# Identification of Future Oil Potential from Upper Devonian Venango Sandstones in Central Appalachians*

**Eric G. Ober[1] and Craig Eckert[1]**

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## Abstract

Correlation of discrete sand bodies within the Venango Group sandstones of northern West Virginia allows for mapping of sand bodies with porosities averaging 13%, but as high as 25%. Net sand, pay (sandstone with > 8% porosity), and average porosity were mapped across structural axes where oil had accumulated in the synclines and gas in the anticlines. Volumetric mapping of Venango sandstone reservoirs has been shown to produce results that are consistent with previously published data. Application of this methodology to remaining fields suggests that accurate estimation of in-place reserves is possible. Oil production from many of the fields studied has been less than 25% of the estimated original oil in place, indicating that the vast majority of this resource remains unexploited with current technology.

## Selected References

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# Identification of Future Oil Potential From Upper Devonian Venango Sandstones in the Central Appalachians

Eric Ober, Craig Eckert

May 22, 2013

# Overview

- History of Oil Drilling In West Virginia
- Geology – the Venango Group Sandstones
- Overview of Salem-Wallace Oil Field
- The Gordon Sandstone In Salem-Wallace Field
- Calculating Remaining Oil In Place
- Conclusions

# Overview

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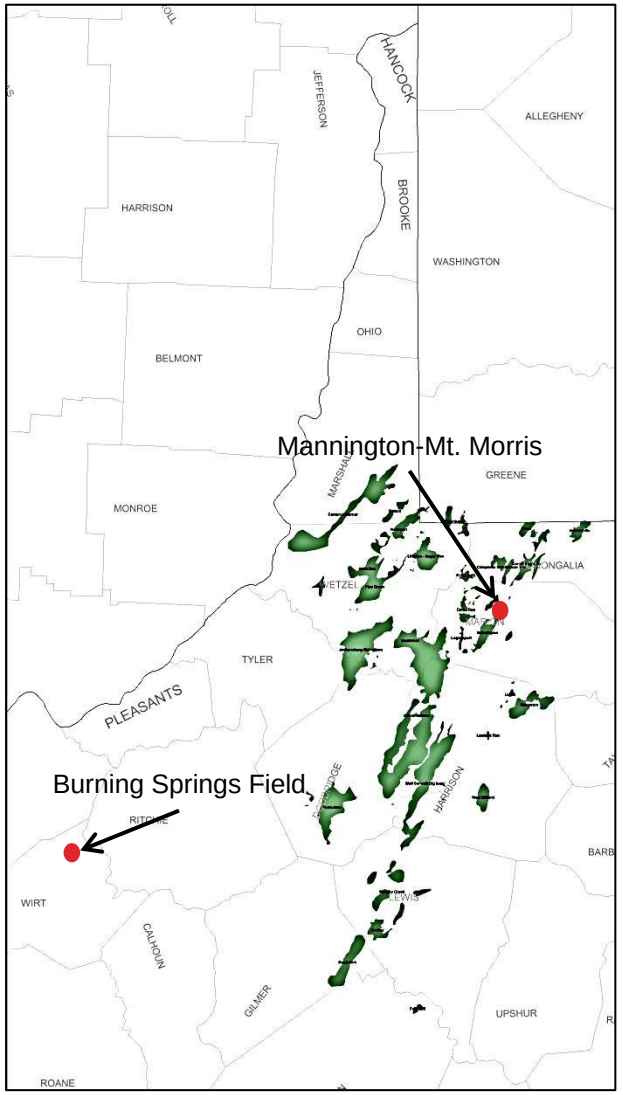
# West Virginia Oil – A history lesson

- **Oil first "discovered" in West Virginia by the local Indians around the Burning Springs area on the Little Kanawha, Kanawha and Big Sandy Rivers.**
- **Oil was first commercially produced in the Burning Springs Oilfield,**
  - Discovered in 1860
  - Produced from various Pennsylvanian and Upper Mississippian age formations; from 300-2000 ft. deep.
- **First Venango Field – Mannington-Mt. Morris Field**
  - Discovered in 1868
  - Producing Formations
    - Devonian - Gordon, Fourth, and Fifth Sands
    - Mississippian – Big Injun
- **Oil production reached a peak in 1900 at 16 MMBO.**
  - By 1934, oil production had nearly stopped.
- **Today oil production continues at low rates with waterfloods being utilized in some areas.**



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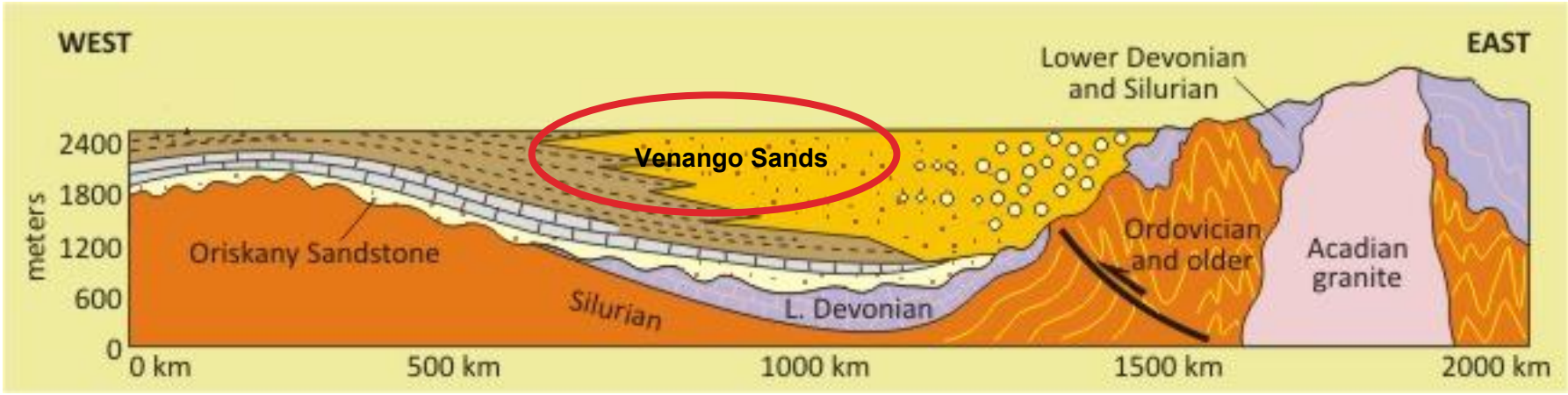
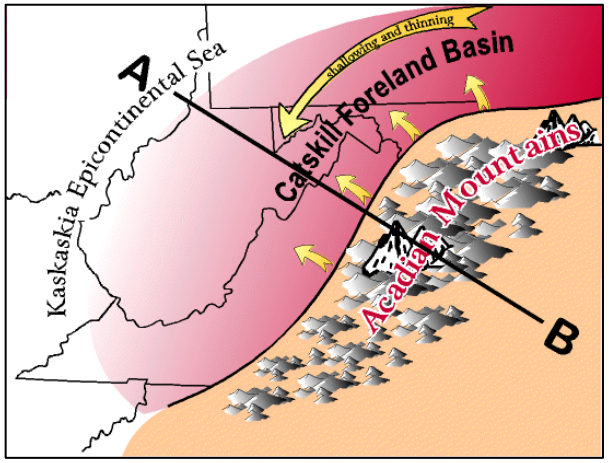
# Geology – The Venango Group Sandstones
## Diagram of the infilling of the Acadian Foreland Basin




