Middle Bakken Play
Technical Problems and Questions
Possible Solutions

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NDIC Dept. of Mineral Resources

Julie A. LeFever
North Dakota Geological Survey

Geologic Investigation No. 16

A little girl complained to her mom that her stomach hurt really bad.

Her mom told her that was because it was empty and she had to put something in it to make it stop hurting.

She had a snack and her stomach ache went away.

That night her mother's boss and his wife came over for dinner.

Before they sat down to eat the boss complained that he must be getting sick. His head was killing him.

The little girl told her mom's boss, "My mom says that's because your head is empty. You have to put something in it to make it quit hurting."

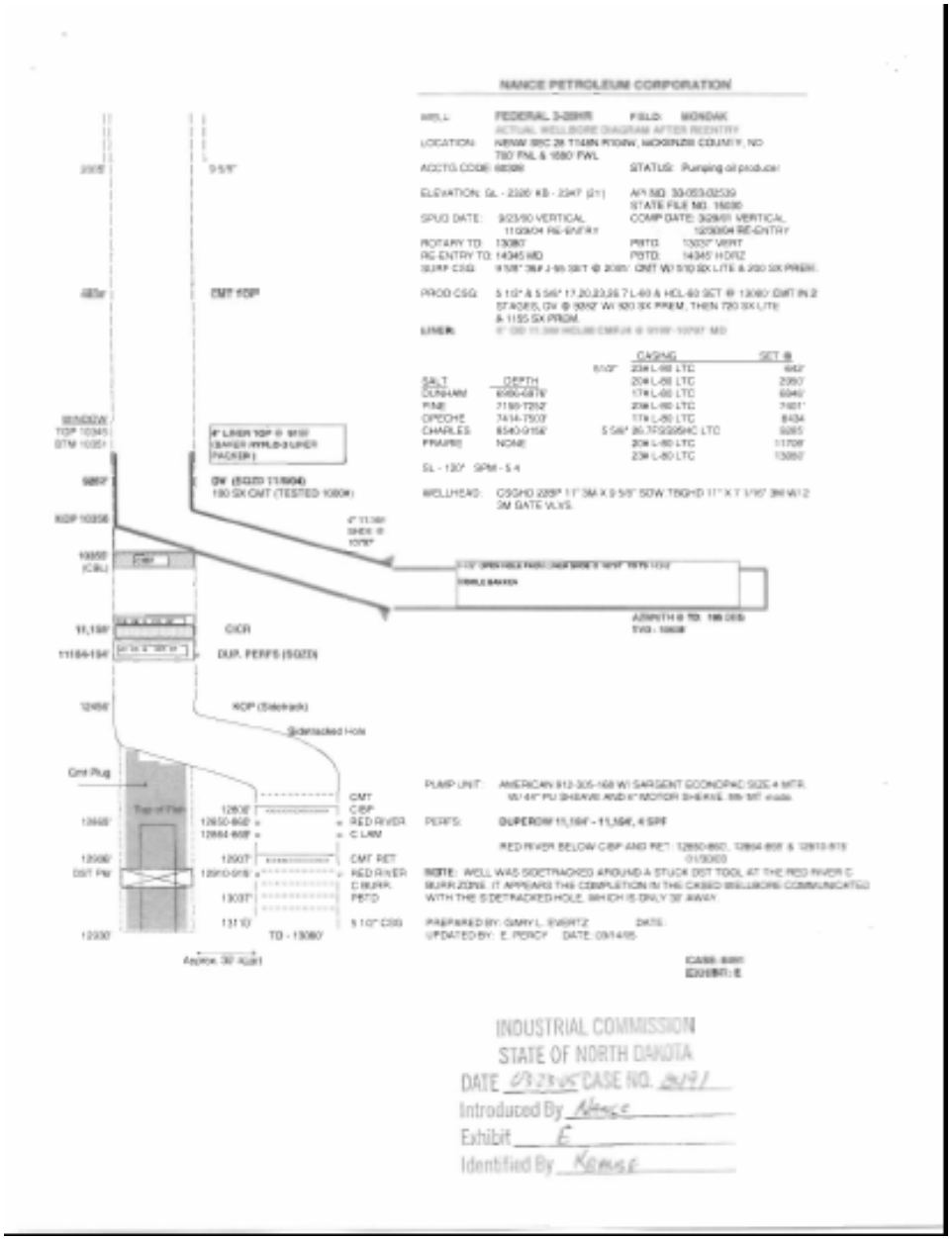
Non-confidential Drilling Results to Date

- Ten (10) wells total
- Single lateral - Open hole re-entry (1)
- Re-Entry – Open hole – Lodgepole liner uncemented (1)
- Dual lateral - OH or perforated liners – Lodgepole liner uncemented (4)
  - Proppant fractured (3), Unstimulated (1)
- Single lateral - Perforated liner (4)
- Dual lateral - Co-planar – Perforated liners (0)

Non-confidential Drilling Results to Date

- Single lateral - Open hole re-entry (1)
  - IP 332 BO / 34 BW / 95 MCFD
  - Proppant Fractured almost immediately
    - 87 BO / 146 BW / 150 MCFD
  - Current 43 BO / 10 BW / 89 MCFD
  - 25,000 cumulative BO
  - Breakeven at $22/BO
  - Problems and Questions
    - 1st ND attempt – marginally succesful
    - Hole stability in upper shale?
    - Proppant fracture growth into Lodgepole?

Re-Entry – Open hole – Lodgepole liner uncemented



NANCE PETROLEUM CORPORATION

WELL: FEDERAL 3-28WR FIELD: MONDAK

ACTUAL WELLBORE DIAGRAM AFTER REENTRY

LOCATION: NENW SEC 28 T148N R100W, MCKENZIE COUNTY, ND
780' FNL & 1680' FWL

ACCTG CODE: 68099 STATUS: Pumping oil producer

ELEVATION: GL - 2320 KB - 2347 (27')

API NO. 33-053-02539
STATE FILE NO. 16030

SPUD DATE: 9/23/80 VERTICAL
11/03/04 RE-ENTRY

COMP DATE: 3/28/81 VERTICAL,
12/30/04 RE-ENTRY

ROTARY TD: 13080' PBTD: 13037' VERT
RE ENTRY TD: 14345 MD TDTD: 14345 HORZ

SURF CSG: 9 5/8" 36# J-55 SET @ 2035' CMT W/ 510 SX LITE & 200 SX PREM.

PROD CSG: 5 1/2" & 5 5/8" 17,20,23,26 P-110 & HCL-80 SET @ 13080' CMT IN 2 STAGES, DV @ 9362' W/ 920 SX PREM., THEN 720 SX LITE & 1155 SX PREM.

LINER:

	CASING	SET @
	5 1/2" 23# L-80 LTC	640'
SALT	DEPTH 204 L-80 LTC	2350'
DUNHAM	6060-6878' 17# L-80 LTC	6946'
PINE	7180-7252' 23# L-80 LTC	7401'
OPECHE	7414-7503' 17# L-80 LTC	8434'
CHARLES	8540-9156' 5 5/8" 26.7# SS95HC LTC	9285'
FRAPIE	NONE 20# L-80 LTC	11709'
	23# L-80 LTC	13080'

SL - 120' SPM - 5.4

WELLHEAD: CSGHD 2.88" 11" 3M X 9 5/8" SOW TBGHD 11" X T 1/16" 3M W/ 2 3M GATE VLVS.

9 5/8"

CMT TOP

4" LINER TOP @ 9150' (BAKER HYFLO II LINER PACKER)

DV (SQZD 11/2004) 180 SX CMT (TESTED 1080#)

5 1/2" SHOE @ 13080'

OPEN HOLE PASO (NEW BORE 5 5/8" 26.7# HCL-80)

TRIPLE BARREL

ARMITH @ TD: 14345' MD
TVD - 10658'

CICR

DUP. PERFS (SQZD)

KOP (Sidetrack)

Sidetracked Hole

Cmt Plug

Top of Fish

DST Pkr

CMT

CIBP

RED RIVER C LAM

CMT RET

RED RIVER C BURR

PBTD

5 1/2" CSG

TD - 13080'

Approx 30' Apart

PUMP UNIT: AMERICAN 912-305-168 W/ SARGENT GOONOPAC SIZE 4 MTR W/ 44" PU SHEAVE AND 6" MOTOR SHEAVE, 86" SPM stroke

PERFS: DUPERO@ 11,156' - 11,164', 4 SPF

RED RIVER BELOW CIBP AND RET: 12850-860', 12864-868' & 12910-916'
01/30/03

NOTE: WELL WAS SIDETRACKED AROUND A STUCK DST TOOL AT THE RED RIVER C BURR ZONE. IT APPEARS THE COMPLETION IN THE CASED WELLBORE COMMUNICATED WITH THE SIDETRACKED HOLE, WHICH IS ONLY 30' AWAY.

PREPARED BY: GARY L. EVERITT DATE:
UPDATED BY: E. PERCY DATE: 09/14/05

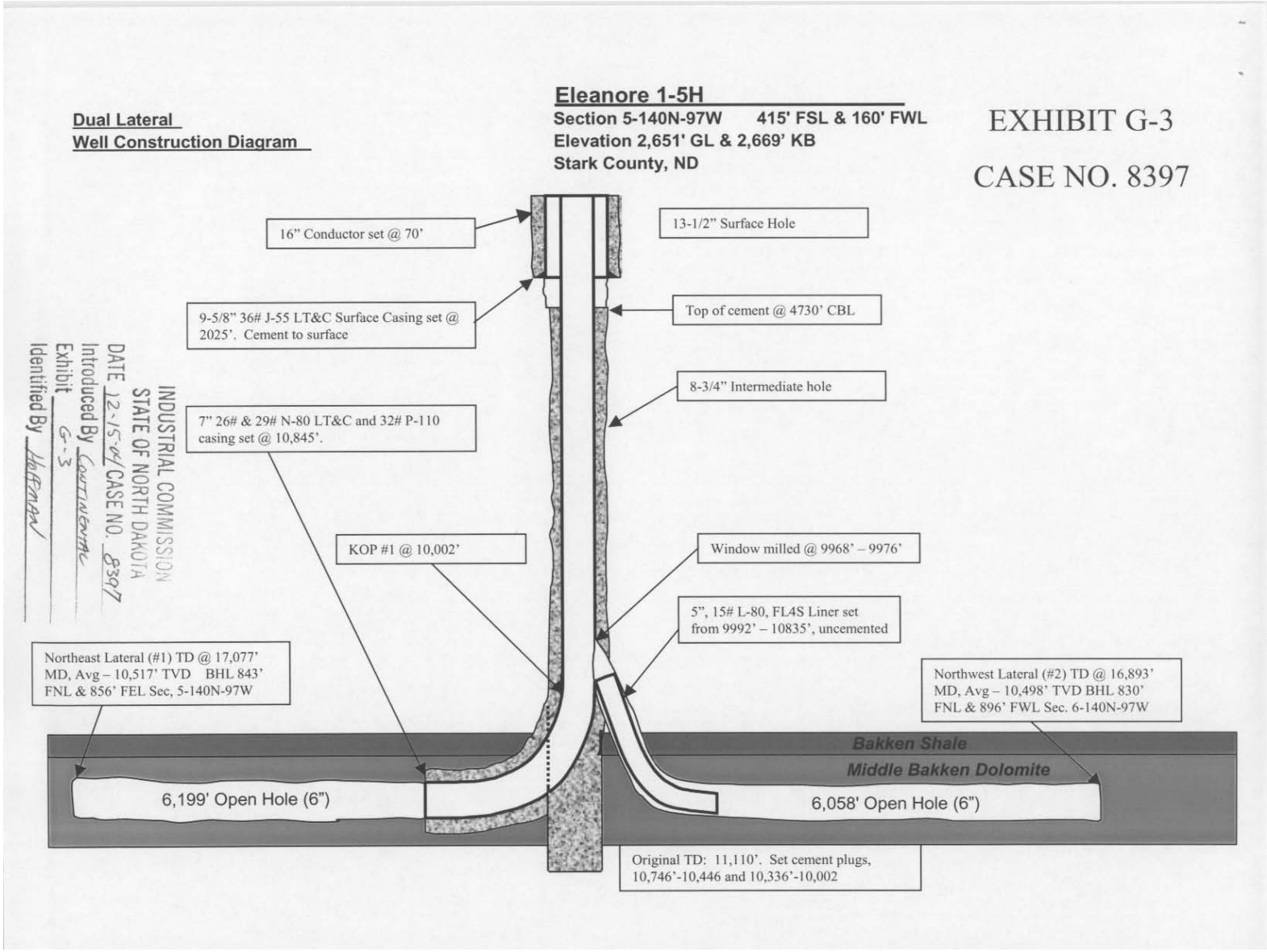
CASE 8997
EXHIBIT E

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 03/28/05 CASE NO. 8997
Introduced By Nance
Exhibit E
Identified By Nance

Non-confidential Drilling Results to Date

- Re-Entry – Open hole – Lodgepole liner uncemented
  - IP 263 BO / 0 BW / 177 MCFD
  - Proppant Fractured after 4 months and 19,000 BO
    - 304 BO / 0 BW / 172 MCFD
  - Current 304 BO / 0 BW / 172 MCFD
  - 23,000 cumulative BO
  - Problems and Questions
    - This worked!
    - Liner maintained hole stability?
    - Liner hanger packer kept proppant fracture in zone?
    - Pressure drawdown kept proppant fracture in zone?
    - Good rock?

