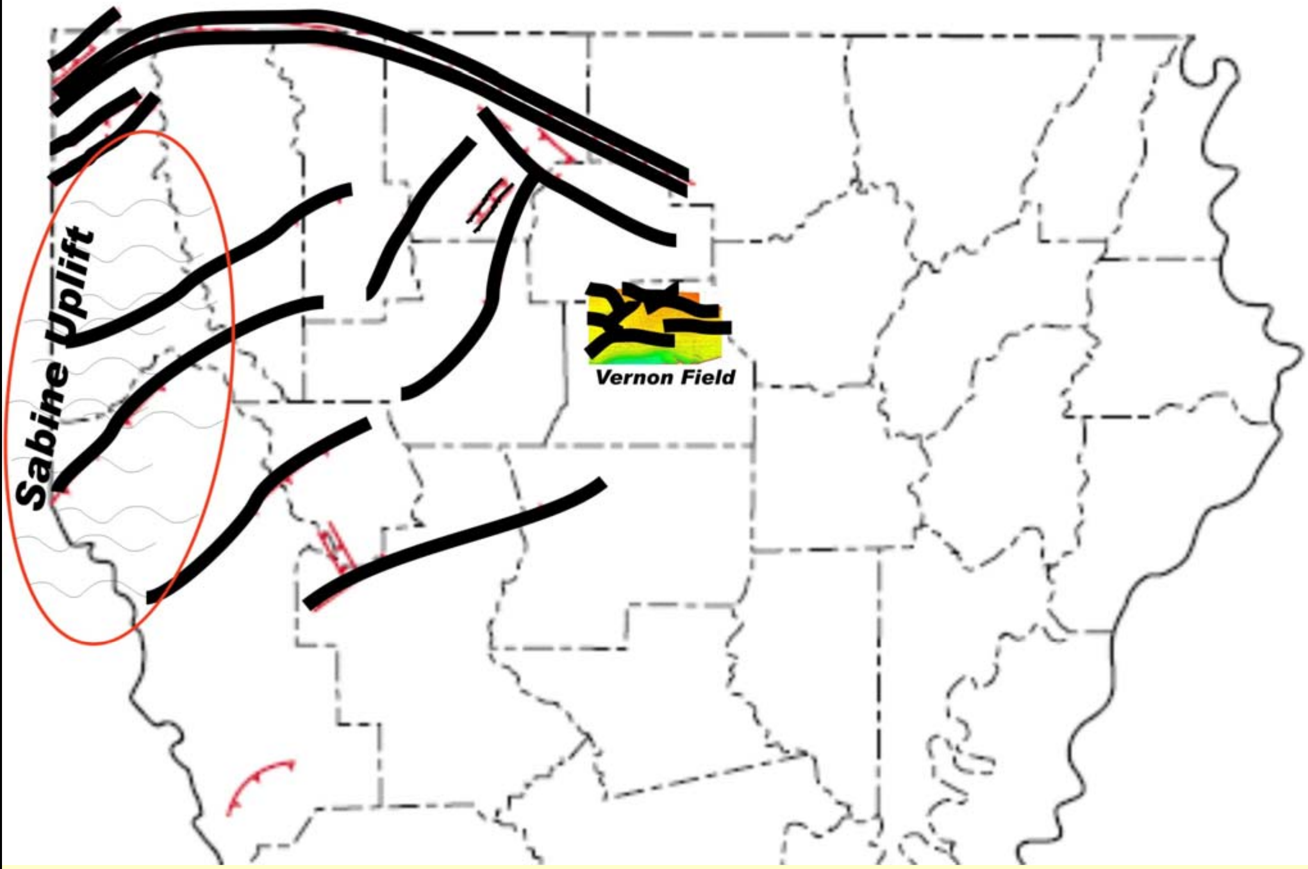

3D Seismic
SOUND SOURCE
RECEIVER
Bossier-Haynesville Shale