After Prothero & Dott, 2003




Fitcher, 1999

# Geology – The Venango Group Sandstones Stratigraphic Chart

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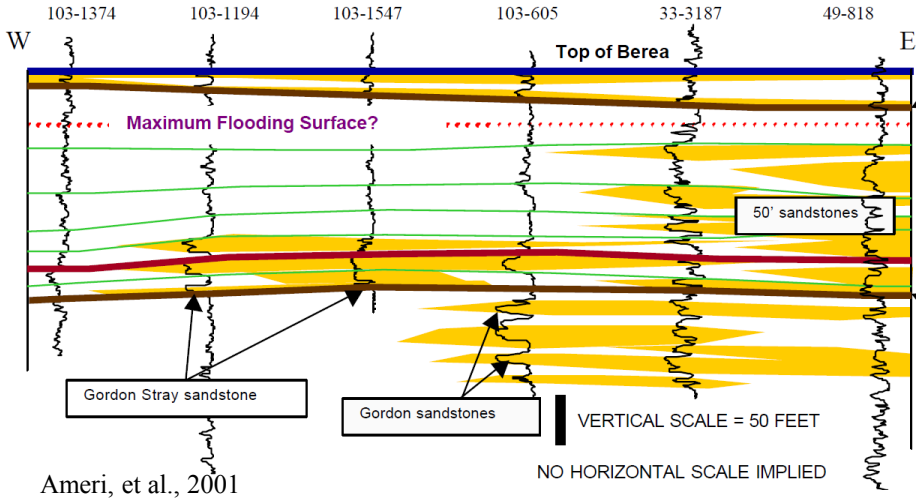
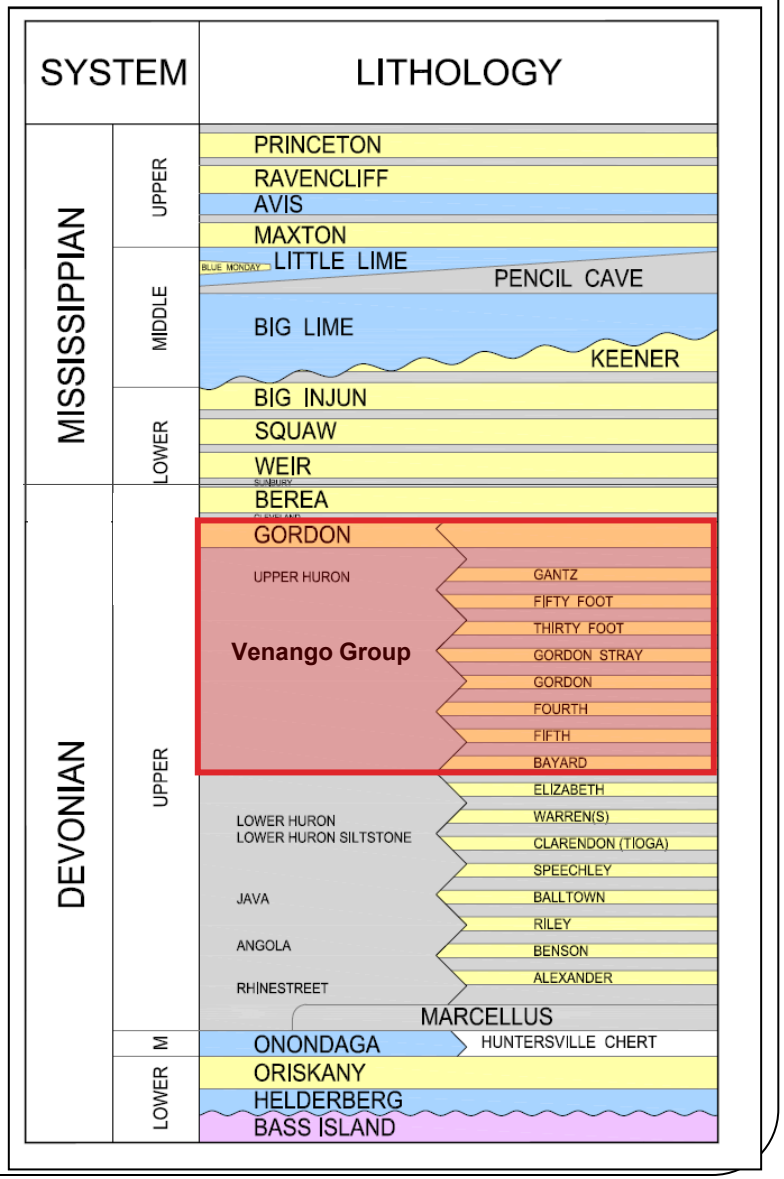
## Venango Group

- Nomenclature varies by area.
  - Gantz, Fifty Foot, Thirty Foot, Gordon Stray, Gordon, Fourth, Fifth, and Bayard
  - Hundred Foot, Nineveh, Third Sand
- Characteristics change from West to East
  - West – distal marine shale
    Chagrin, Ohio and Chattanooga
  - **Central – Marine shoreline sandstone**.
  - East – non-marine fluvial sandstone Hampshire formation.