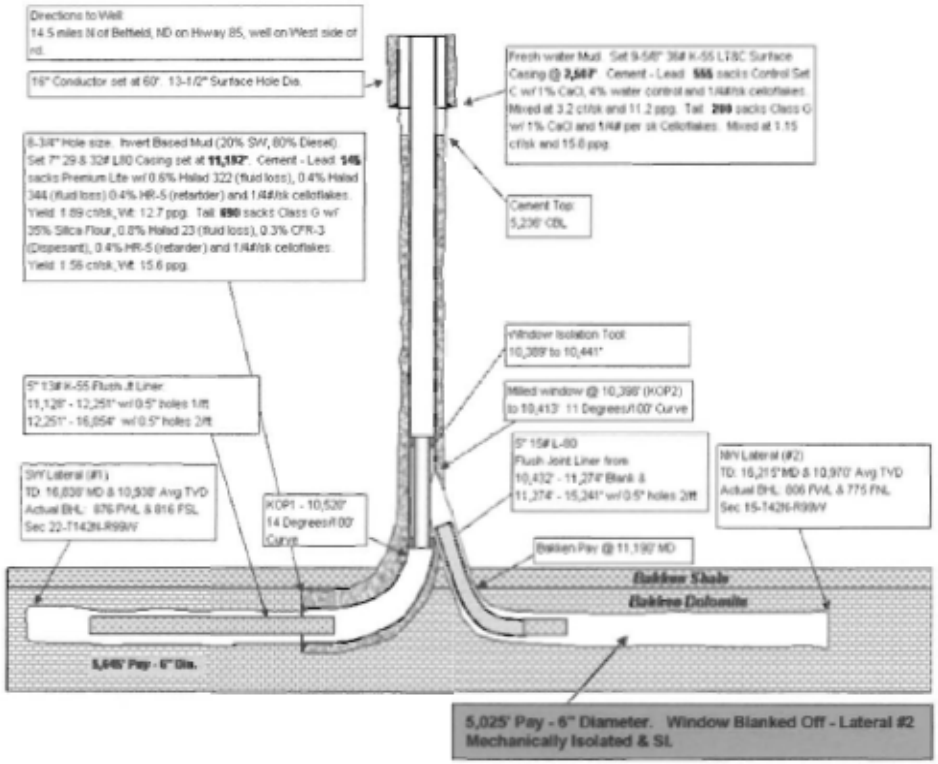
Dual lateral - OH or perforated liners – Lodgepole liner uncemented



Docket #8411

CONSTRUCTION DIAGRAM

LOGOSZ 44X-15



HEADINGTON OIL, LIMITED PARTNERSHIP

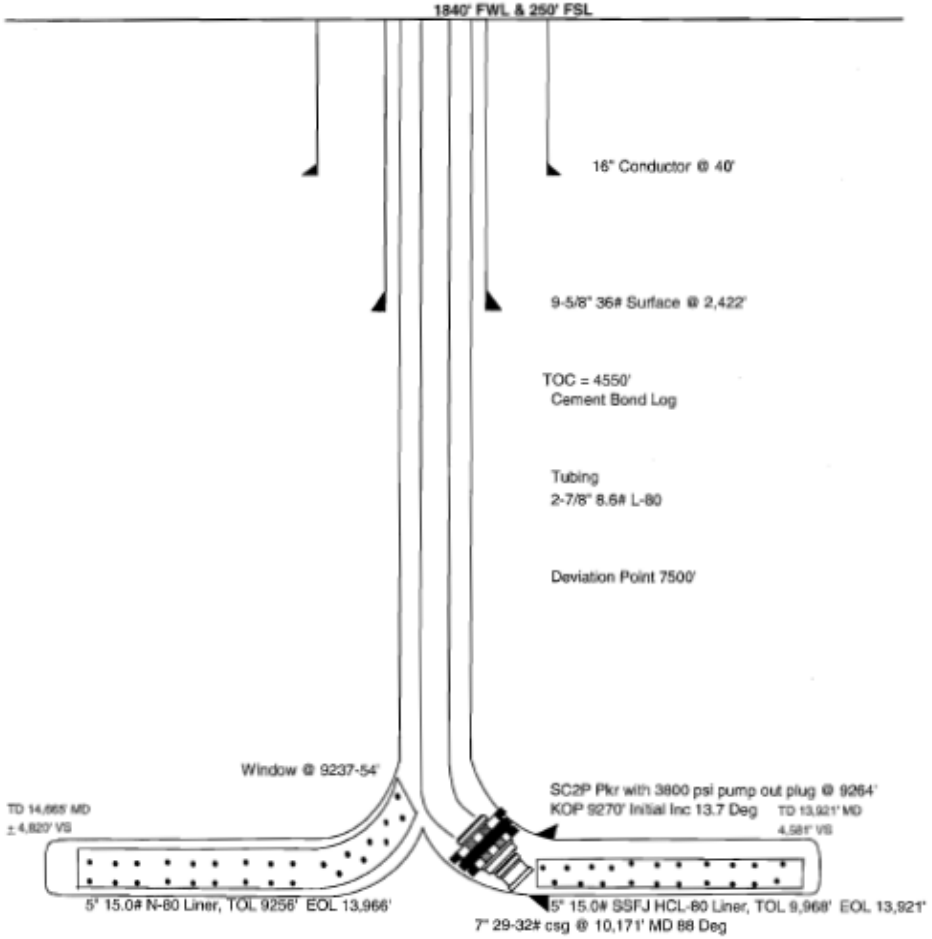
EXHIBIT 6

Non-confidential Drilling Results to Date

- Dual lateral - OH or perforated liners – Lodgepole liner uncemented
  - IP 51 BO / 171 BW / 44 MCFD
  - Proppant Fractured immediately to after 1 month
    - 134 BO / 179 BW / 125 MCFD
  - Current 32 BO / 37 BW / 72 MCFD
  - 11,000 cumulative BO
  - Breakeven at $45/BO
  - Problems and Questions
    - This has not worked!
    - Liner maintains hole stability?
    - Proppant fracture growth into Lodgepole?
      - One well has water salinity and H_2S indicative of Mission Canyon
      - 2 wells have isolated the lateral the uncemented through the Lodgepole leg (what to do with spacing?)
    - Only the best rock and more pressure drawdown to keep prop fracture in zone?

CURRENT WELLBORE DIAGRAM

Well:	Stacey Lynne #1-12H	Cnty/State:	Williams, ND	Formation:	Bakken
Field:	Wildcat	Location:	Sec 1-156N-96W 1840' FWL & 250' FSL	Date:	5/23/2004



INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 6-23-05 CASE NO. 8561
Introduced By Murex
Exhibit # 10
Identified By D. Falckner

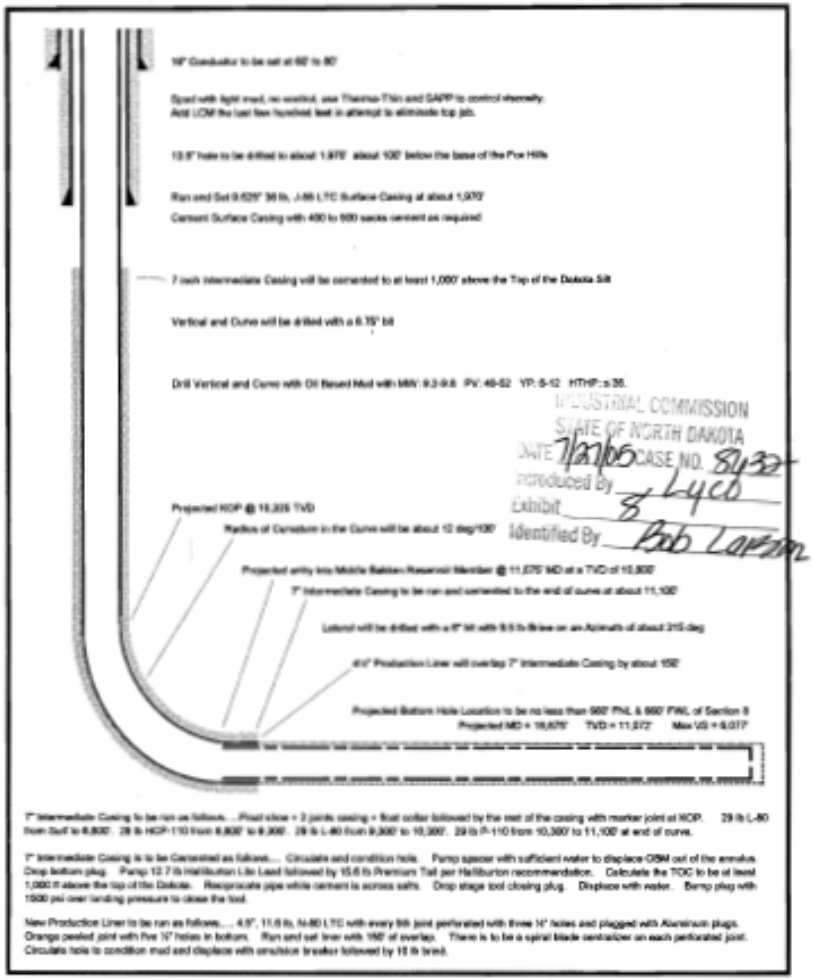
Murex Petroleum Corporation
Case No. 8561
6/23/05
Exhibit No. 10

Non-confidential Drilling Results to Date

- Dual lateral - OH or perforated liners – Lodgepole liner uncemented
  - IP 463 BO / 12 BW / 512 MCFD
  - Not proppant fractured yet (planned to wait – MECHANICAL)
  - Current 172 BO / 0 BW / 166 MCFD
  - 22,000 cumulative BO
  - Breakeven at $18/BO
  - Problems and Questions
    - This worked (sort of)
    - Liners maintaining hole stability?
    - Complicated mechanically?
    - Good rock?
    - Pressure drawdown may keep proppant fracture in zone?
    - Mechanical problems may prevent proppant fracturing?

Single lateral - perforated liner – Lodgepole cemented

APPLICATION for a 640 acre DRILLING UNIT
NDIC CASE # 8632 Exhibit # 8
Lyco Energy Corporation Titan C - Severson 8-16-H
GENERALIZED WELLBORE DIAGRAM



Non-confidential Drilling Results to Date

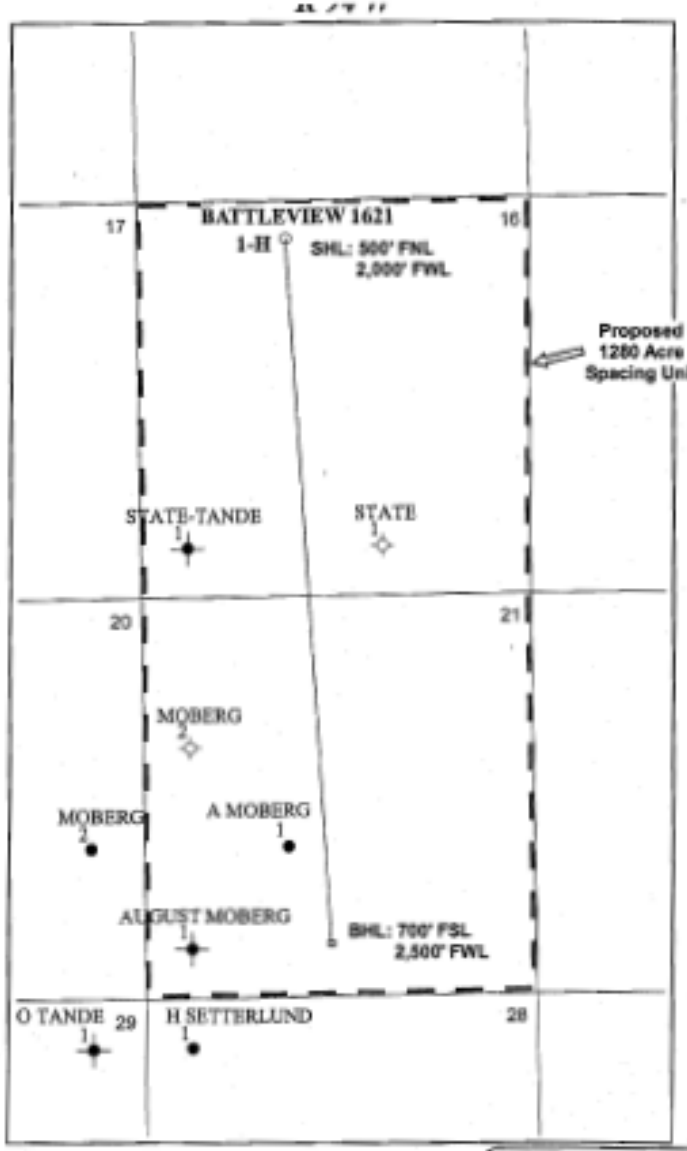
- Single lateral - perforated liner – Lodgepole cemented
  - IP 275 BO / 107 BW / 264 MCFD
  - Proppant Fractured immediately to after 3 months
    - 179 BO / 110 BW / 183 MCFD
  - Current 83 BO / 20 BW / 126 MCFD
  - 12,000 cumulative BO
  - Breakeven at $25/BO
  - Problems and Questions
    - This has worked (fairly well)
    - Casing maintains hole and stops fracture growth into Lodgepole?
    - Mechanically simple?
    - Good rock?
    - More pressure drawdown to improve keep proppant fracture in zone?