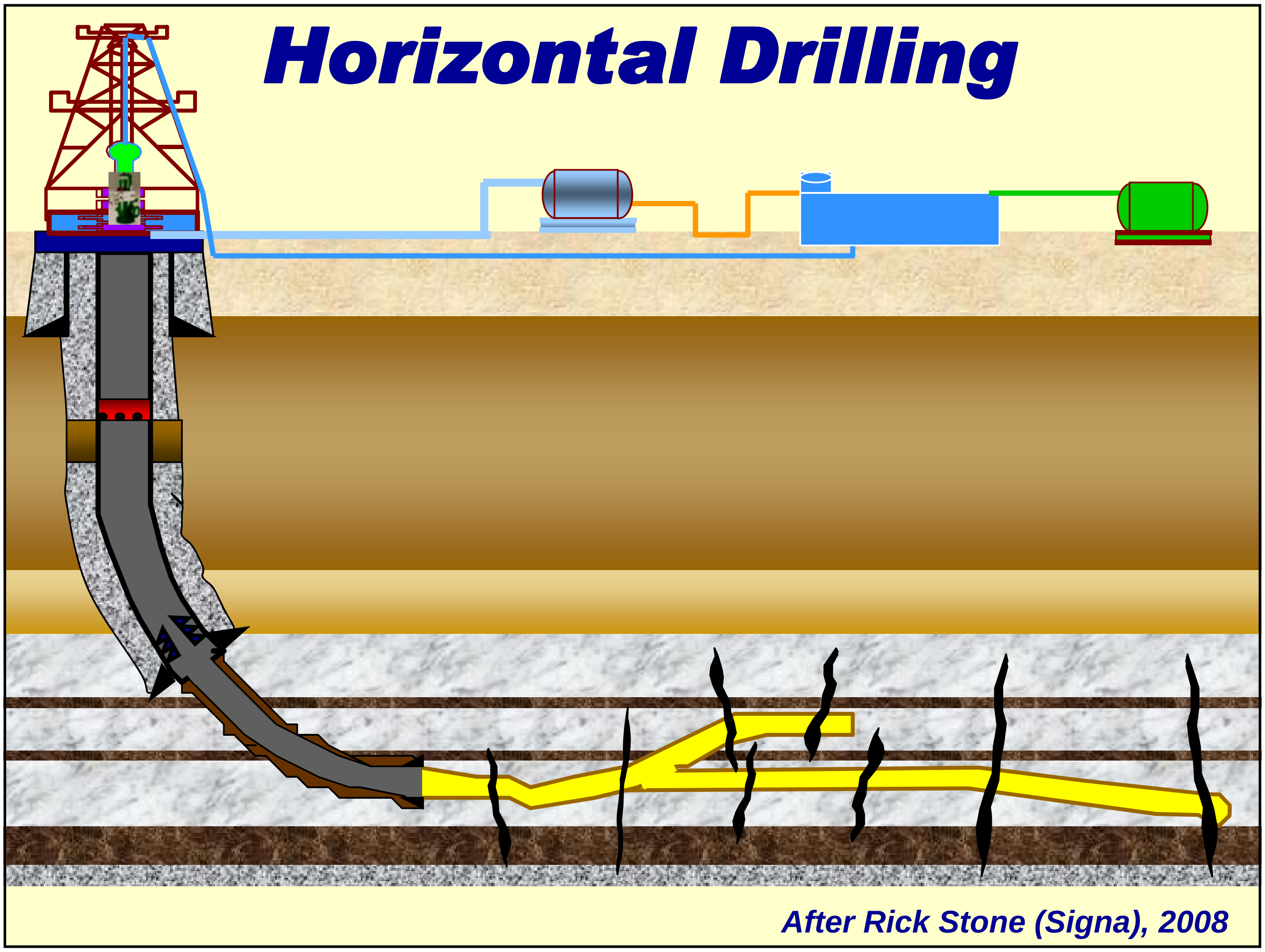
3D Seismic Line: Woodford Shale Play, Oklahoma