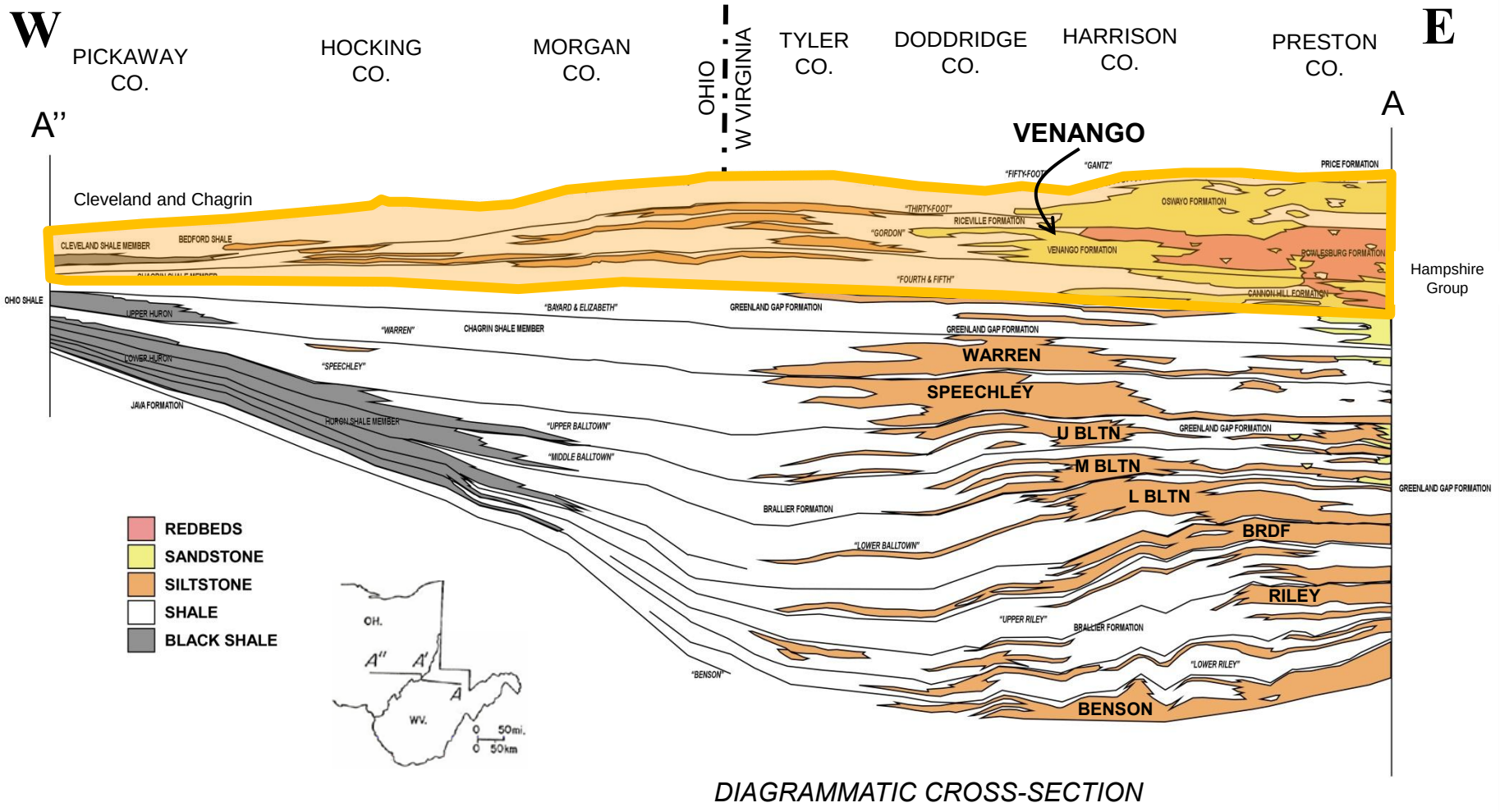



Ameri, et al., 2001



# Geology – The Venango Group Sandstones

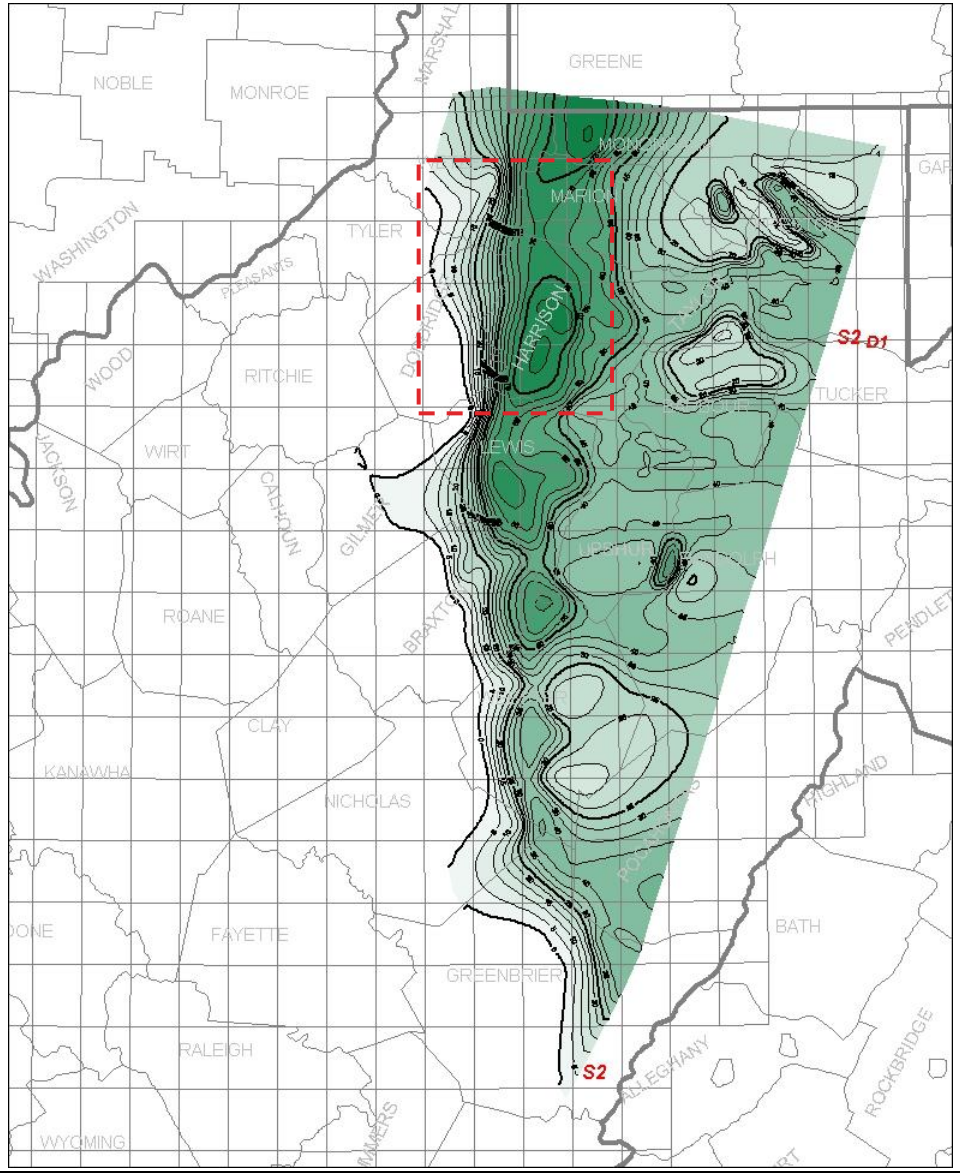
## Sequence Stratigraphic Cross-section of the Famenian Stage of East OH to Central WV




*DIAGRAMMATIC CROSS-SECTION*

Modified from Boswell, 1988

# Geology – The Venango Group Sandstones
## Gordon Sandstone Isolith
(After Boswell, 1988)



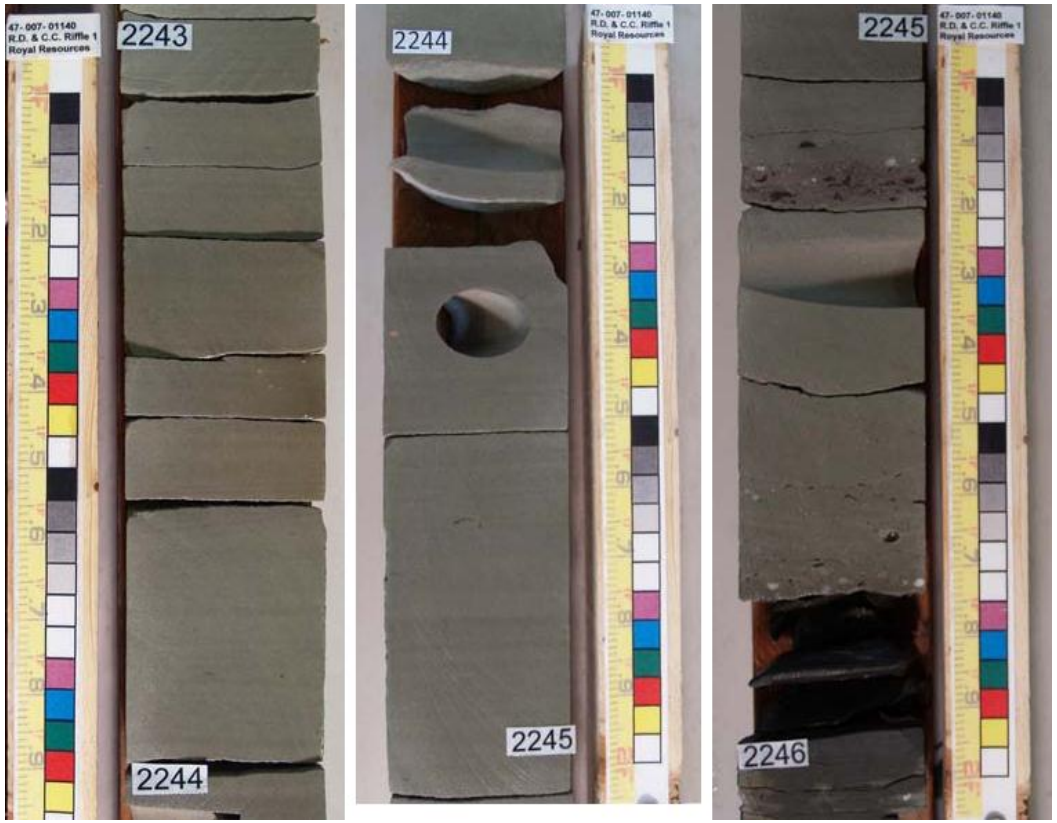

10 miles

*CI = 5 ft*

# Geology – The Venango Group Sandstones
# Gordon Sandstone

- **Late Devonian Shoreface Sandstone**
- **Fine-medium grain sandstone**
  - Fines upward from basal lag deposits.
- **High Porosity**
  - Log Porosity ranges from 10% – 14% within the Salem Wallace Field
- **Five reservoir units (A – E)**
  - Total reservoir net pay thickness up to 89 ft.
- **Venango Group Oil Gravity**
  - 32 – 52° API*