Conclusions

- ND bottom hole temperature is higher
- ND is clastic versus carbonate
- ND bottom hole pressure is higher (.50-.58 psi/ft)
- Bakken shale open hole is not stable
- Rock properties (Julie)
  - Naturally fractured
  - Oil wet
  - Swelling and migrating clays

Planar and Co-planar Designs

- BTA, JMG, Black Rock
  - Long Single lateral 1280
- Murex
  - Coplanar 1280
- Headington, Ansbro, Burlington, Missouri Basin, Stephens
  - Coplanar 1280
- Continental
  - Coplanar 1280
- BR & Denali
  - Coplanar 640
- Nance, Amerada, EOG, Tri-C, Lyco, Hunt, Sam Gary, Headington, Stephens
  - Single lateral and coplanar 640



0 2,000
FEET

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 03-23-05 CASE NO. 8498
Introduced By BTA Oil Producers
Exhibit 1
Identified By Jim Kerns

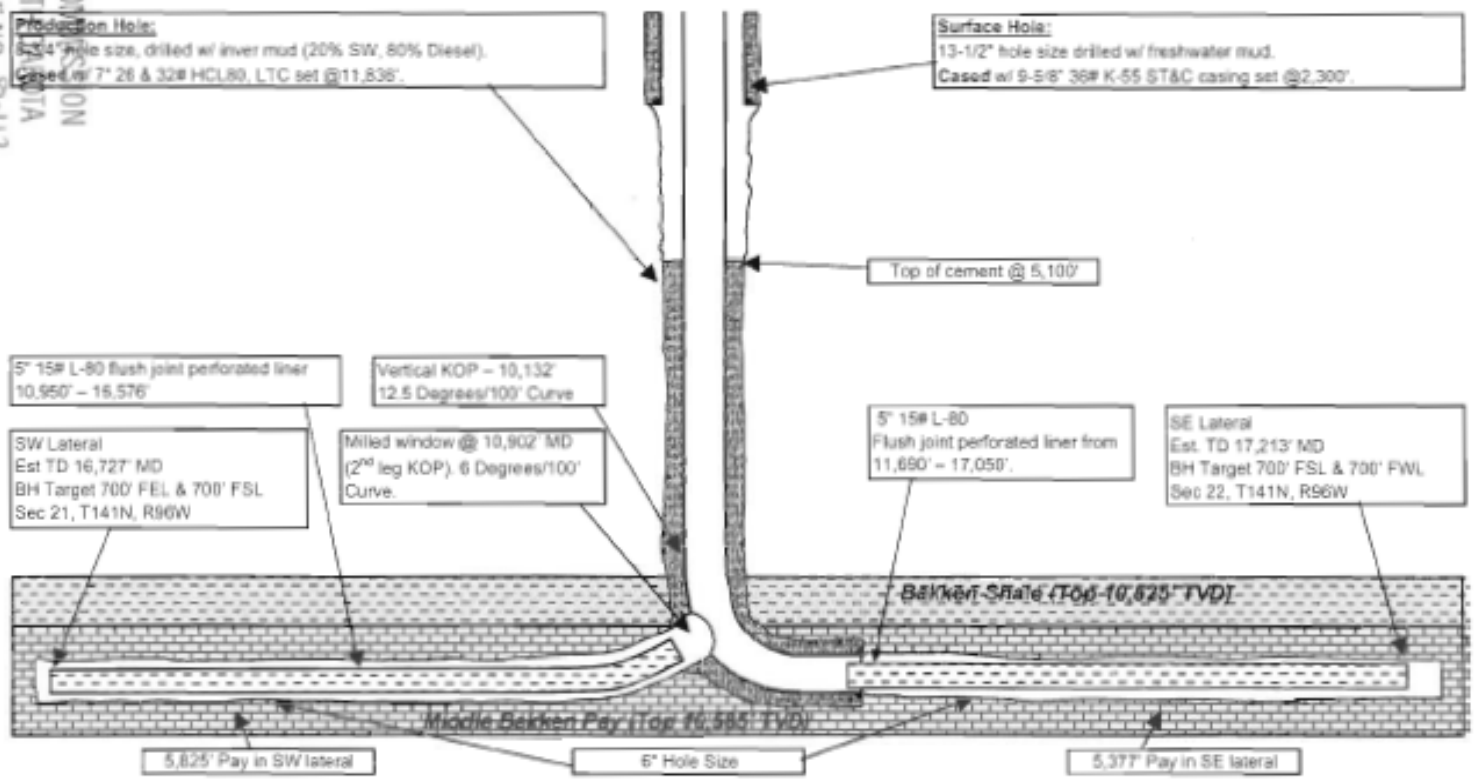
BTA Oil Producers

Proposed Spacing Unit
CASE #8498
Exhibit 1
March 23, 2005

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 7/28/05 CASE NO. 8642
Introduced By Ansbro
Exhibit 10
Identified By

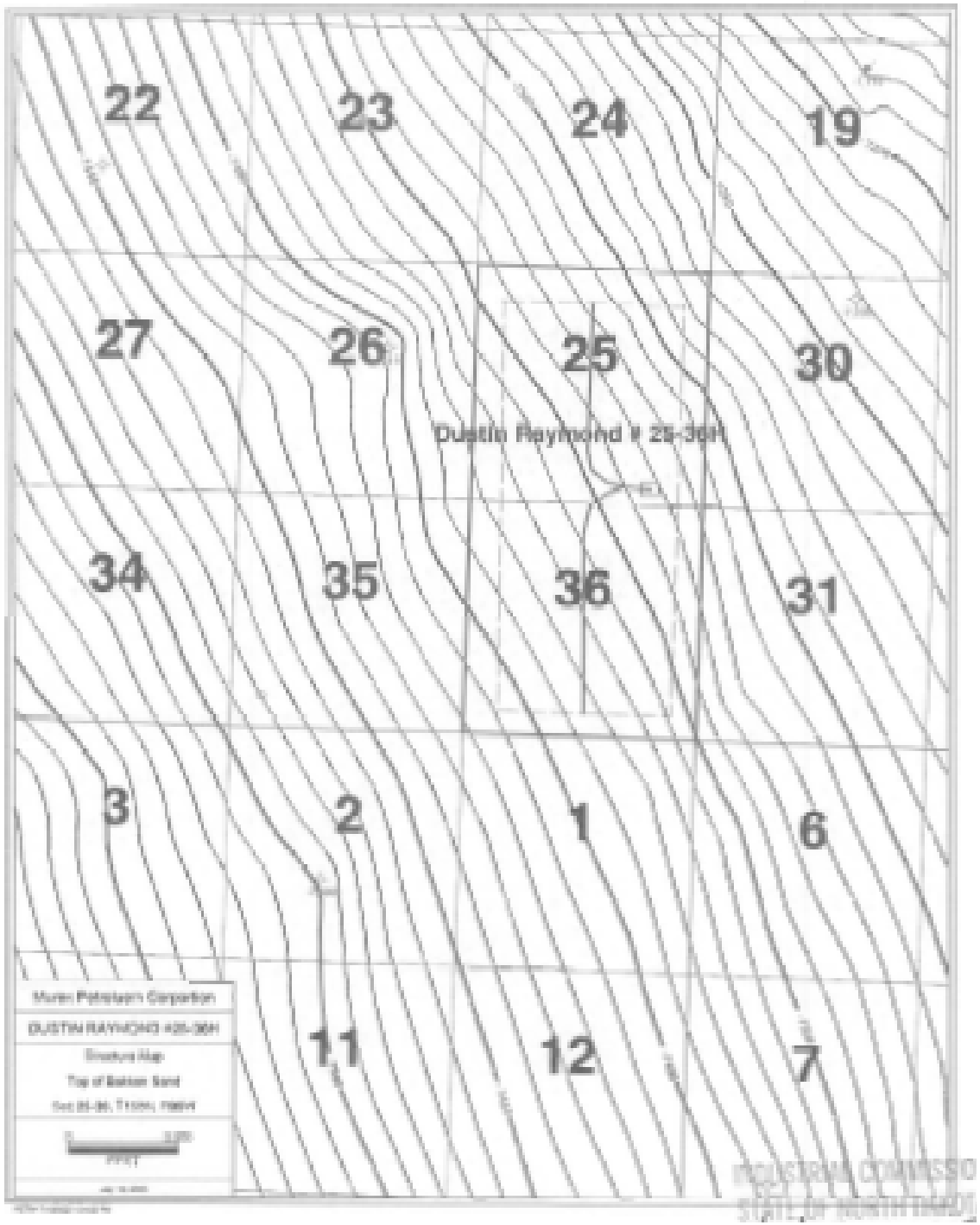
Russian Creek Prospect - Ficek 41-21H
SHL: 275 ft FNL; 300 ft FEL Sec 21
NE NE Sec 21 T141N-R96W
Elevation: 2641 GL 2661 KB
Dunn County, ND

Well Construction Diagram



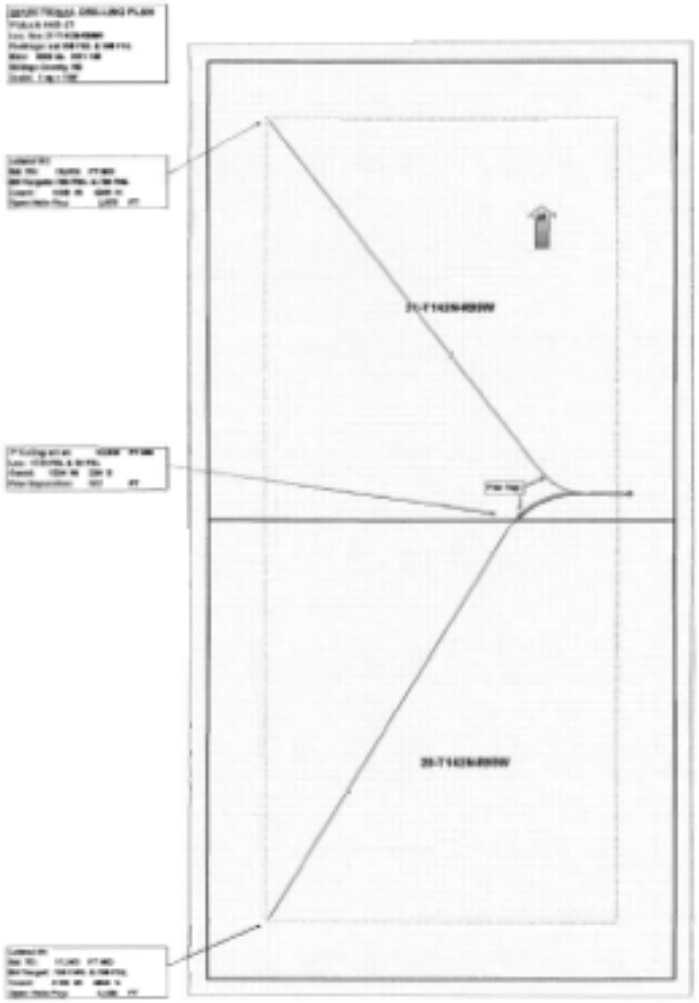
Case No. 8642
Exhibit 6
July 27, 2005

ANSBRO
PETROLEUM COMPANY


22
23
24
19
27
26
25
30
Dustin Rayhound # 25-36H
34
35
36
31
3
2
1
6
11
12
7
Muren Petroleum Corporation
DUSTIN RAYHOND #25-36H
Structure Map
Top of Bakken Sand