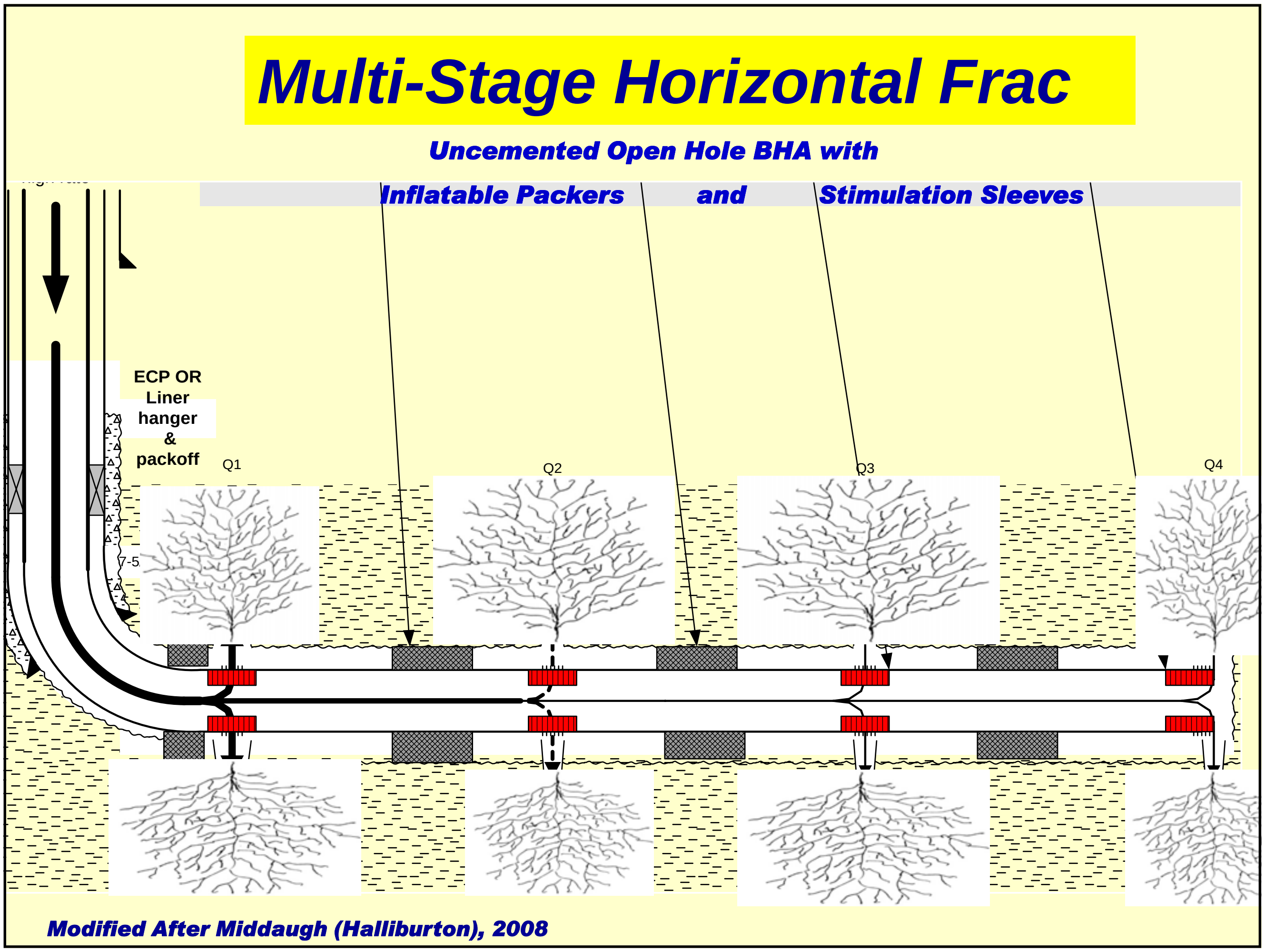
Modified After Miller & Young, AAPG, 2007