47-007-01140 – R.D. Riffle #1– Braxton County
1976 - Royal Resources




*Range compiled from Thompson, 1916, and Sherrill, et al., 1941

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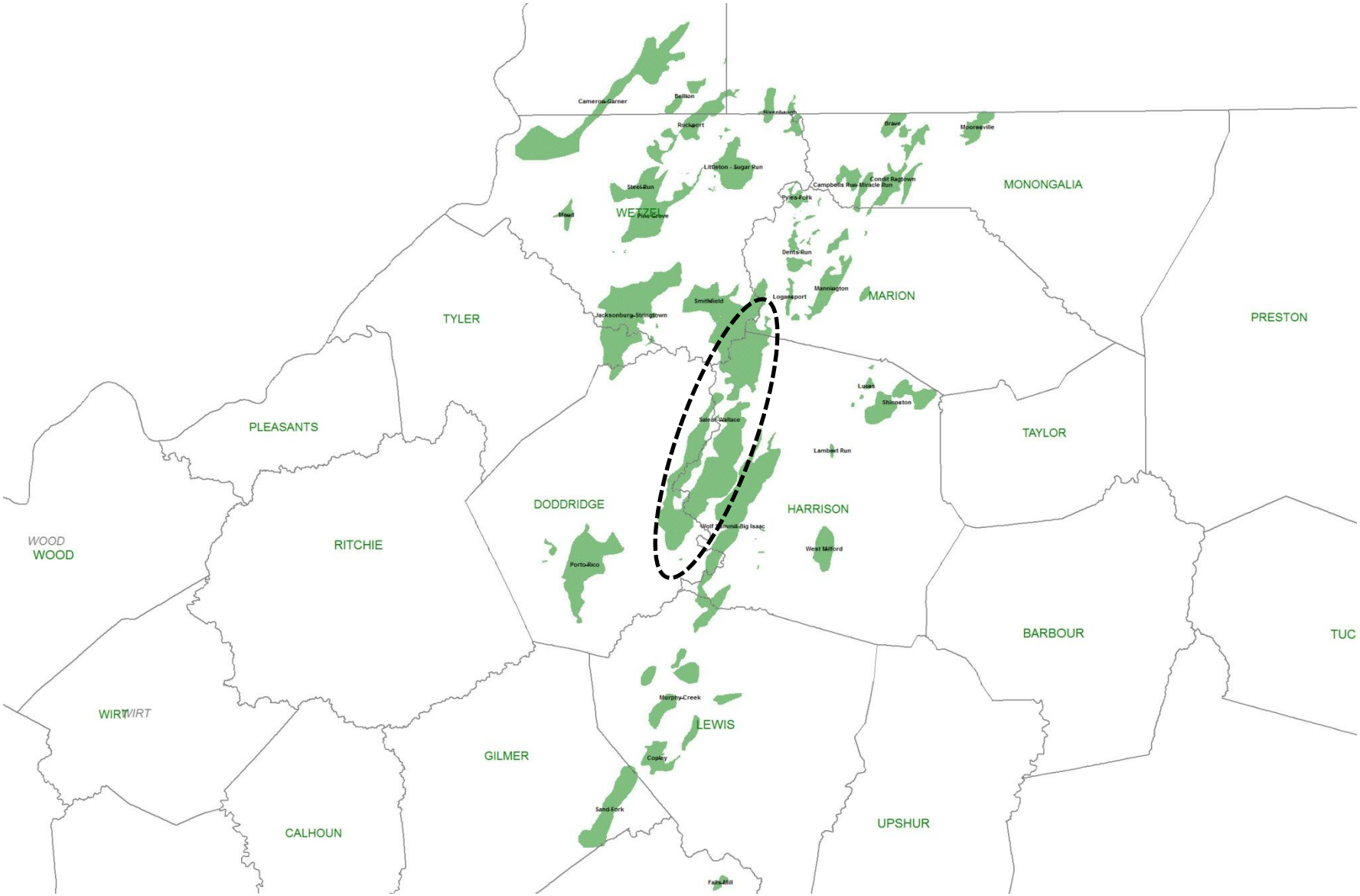
# Overview of Salem-Wallace Oil Field
# Venango Oil Fields of West Virginia



# Salem-Wallace Oil Field

- **Salem-Wallace has been the most productive oil field in West Virginia**
  - Produced 41 MMbbl of oil from discovery in 1895 to 1960
  - OOIP (1895) = 242 MMBO*
  - Cumulative Production through 1960 = 41 MMBO*
    - Production from 1985 to present = 47,091 BBL
  - Oil Gravity
    - Venango Group - 32 – 52° API**
    - Mannington-Mt. Morris – 42.3° API*
- **Good data availibility**
  - 1500 well logs available in the 16 quad area centered on the field
  - Gordon Sandstone core available from WVGES

*Whieldon & Eckard, 1963

**Range compiled from Thompson, 1916, and Sherrill, et al., 1941

# Overview of Salem-Wallace Oil Field
## Venango Oil Fields of West Virginia Oil Production

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### POTENTIAL RESERVES IN VENANGO OIL FIELDS

Production data from Bureau of Mines Bulletin 607, 1963

| Field Name | Producing Formations | Geologic Age | OOIP (MBbl)* | Primary Oil Production (MBbl) | Remaining Oil (MBbl) | Primary Oil Recovery Factor (V/V) |
|---|---|---|---|---|---|---|
| Bellton | Fourth, Gordon | Upper Devonian | 1,920 | 541 | 1,379 | 0.28 |
| Brave | Gordon, Fourth, Big Injun | Upper Devonian, Mississippian | 11,443 | 3,360 | 8,083 | 0.29 |
| Cameron-Garner | Gordon | Upper Devonian | 25,160 | 5,975 | 19,185 | 0.24 |
| Campbells Run-Miracle Run | Fourth, Gordon, Gordon Stray, Fifth | Upper Devonian | 30,965 | 7,544 | 23,421 | 0.24 |
| Cappo Run(Hixenbaugh) | Fourth, Gordon | Upper Devonian | 4,708 | 1,353 | 3,355 | 0.29 |
| Condit-Ragtown | Fourth, Fifth, Gordon, Big Injun, Gordon Stray | Upper Devonian, Mississippian | 34,830 | 11,996 | 22,834 | 0.34 |
| Copley | Fifth, Gordon, Gordon Stray | Upper Devonian | 8,160 | 2,973 | 5,187 | 0.36 |
| Deep Valley | Big Injun, Maxton, Gordon, 1st Cow Run | Mississippian, Upper Devonian, Pennsylvanian | 9,502 | 2,084 | 7,418 | 0.22 |
| Dents Run | Thirty-Foot | Upper Devonian | 21,912 | 5,049 | 16,863 | 0.23 |
| Falls Mill*6 | Gordon | Upper Devonian | 1,750 | 345 | 1,405 | 0.20 |
| Follansbee | Berea, Hundred-Foot | Mississippian, Upper Devonian | 1,152 | 333 | 819 | 0.29 |
| Jacksonburg-Stringtown | Gordon Stray | Upper Devonian | 88,469 | 20,458 | 68,011 | 0.23 |
| Lambert Run*2 | Fourth | Upper Devonian | 1,242 | 599 | 643 | 0.48 |
| Littleton | Gordon, Fourth, Fifth, Gordon Stray | Upper Devonian | 9,200 | 2,020 | 7,180 | 0.22 |
| Logansport*5 | Thirty-Foot | Upper Devonian | 2,600 | 599 | 2,001 | 0.23 |
| Lucas and Lambert Run | Fourth | Upper Devonian | 3,675 | 1,772 | 1,903 | 0.48 |
| Mannington-Mt. Morris | Big Injun, Gordon, Fifth, Fourth | Mississippian, Upper Devonian | 127,617 | 32,017 | 95,600 | 0.25 |
| Mooresville | Fifth, Bayard | Upper Devonian | 10,496 | 2,575 | 7,921 | 0.25 |
| Pine Grove | Gordon Stray | Upper Devonian | 32,910 | 1,575 | 31,335 | 0.05 |
| Porters Falls(Maud) | Gordon, Big Injun | Upper Devonian, Mississippian | 7,580 | 1,522 | 6,058 | 0.20 |
| Porto Rico | Gordon, 1st Cow Run | Upper Devonian, Pennsylvanian | 36,315 | 6,791 | 29,524 | 0.19 |
| Pyles Fork*5 | Thirty-Foot | Upper Devonian | 3,916 | 902 | 3,014 | 0.23 |
| Rockport | Gordon | Upper Devonian | 6,144 | 1,469 | 4,675 | 0.24 |
| **Salem-Wallace** | **Gordon** | **Upper Devonian** | **242,440** | **41,162** | **201,278** | **0.17** |
| Sand Fork | Fifth Sand | Upper Devonian | 3,808 | 1,072 | 2,736 | 0.28 |
| Shinnston | Fifty-Foot | Upper Devonian | 10,800 | 5,144 | 5,656 | 0.48 |
| Smithfield | Big Injun, Gordon, Maxton | Mississippian, Upper Devonian | 83,392 | 11,646 | 71,746 | 0.14 |
| Steele Run | Gordon Stray, Gordon | Upper Devonian | 26,629 | 3,969 | 22,660 | 0.15 |
| West Milford | Gordon | Upper Devonian | 6,475 | 1,276 | 5,199 | 0.20 |
| Wolf Summit-Big Isaac | Fifth, Gordon, Gordon Stray | Upper Devonian | 68,919 | 12,629 | 56,290 | 0.18 |
| **Total** | | | **924,129** | **190,750** | **733,379** | **0.21** |