Case #8484

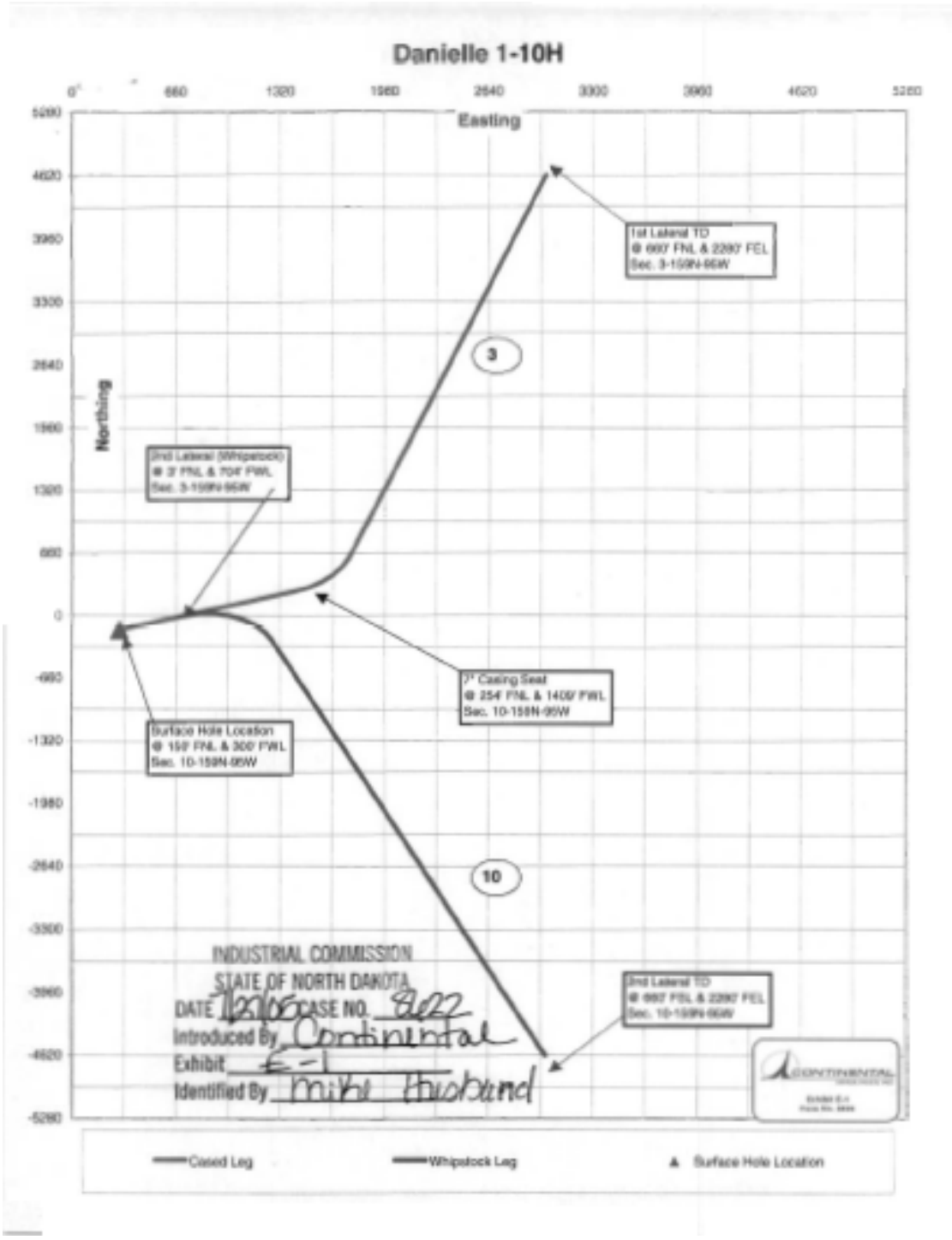
PRELIMINARY DIRECTIONAL DRILLING PLAN



INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 03-28-05 CASE NO. 8484
Introduced By Headington
Exhibit 7
Identified By Lecuyer

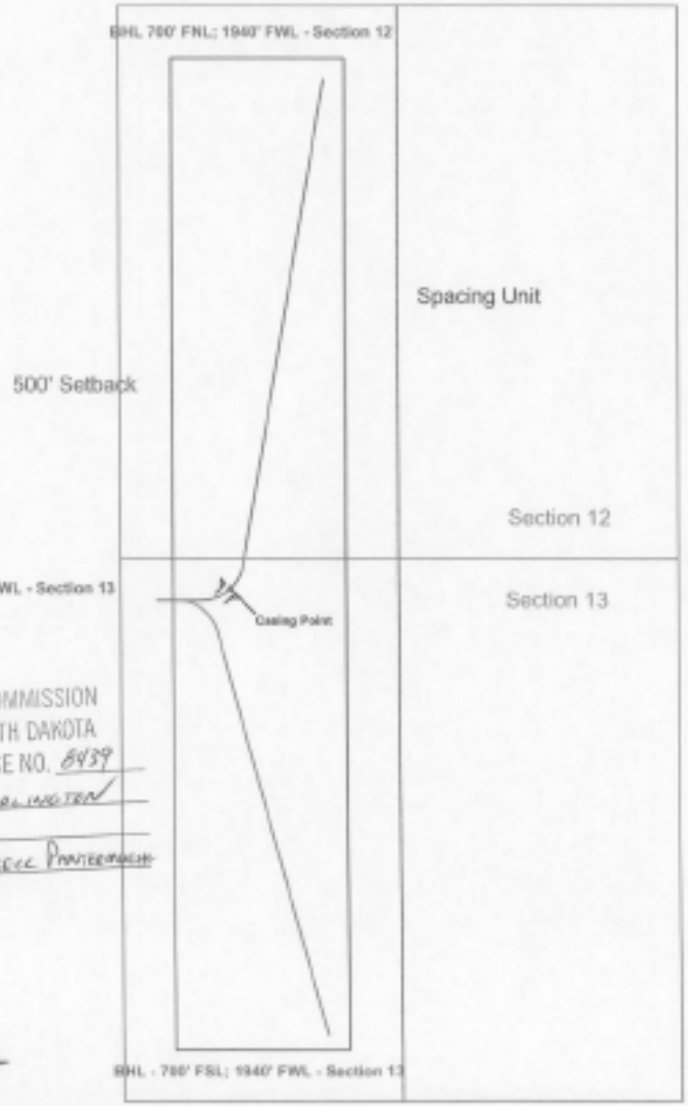
HEADINGTON OIL, LIMITED PARTNERSHIP

EXHIBIT 7


Danielle 1-10H
Easting
Northing
0
660
1320
1980
2640
3300
3960
4620
5280
1st Lateral TD
@ 690' FNL & 2280' FEL
Sec. 3-159N-95W
3
2nd Lateral (Whipstock)
@ 3' FNL & 704' FWL
Sec. 3-159N-95W
7" Casing Seat
@ 254' FNL & 1409' FWL
Sec. 10-159N-95W
Surface Hole Location
@ 150' FNL & 300' FWL
Sec. 10-159N-95W
10
2nd Lateral TD
@ 690' FSL & 2280' FEL
Sec. 10-159N-95W
INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 12/16/15 CASE NO. 9822
Introduced By Continental
Exhibit E-1
Identified By Mike Hudson
CONTINENTAL
Cased Leg
Whipstock Leg
Surface Hole Location

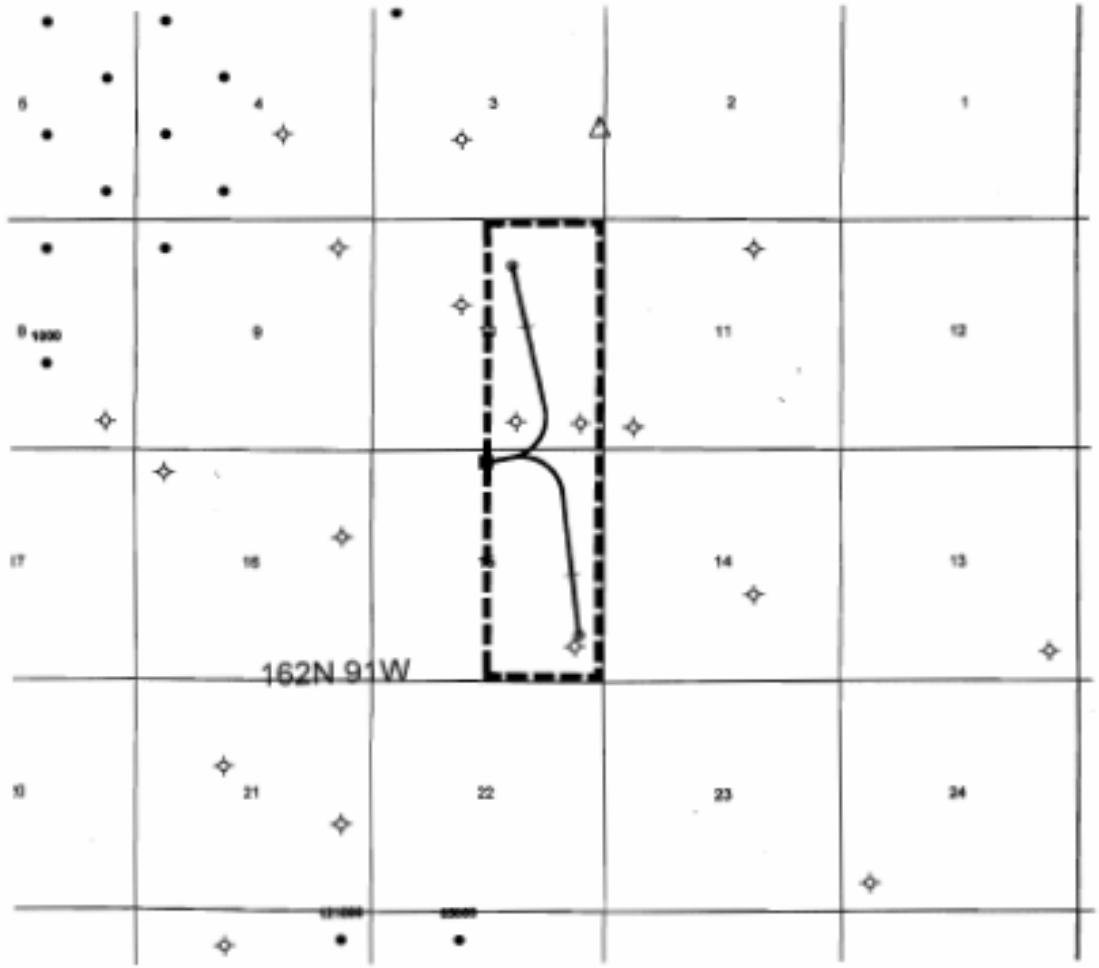
Burlington Resources

Well	Field	NDIC Hearing
BR Fed Angie 11-13H	McKenzie County, North Dakota	Case# 8439, Exhibit# 3.1



INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 02-01-05 CASE NO. 8439
Introduced By BURLINGTON
Exhibit 3.1
Identified By RUSSELL PATTERSON

Schlumberger



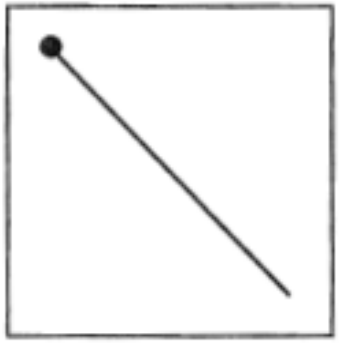
INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 6-27-05 CASE NO. 8587
Introduced By Denbury
Exhibit L-2
Identified By SALTE

Denbury Oil & Gas
PROPOSED SPACING UNIT
Case # 8587
Exhibit L2
June 23, 2005

ALTERNATIVE NO. 1

DUAL HORIZONTAL BAKKEN LATERAL

ALTERNATIVE NO. 2



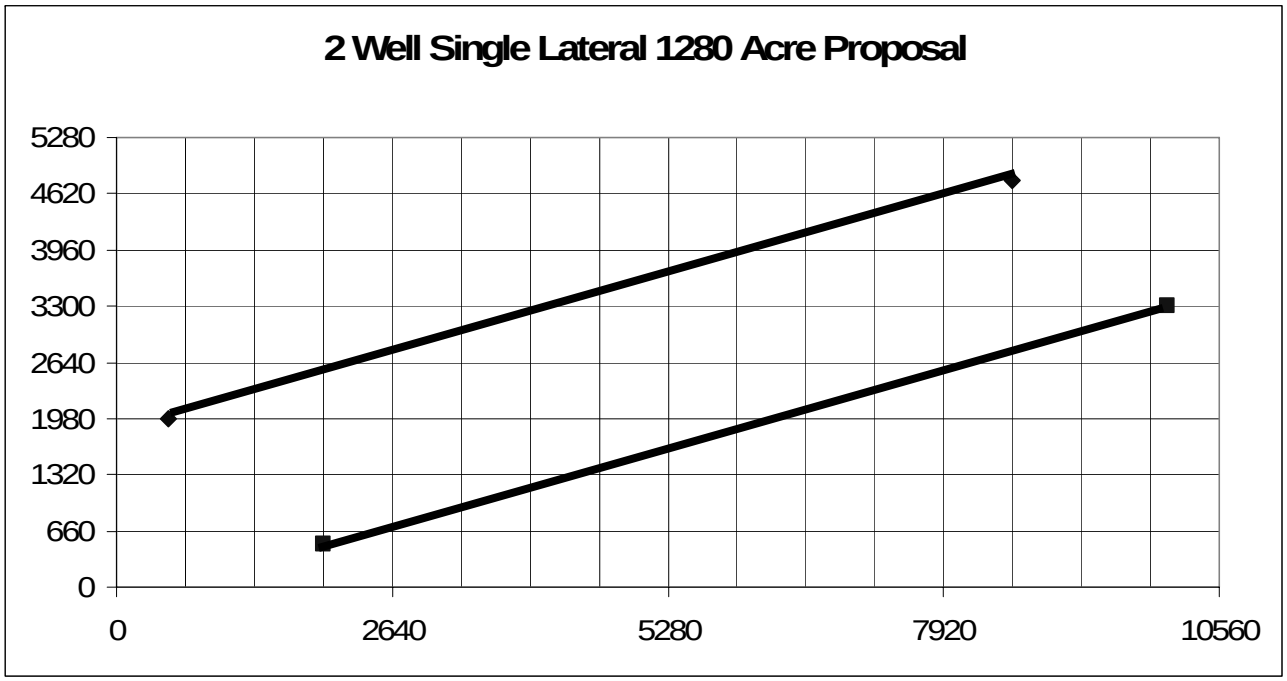
SINGLE HORIZONTAL BAKKEN LATERAL

CASE NO. 8520
EXHIBIT NO. D

INDUSTRIAL Conference
STATE OF NORTH DAKOTA
DATE 04-22-05 CASE NO. 8520
Entered By Nance
Exhibit D
Identified By Larry Kehrer

Planar and Co-planar

- Long Single Planar Lateral - $2,900,000
  - Less mechanical risk
  - Simpler more effective re-frac
- Coplanar - $3,500,000 if nothing goes wrong
  - $4,000,000+ and no proppant frac if liner or tool problems
  - Ability to re-frac?