Northwest Louisiana Structural Systems



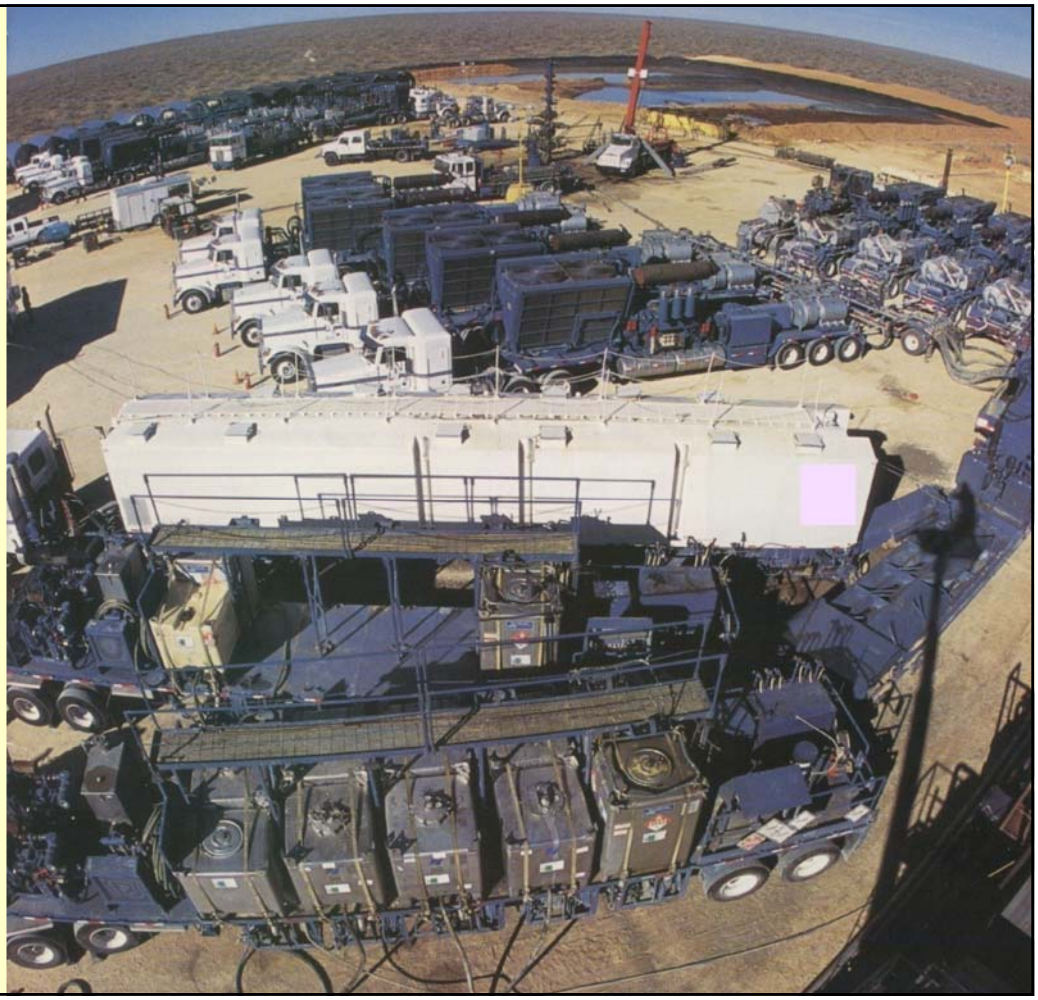


Horizontal Drilling
After Rick Stone (Signa), 2008



Multi-Stage Horizontal Frac
Uncemented Open Hole BHA with
Inflatable Packers and Stimulation Sleeves
ECP OR Liner hanger & packoff
Q1
Q2
Q3
Q4
Modified After Middaugh (Halliburton), 2008

Hydraulic Fracture Operation



CONCLUSIONS

Results of the Geochemical Analyses (Rock-Eval, TOC & Visual kerogen) analyses) indicate that the Cotton Valley-Bossier Group & Haynesville fine-grained rocks contain mostly gas-prone type III kerogen and have very good oil & gas generative potential.

The thickness and widespread deposition of the Bossier-Haynesville strata allows it to be an excellent source rock responsible for some of the oil & gas accumulations in the overlying Cotton Valley Hosston and Sligo reservoirs.

The Bossier-Haynesville interval in north Louisiana is also considered a potential shale gas reservoir with large reserves.

- ***Such shale gas reservoirs can be economically attractive for the following reasons:***
  1) ***The reserves are large.***
  2) ***There's a demand for gas.***
  3) ***The high price of gas ($6 - $12 per mcf).***
  4) ***The availability of technologies to drill and produce them.***