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# The Gordon Sandstone In Salem-Wallace Field
## Gordon Sandstone – Mapping – Net Pay

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## Gordon A

- Minor reservoir unit within field
- Present in Northern part of the field
- < 10 ft. Net Pay
- Porosity 10%-12%

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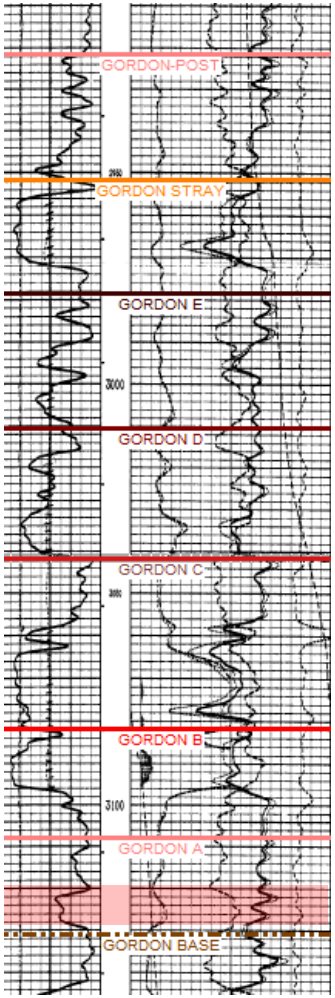
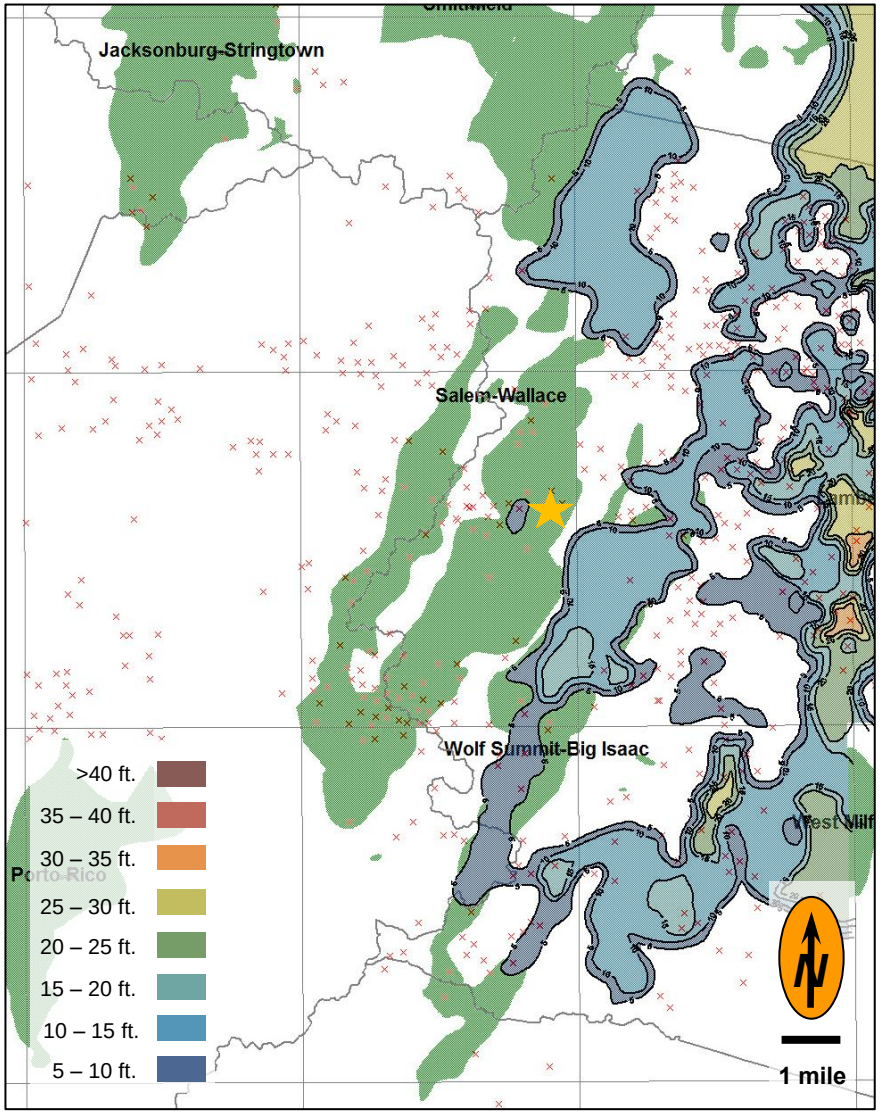
J Ritter #2896
CNG - 1987



# The Gordon Sandstone In Salem-Wallace Field
## Gordon Sandstone – Mapping – Net Pay

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## Gordon B

- Present throughout field
- Up to 25 ft. of Net Pay
- Porosity 10%-14%

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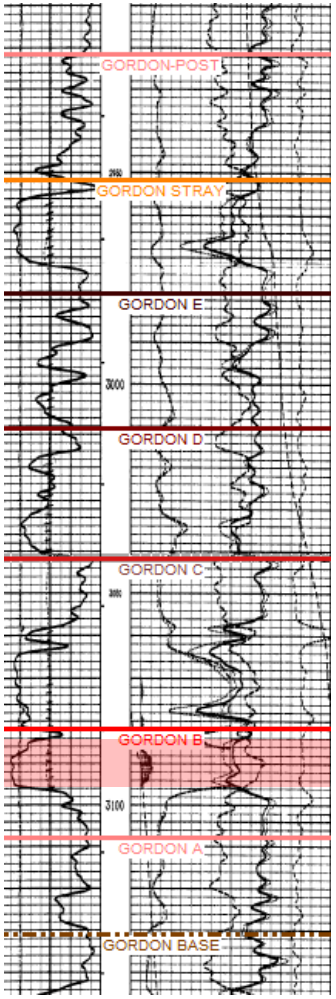