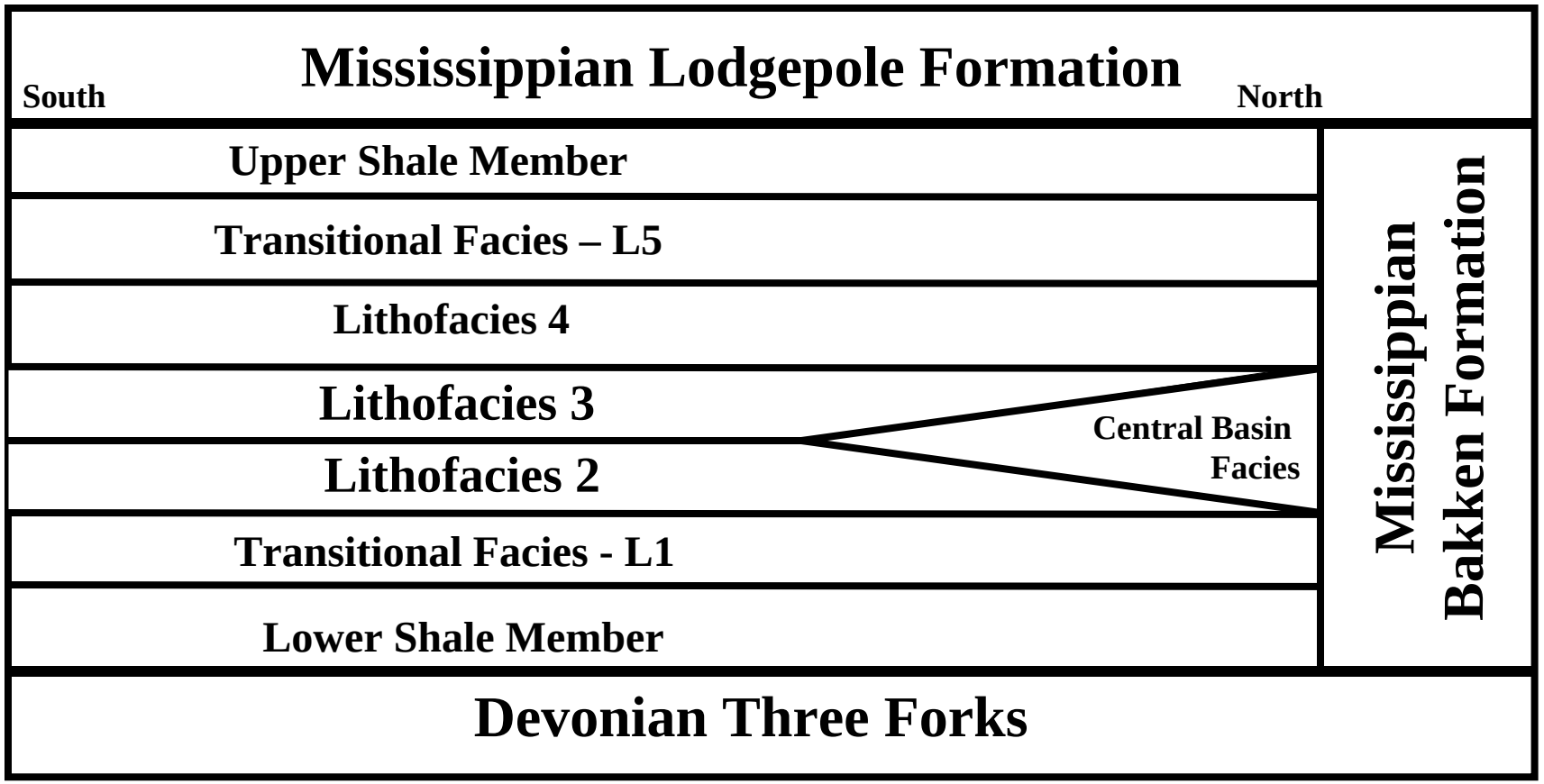
- Can evaluate spacing unit for $2,900,000 (8550’ lateral $340/ft)
  - Less mechanical risk and simpler more effective frac and re-frac
  - $5,800,000 total development cost if 2nd well justified (17,100’ of lateral)
  - Wells are just 500’ closer than if drilled down quarter section lines
- Coplanar - $3,500,000 if nothing goes wrong
  - 9,600-13,000’ lateral $265-366/ft)
  - $4,000,000+ and no proppant frac if liner or tool problems ($303+/ft)
  - Ability to re-frac?
  - $7,000,000 total development cost if 2nd well (20-21,500’ of laterals $327/ft)

The Basics
Bakken Formation in North Dakota

- **Upper & Lower Black Shale**
  - **World Class Source Rock**
    - **TOC's as high as 40%**
    - **HC Generation - 200 to 400 BBbls of Oil**
- **Clastic Middle Member**
  - **5 Lithofacies**
    - **Primarily Sandstones and Siltstones with Interbeds of Dolostone and Limestone**
    - **Low Porosity & Permeability**

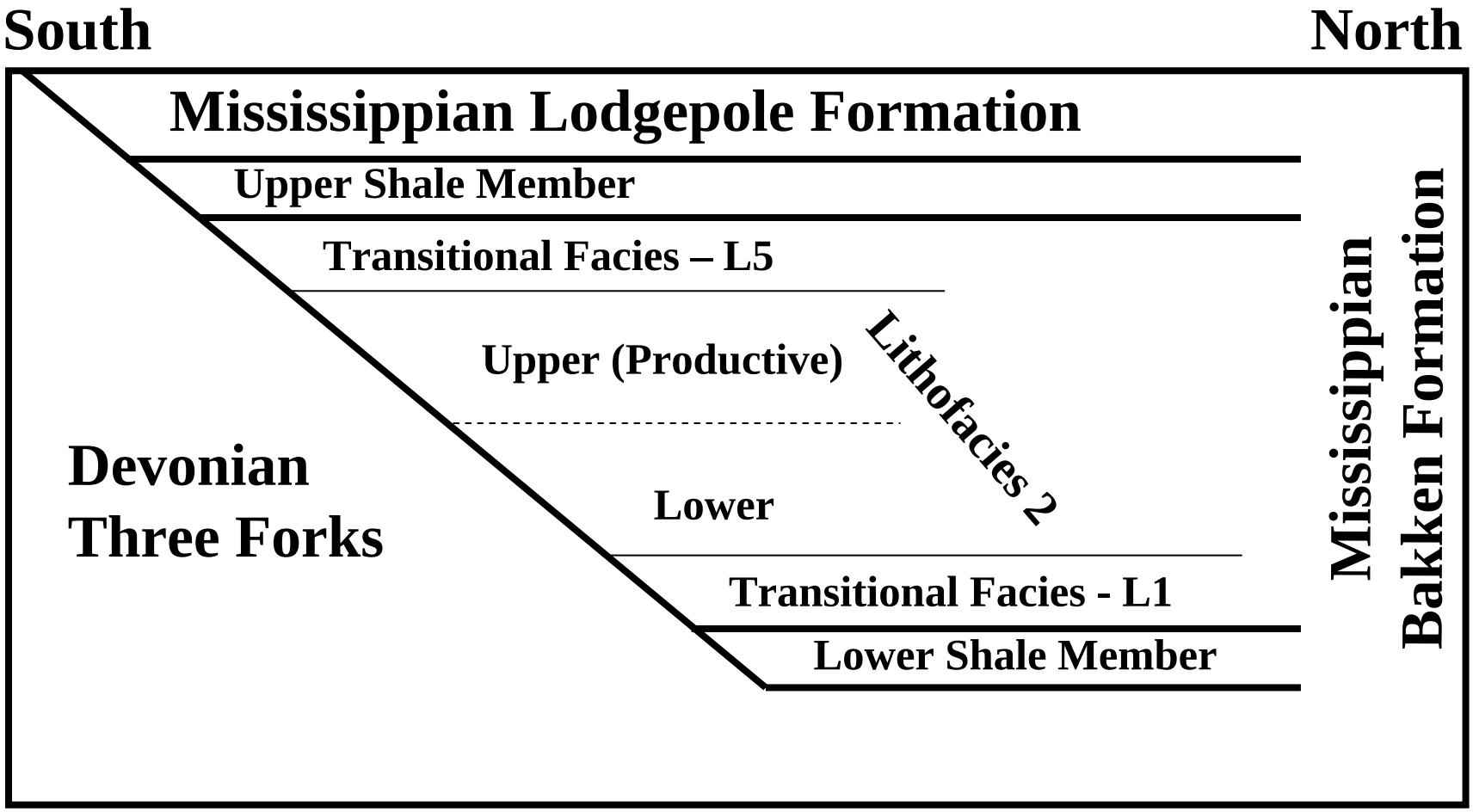
Stratigraphy

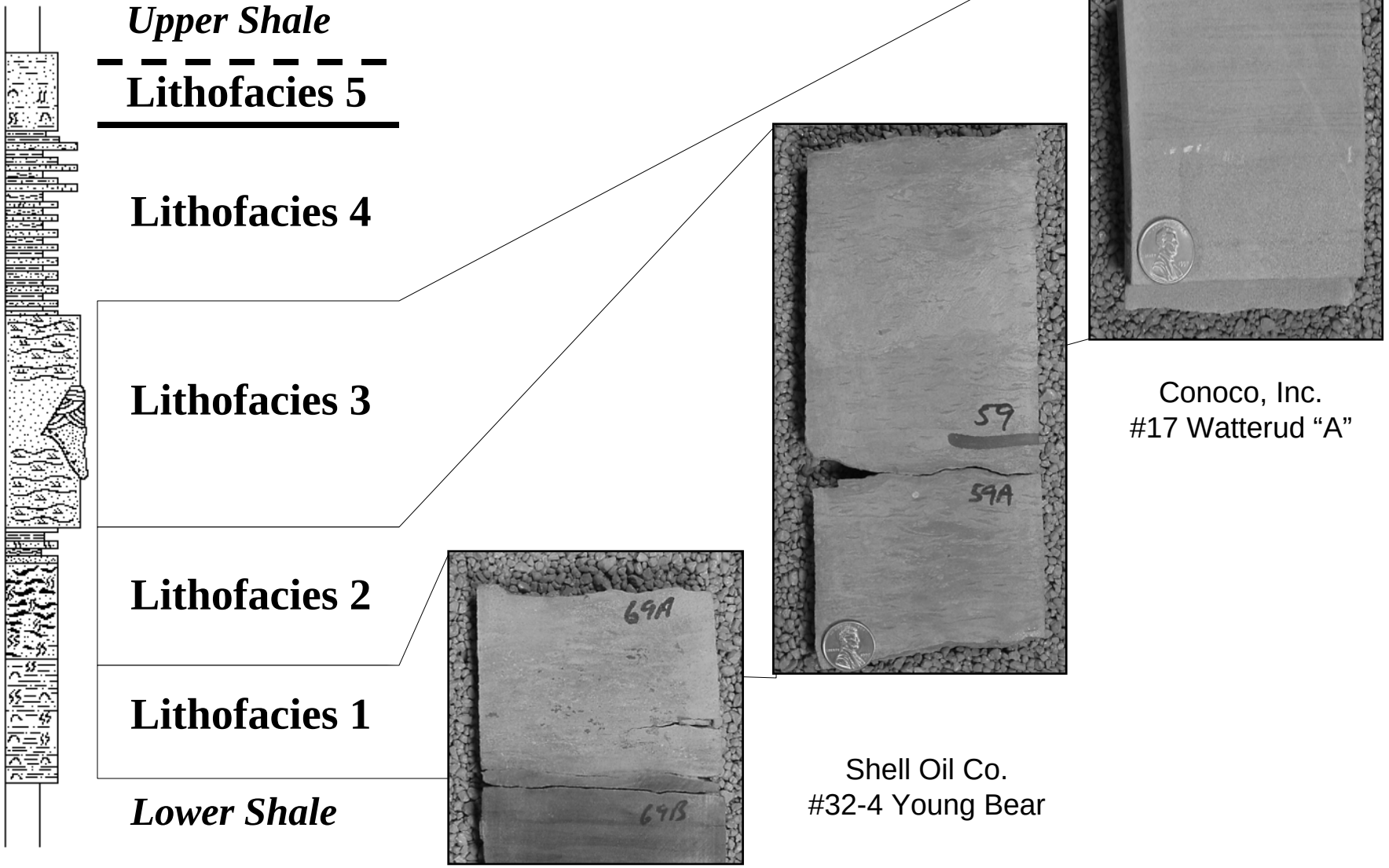
Central Bakken Basin in North Dakota



Stratigraphy

Bakken Limit in North Dakota




Upper Shale
Lithofacies 5
Lithofacies 4
Lithofacies 3
Lithofacies 2
Lithofacies 1
Lower Shale
59
59A
69A
69B
Conoco, Inc.
#17 Watterud “A”
Shell Oil Co.
#32-4 Young Bear