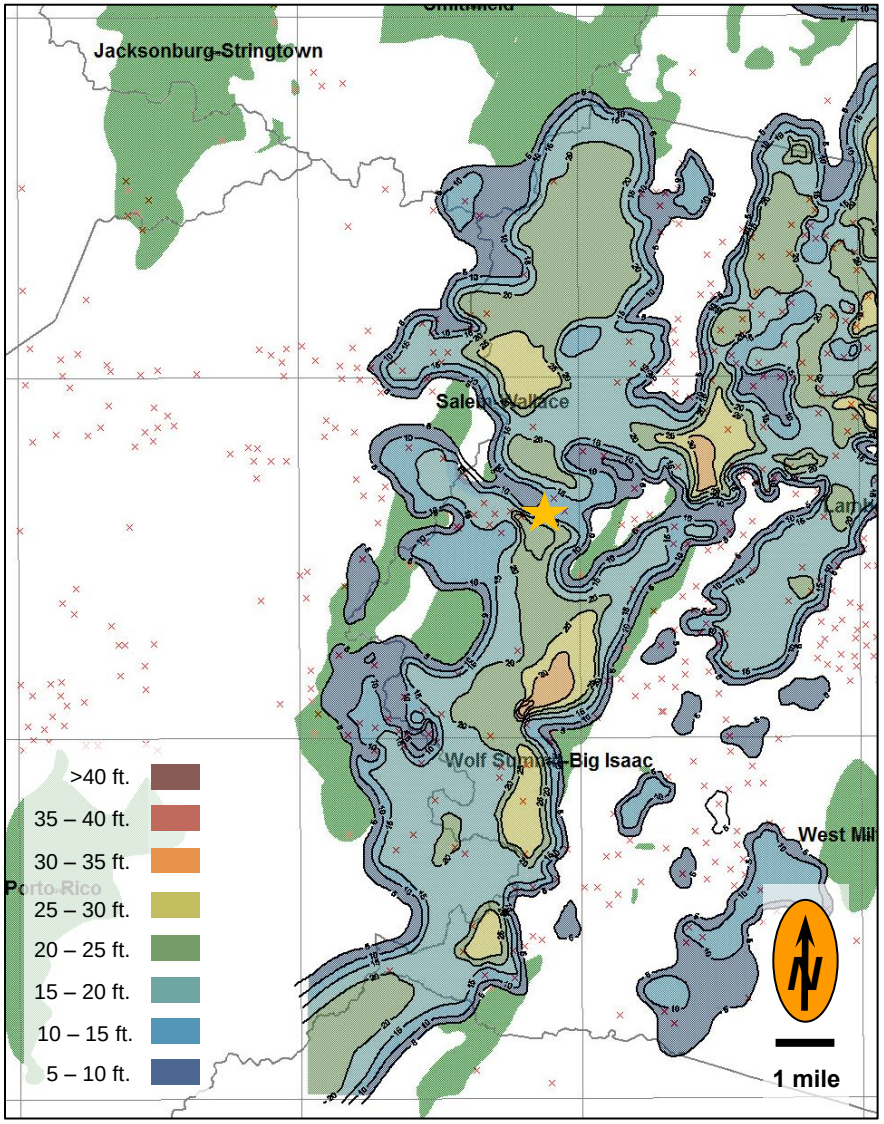

# The Gordon Sandstone In Salem-Wallace Field
## Gordon Sandstone – Mapping – Net Pay

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### Gordon C

- Present throughout field
- Up to 25 ft. of Net Pay
- Porosity 8%-14%

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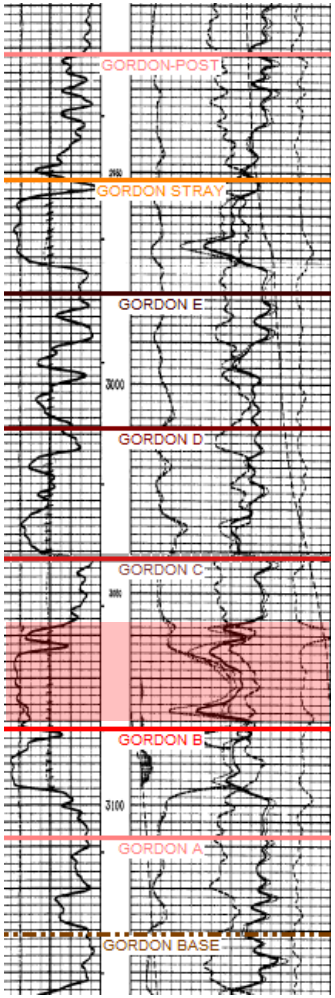


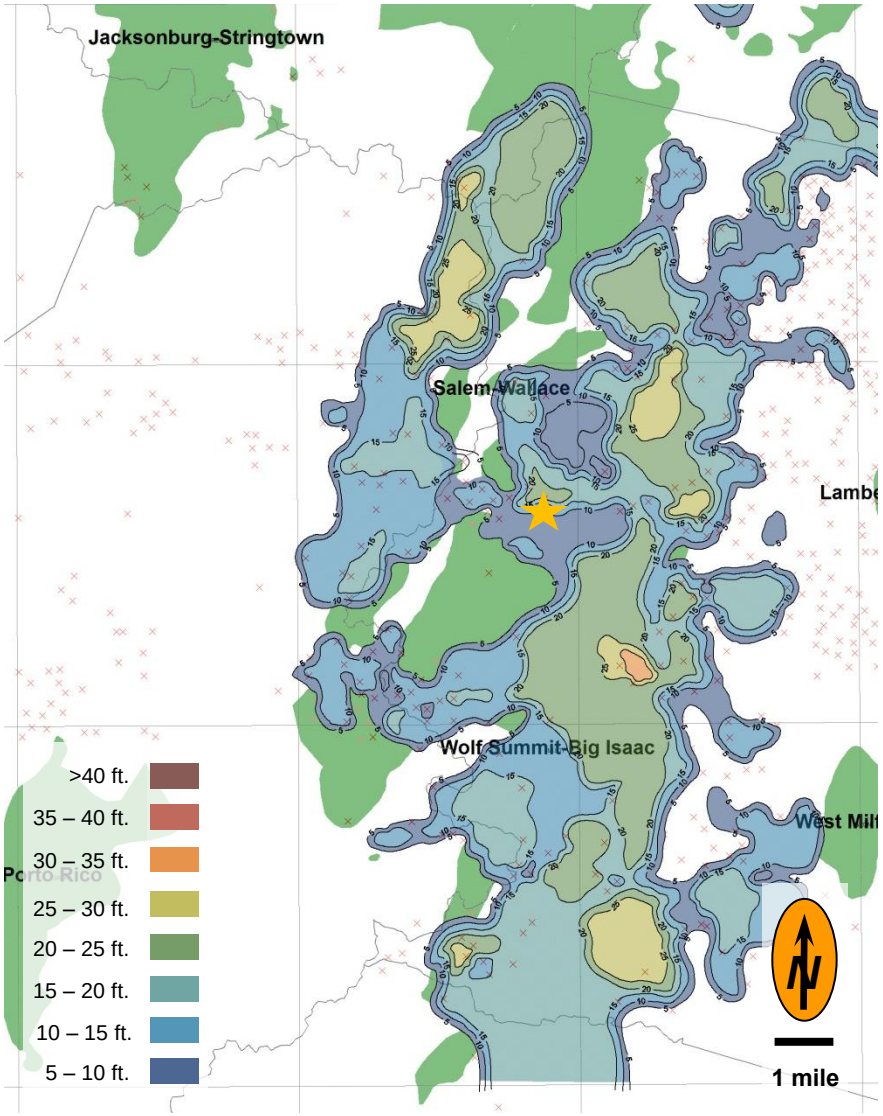

# The Gordon Sandstone In Salem-Wallace Field
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### Gordon D

- Present in ~ 25% of the field
- Up to 25 ft. of Net Pay
- Porosity 10%-14%

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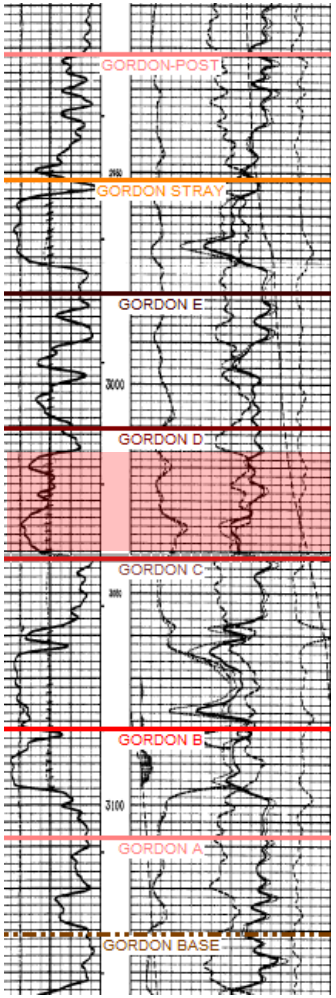


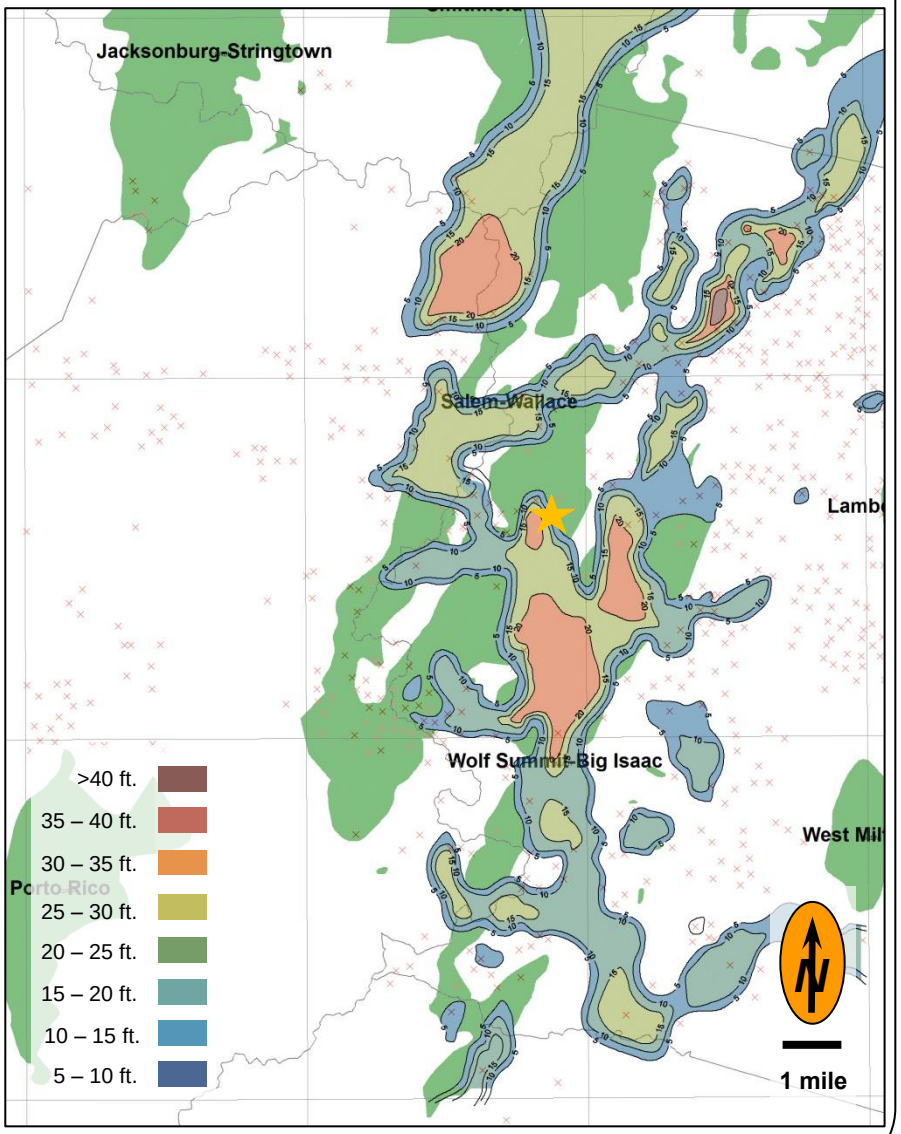

# The Gordon Sandstone In Salem-Wallace Field
## Gordon Sandstone – Mapping – Net Pay

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## Gordon E

- Minor Reservoir unit within field
- Up to 8 ft. of Net Pay
- Porosity 4%-10%

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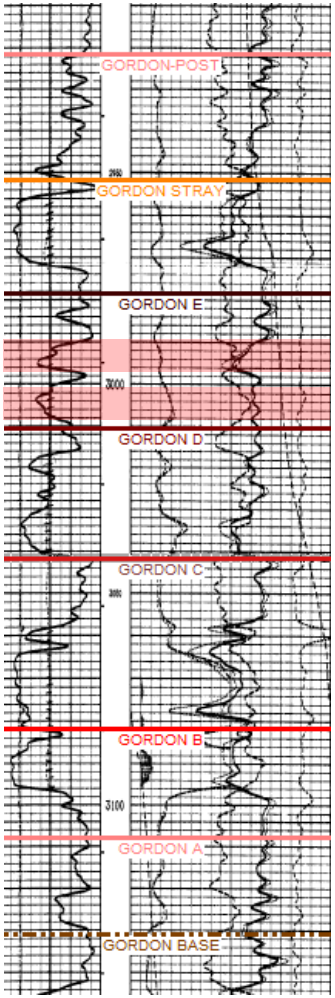


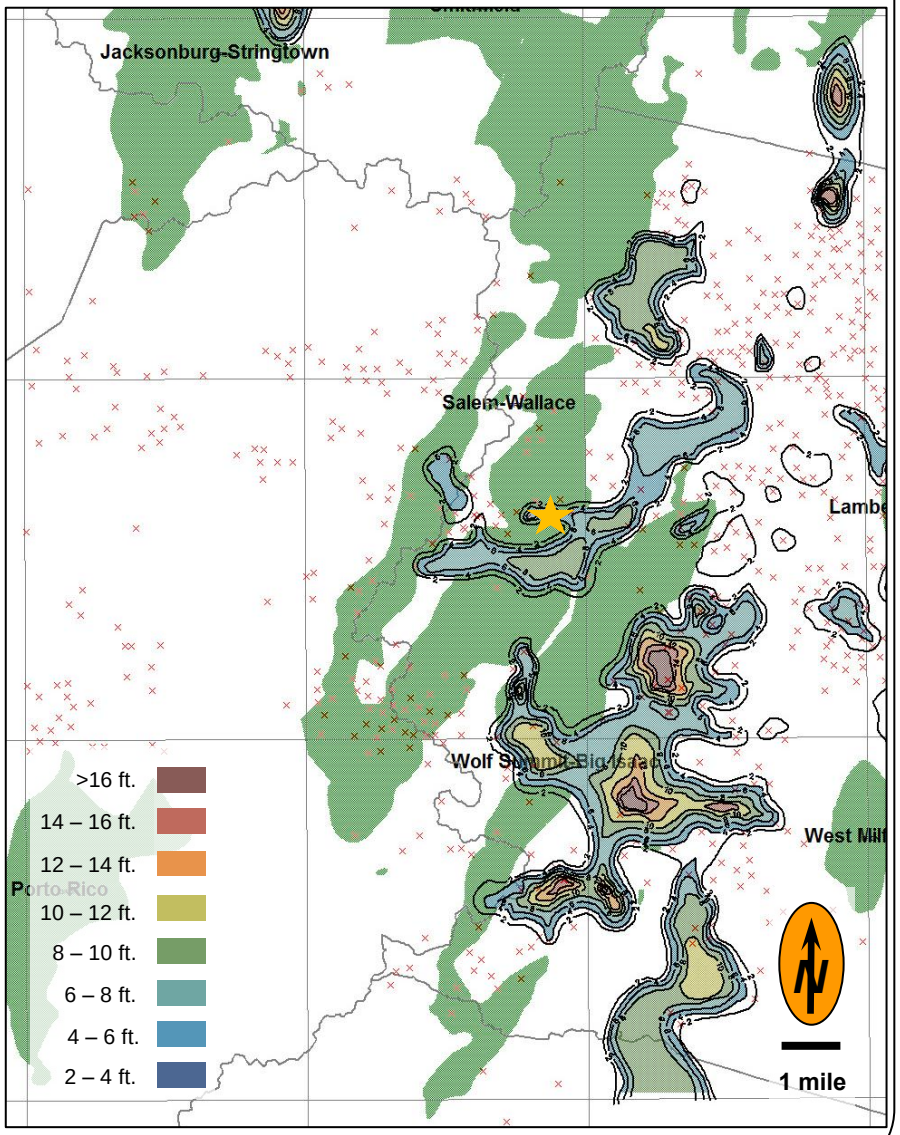

# The Gordon Sandstone In Salem-Wallace Field
## Gordon Sandstone – Mapping – Net Pay

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## All Gordon

- **Up to 89 ft. of pay**
- **4% to 20% Porosity**
  - 10.25% average where pay > 10 ft.

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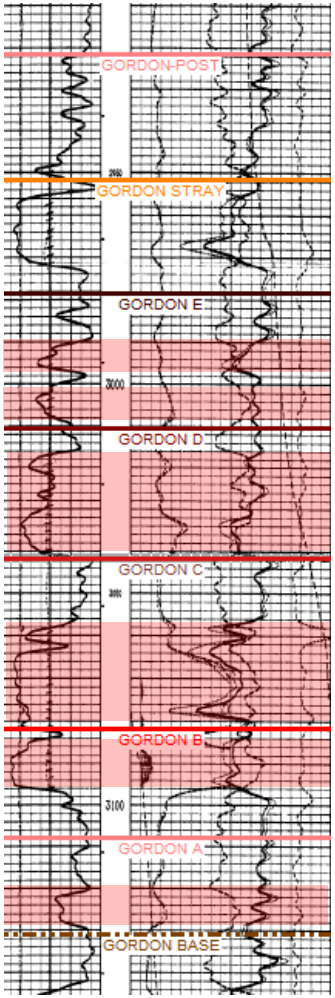