Upper Shale

Lithofacies 5

Lithofacies 4

Lithofacies 3

Lithofacies 2

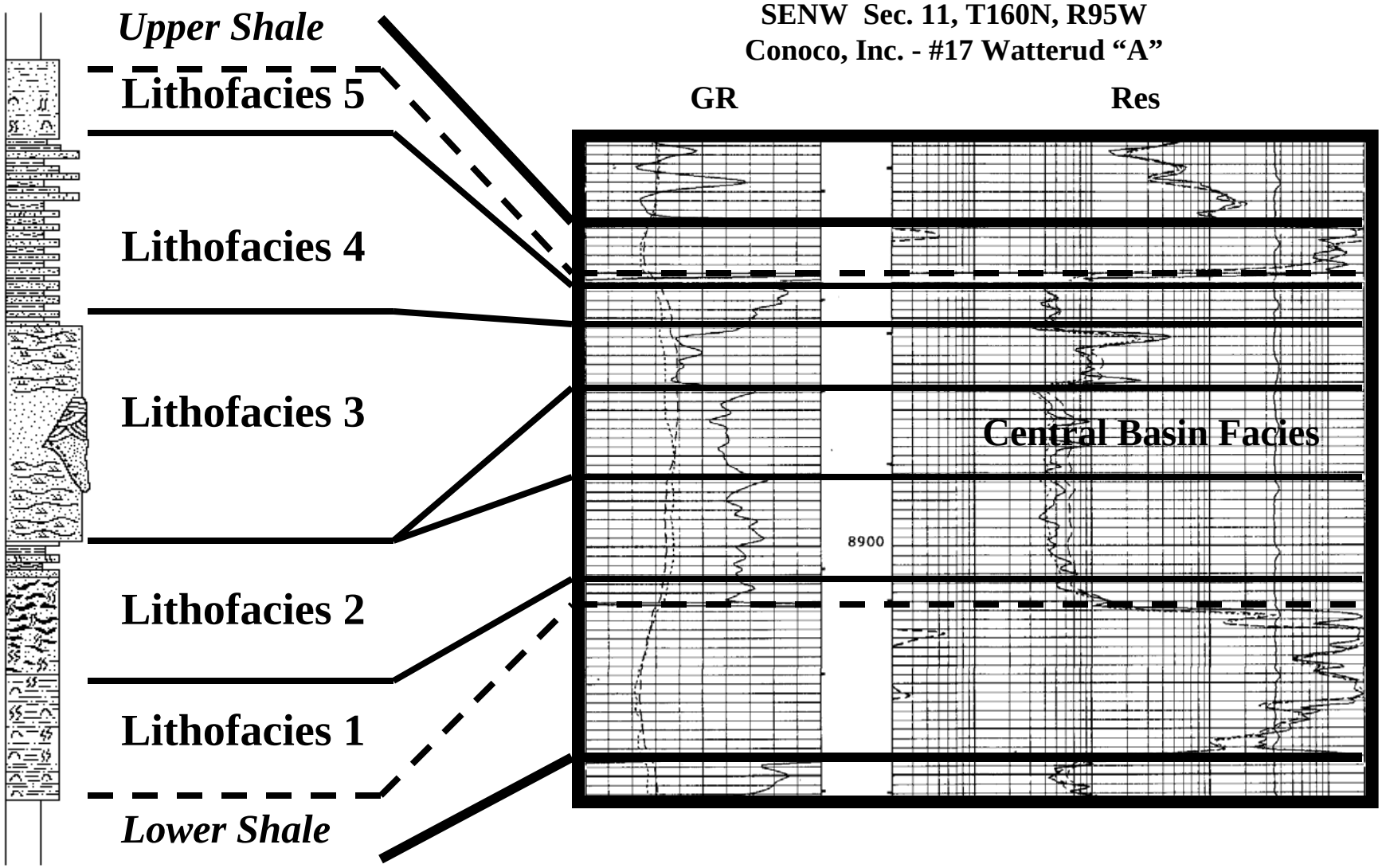
Lithofacies 1

Lower Shale

Shell Oil Co.
#32-4 Young Bear

Meridian Oil, Inc.
#44-27 MOI

Lithofacies of the Middle Member



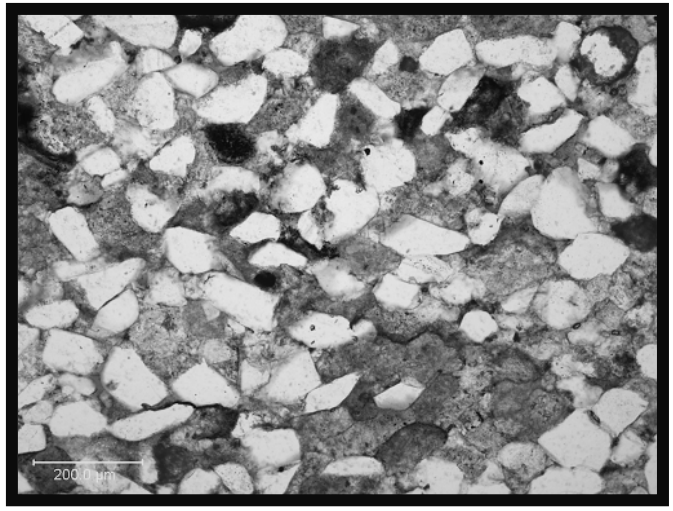
(From LeFever and others, 1991)

Middle Member Bakken

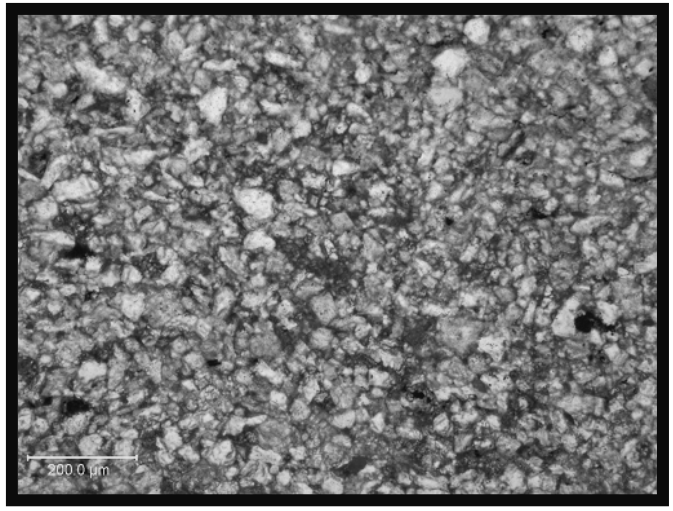
Porosity Types

- **Clastic Sequence with Carbonate Interbeds**
- **Primary Porosity**
  - **Interparticle to Intercrystalline**

Interparticle



Intercrystalline

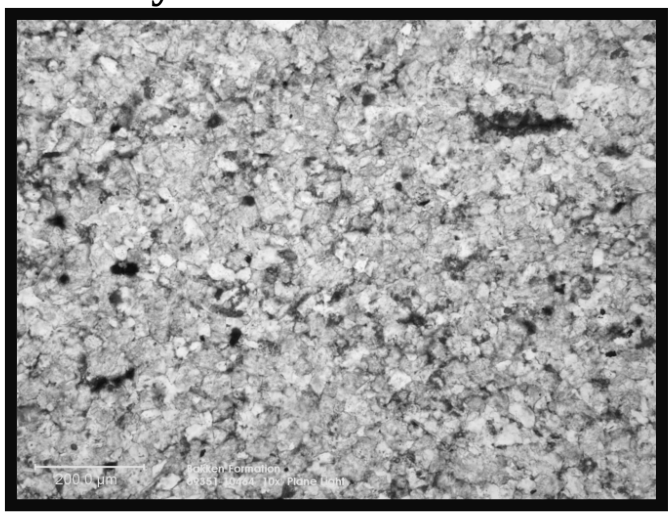


Middle Member Bakken

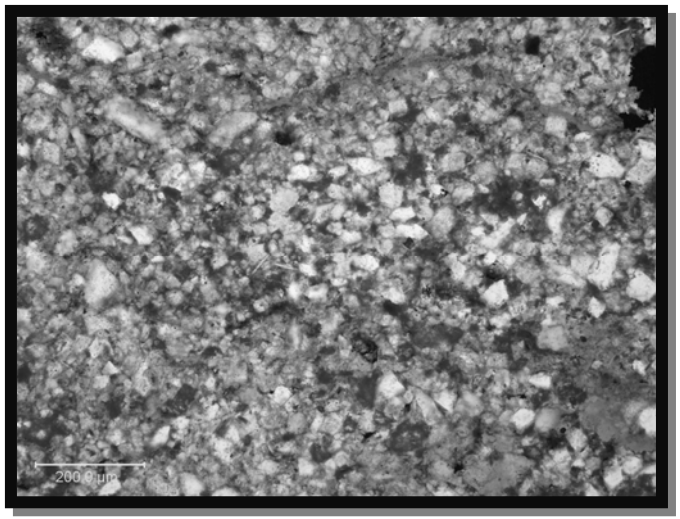
Porosity Types

- **Secondary Porosity**
  - **Dolomitization**
    - **Matrix**
    - **Cement**
  - **Fractures**
    - **Regional**
    - **HC Generation**

Intercrystalline



Fracture

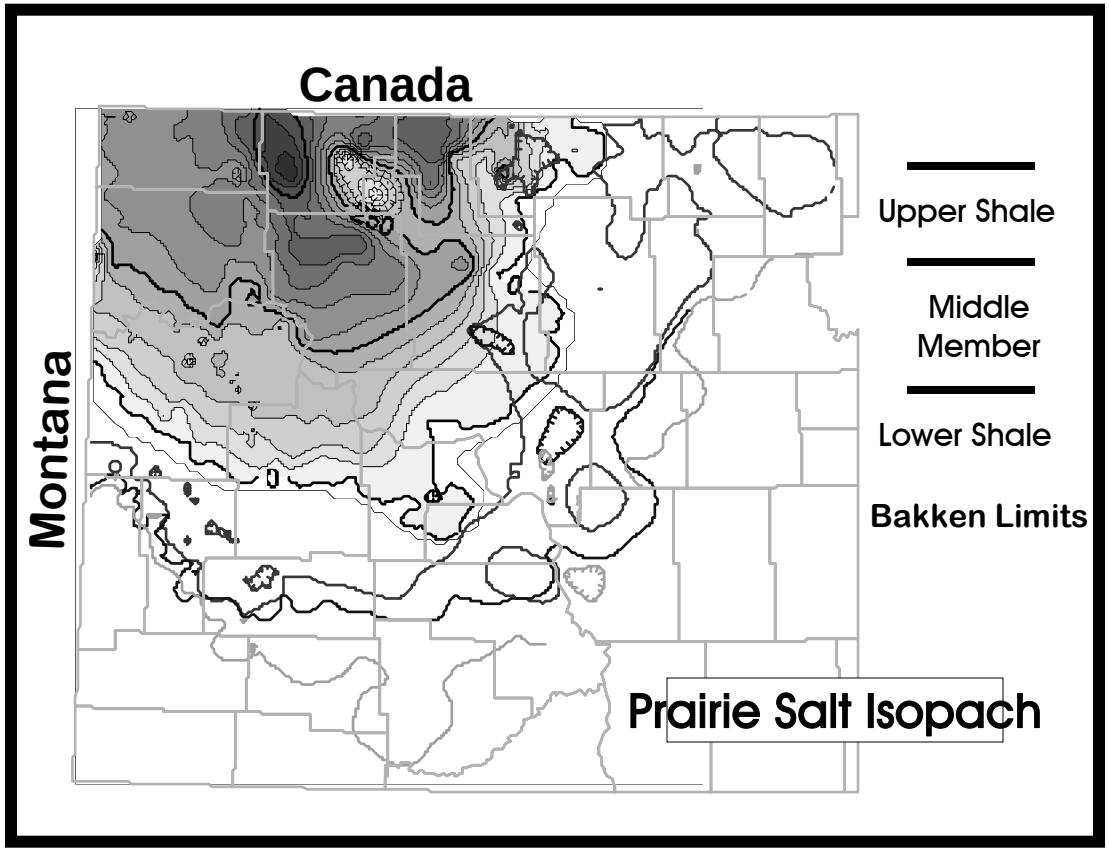


Tectonic Fracturing

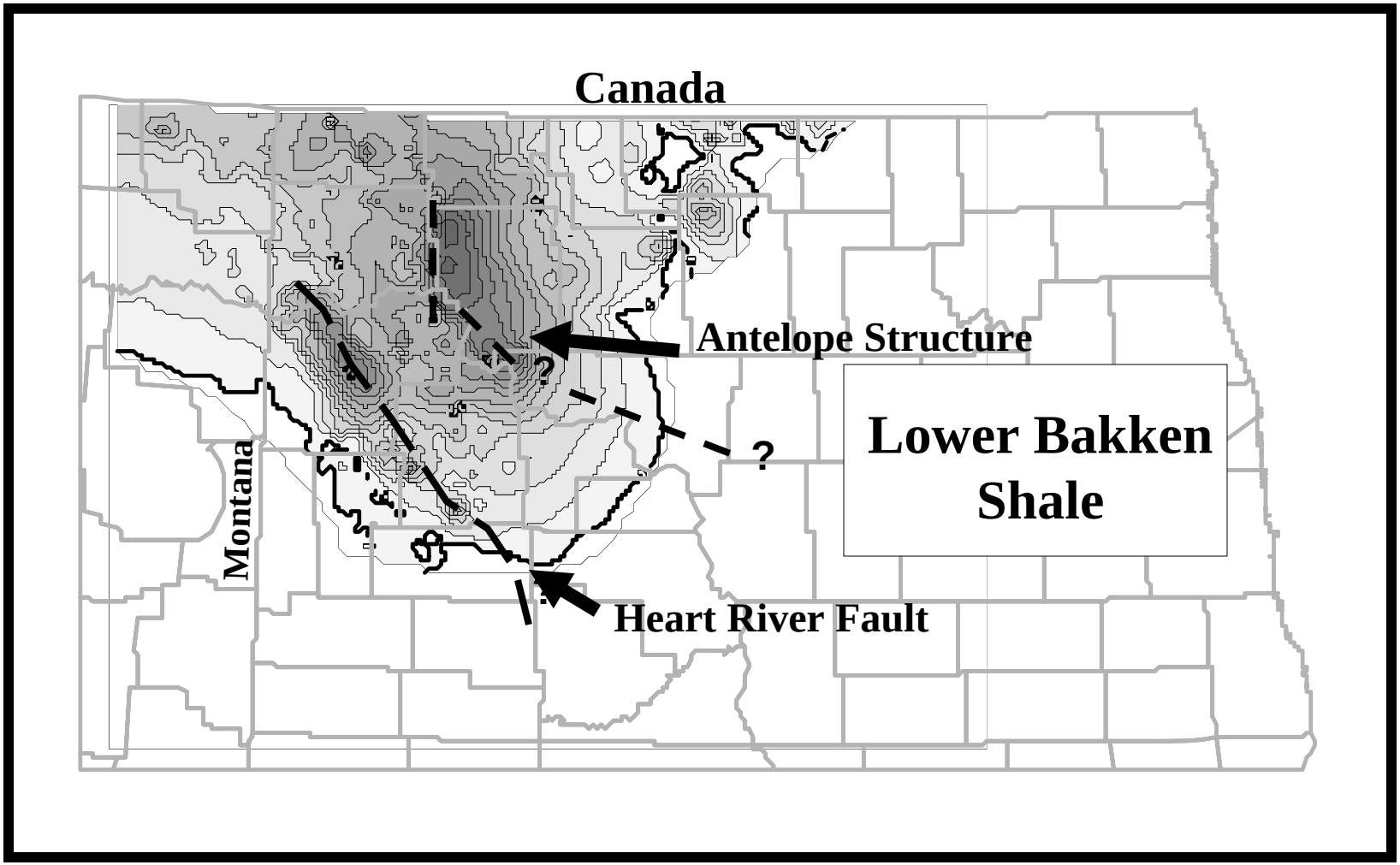
Salt Dissolution

Complete or Partial Dissolution of the Prairie Salt

- **Depositional Edge**
- **Overlying Basement Structures**
- **Other Geologic Features**

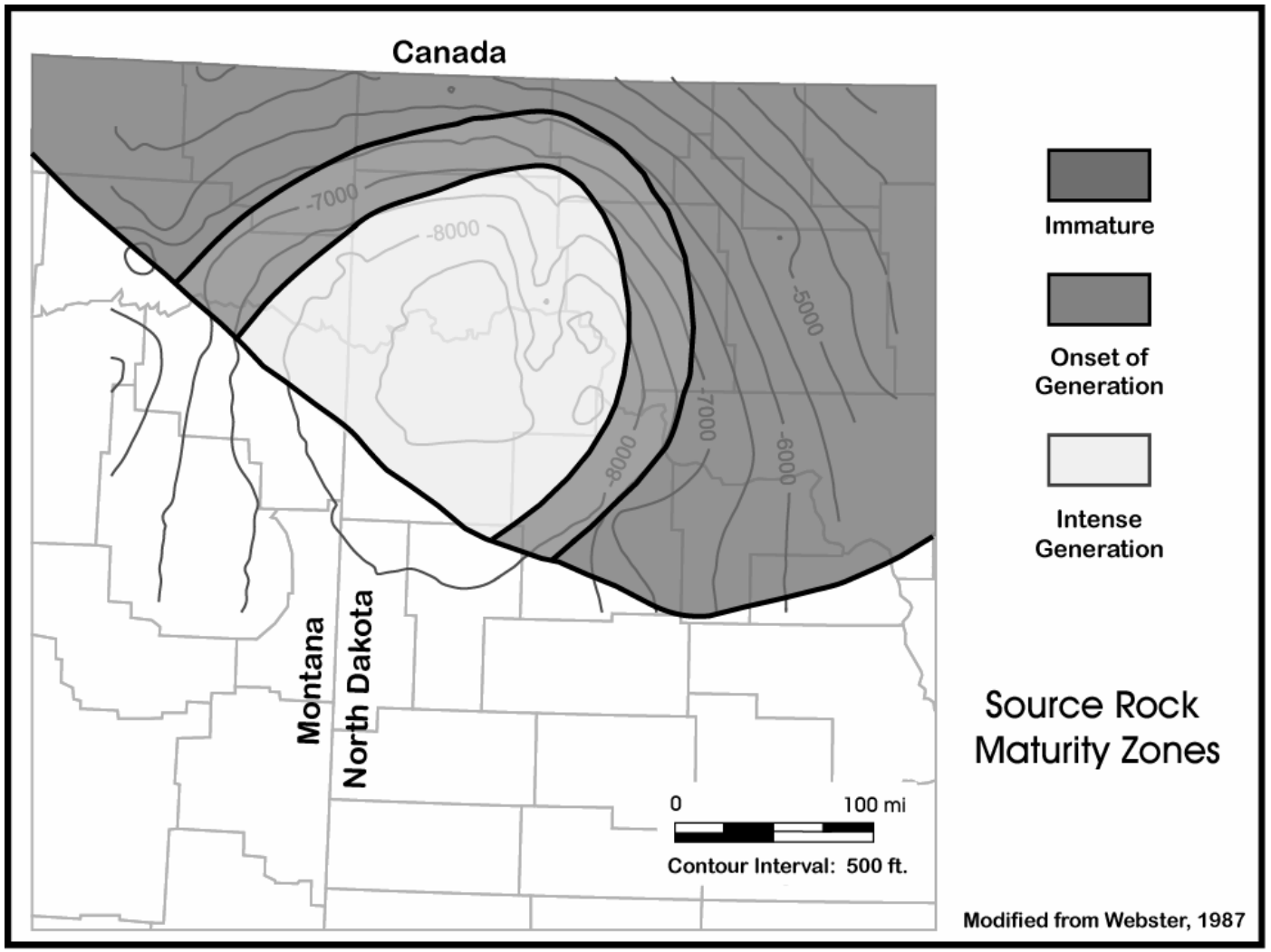


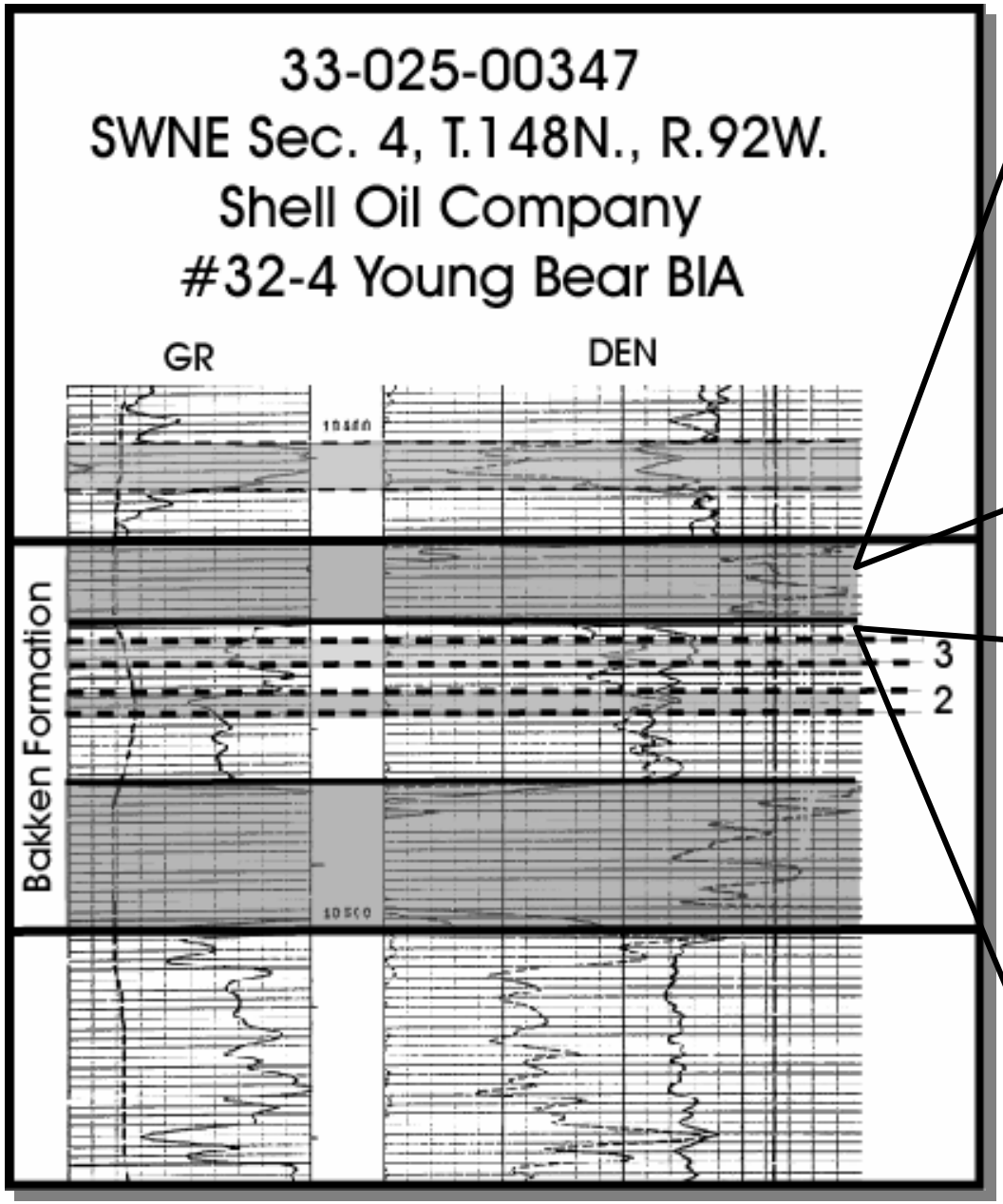
Tectonic Fracturing
Regional Fractures

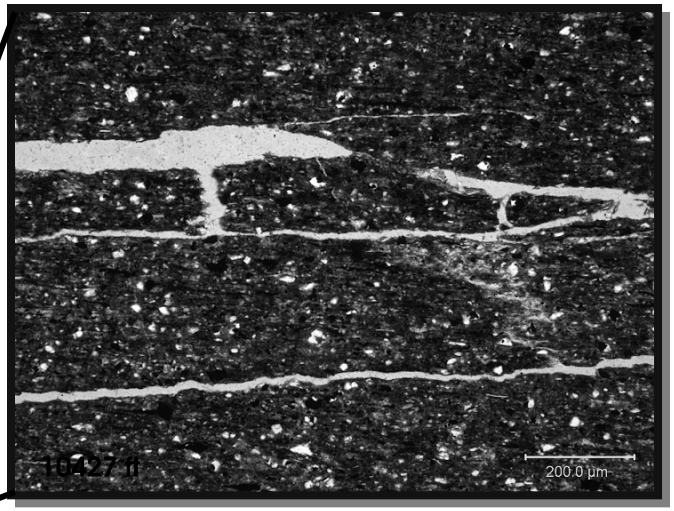


Fractures

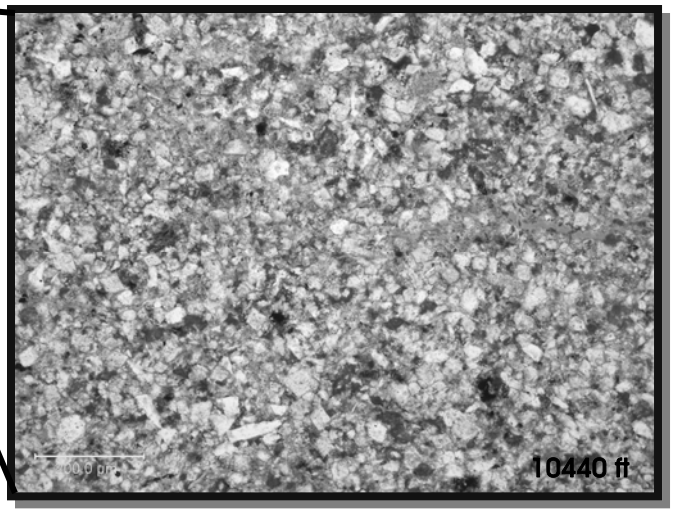
HC Generation







Upper Bakken Shale

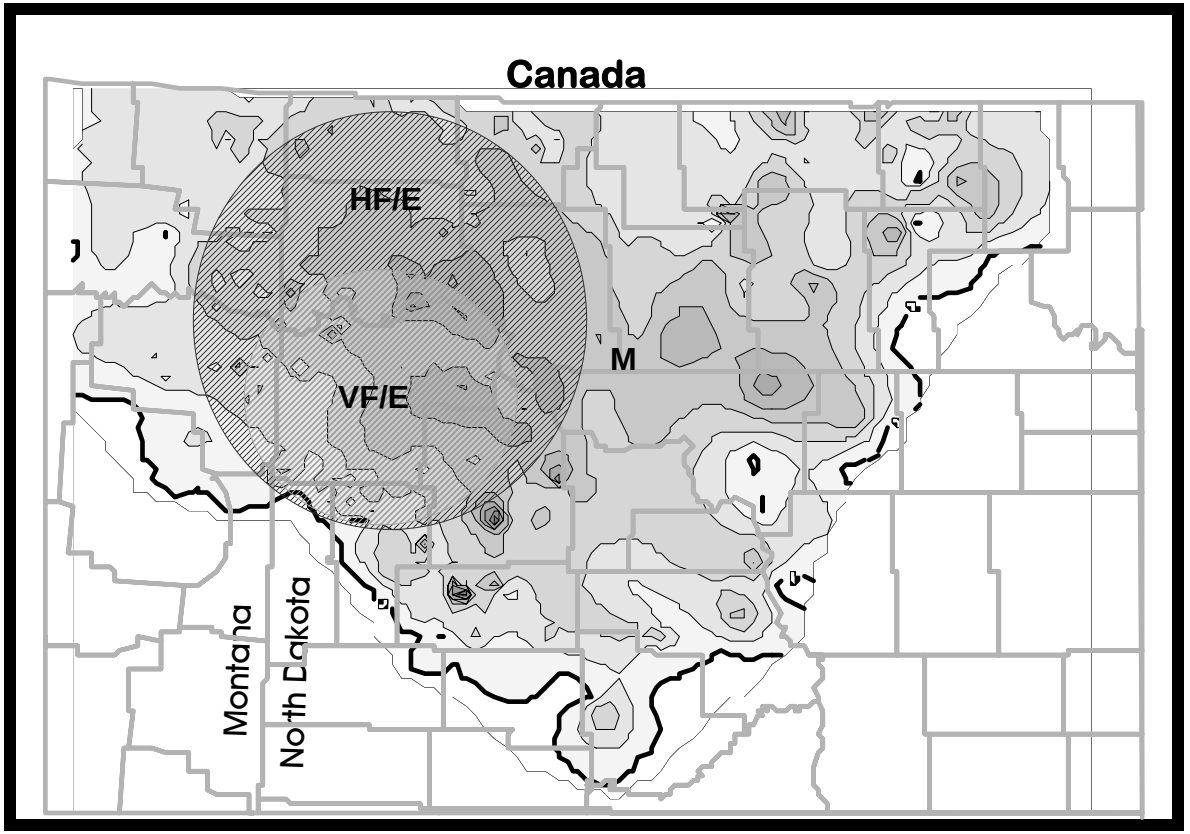


Lithofacies 4

Non-Tectonic Fractures

HC Generation - Upper Bakken Shale

Texaco, Inc - #1-5 Thompson



Implications
Fractures

- **Necessary for Production?**
  - **Natural**
  - **Artificial**
    - **Enhances Existing ϕ and K and Fractures**
    - **Production pathway for the Shales**
- **Result in an Increase in Production**
  - **Providing a Conduit for Oil to the Borehole resulting in High Production Rates**

Implications

Fractures

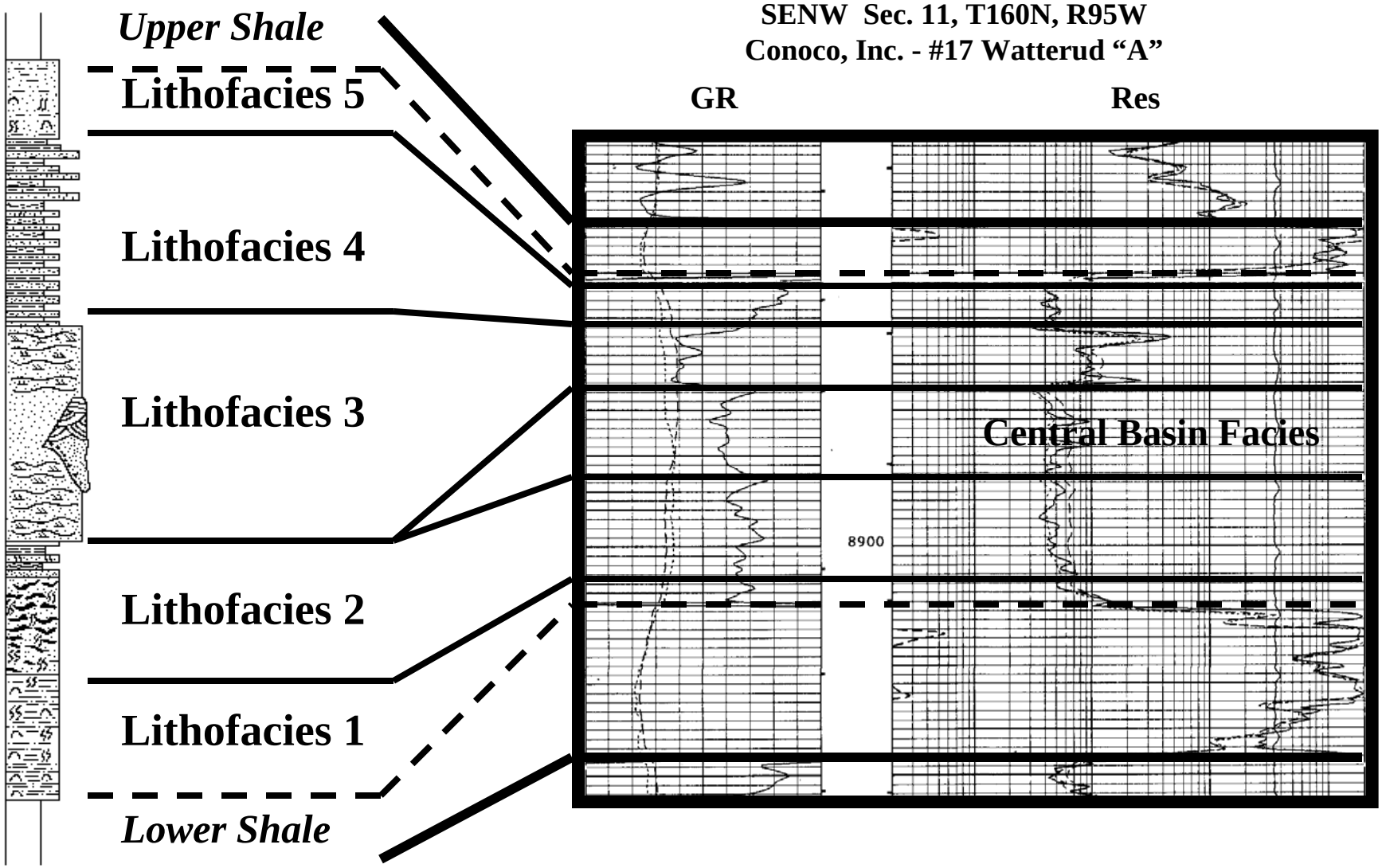
- **Problems**
  - **Result in Borehole Stability Problems**
  - **High Potential for Damage of Micro-fractures**
    - **Over-balanced muds**
    - **Rapid Pressure Drawdown**
    - **Water-blocking (Bakken is “Oil-Wet”)**
  - **May Influence the direction of the Fracture-Stimulation Treatment**

Middle Member Bakken

Accessory Minerals

- **Pyrite**
  - **Iron Oxides**
    - **Response to Acid**
    - **Wireline Log Effects**
- **Clays**
  - **Illite, Chlorite & mixed-layer Clays**
    - **Response to Acid**
    - **Response to Water**
- **Organic Material**
  - **TOC's > 0.5%**
    - **Wireline Log Effects**

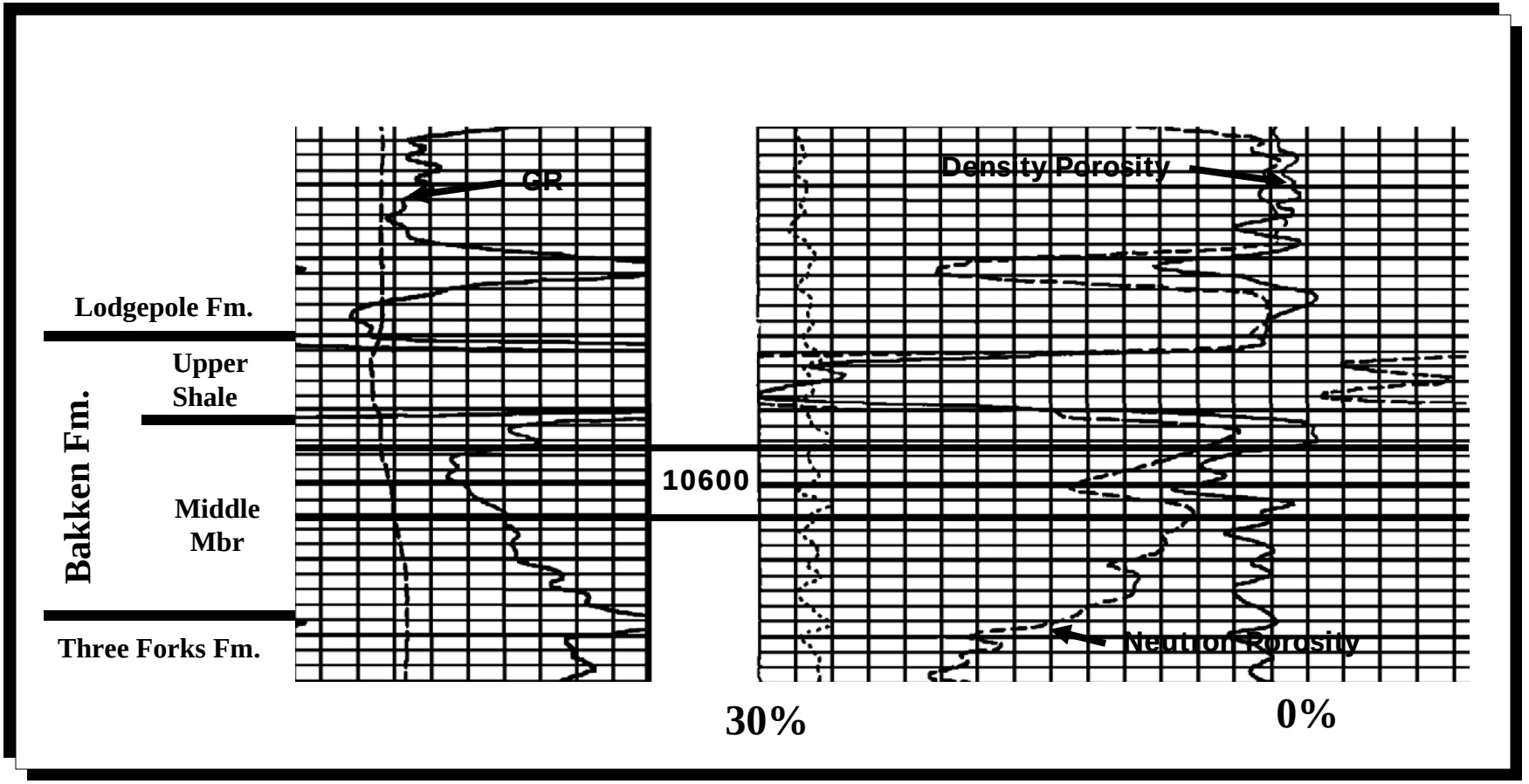
Lithofacies of the Middle Member



(From LeFever and others, 1991)

Shell Oil Company - #12-6-44 U.S.A.

SENWNW Sec. 6-T.148N.-R.104W.



Conclusions

- **The Lithofacies are present basinwide.**
- **Primary reservoir porosity may be enhanced by diagenesis, tectonic fractures, and/or fractures from HC generation.**
- **Porosity enhancement is not restricted to a single lithofacies within the Middle Member.**
- **Type of fluid used while drilling may have adverse effects on production.**
- **The presence of vertical fractures in areas of intense HC generation may affect the outcome of stimulation treatment.**

Conclusions

- **Barnett Shale, Texas is a good analog to the Bakken**
  - **Low Porosity/Low Permeability Source Rock**
  - **Gelled-water vs. Slick-water Fracture Stimulation Treatment**
  - **Success with Multiple Fracture Treatments**