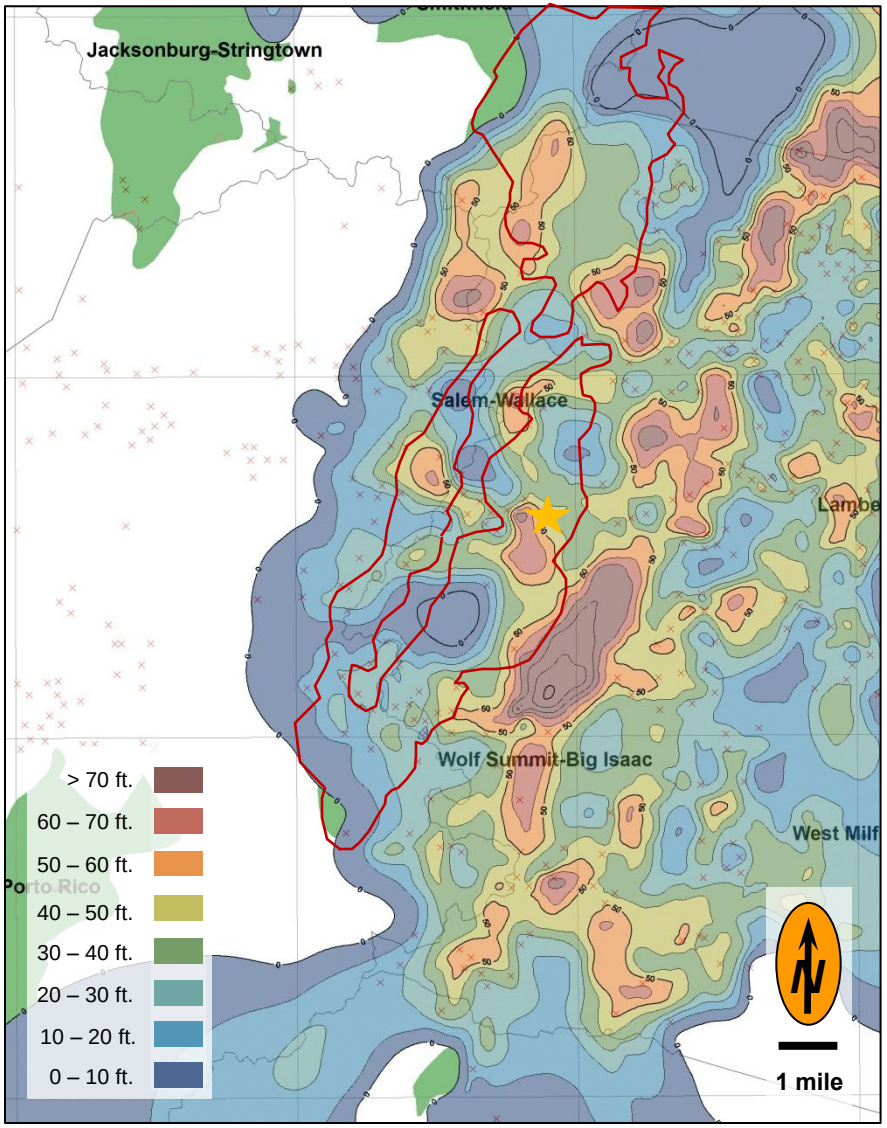

# The Gordon Sandstone In Salem-Wallace Field
# Salem–Wallace Stratigraphic and Structural Control

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## Structure top sub-sea

- **Oil Production is Stratigraphically controlled**
  - Gordon pinches out to the West
- **Oil Production in Salem-Wallace field is structurally controlled**
  - Most oil wells have been drilled above approximately -1790 ft. subsea.

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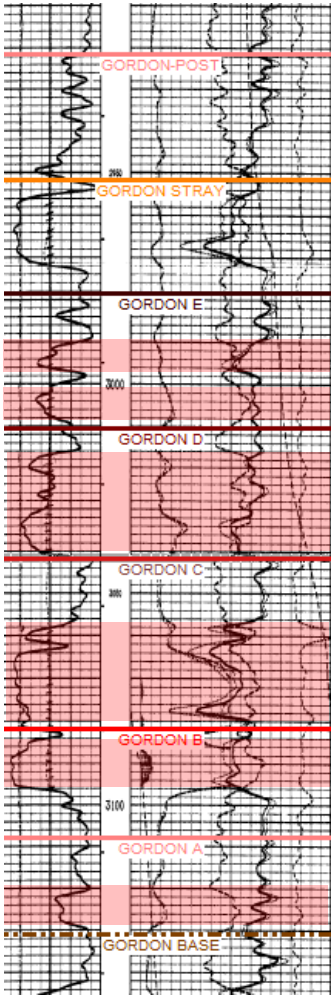


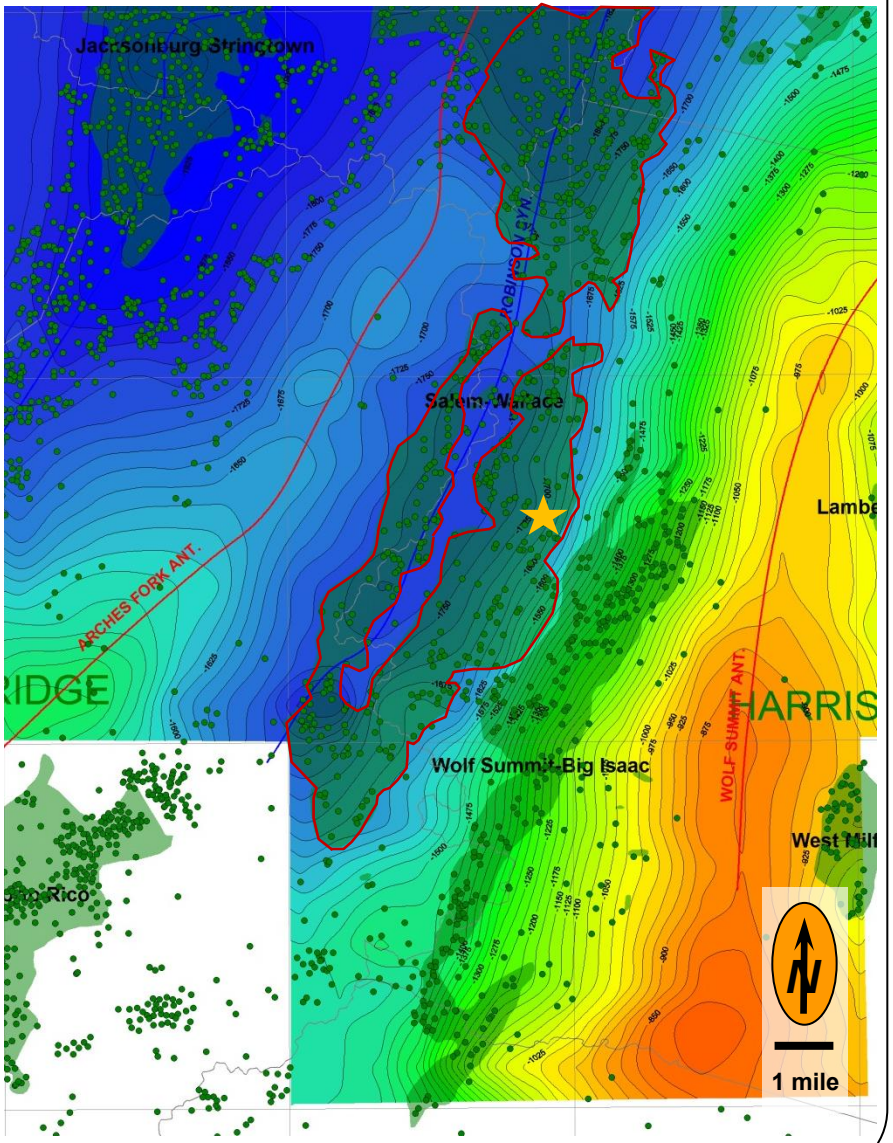

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# Calculating Remaining Oil In Place

## Two Aproaches

1. Historical and Modern Production Analysis
   - Create cumulative production curves to fit historical field production data.
   - Using cumulative curves, generate decline curves.
   - Plot modern production data from 1983-2011 and calculate total production.
   - Verify that this fits the estimated decline curves.
   - Using the cumulative production curves, estimate total production from 1960 to present.
   - Subtract from estimated remaining in 1960.
2. Volumetric Analysis
   - Use OIP equation and grid operations to calculate remaining oil in place.
   - Grid inputs to OIP equation
     1. Gordon net pay map
     2. Gordon average porosity
     3. Gordon average water saturation (constant of 0.7 based on work in Jacksonburg-Stringtown field)
   - Constant inputs to OIP equation
     1. $B_o$ – formation volume factor

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# Calculating Remaining Oil In Place
# Modern Oil Production

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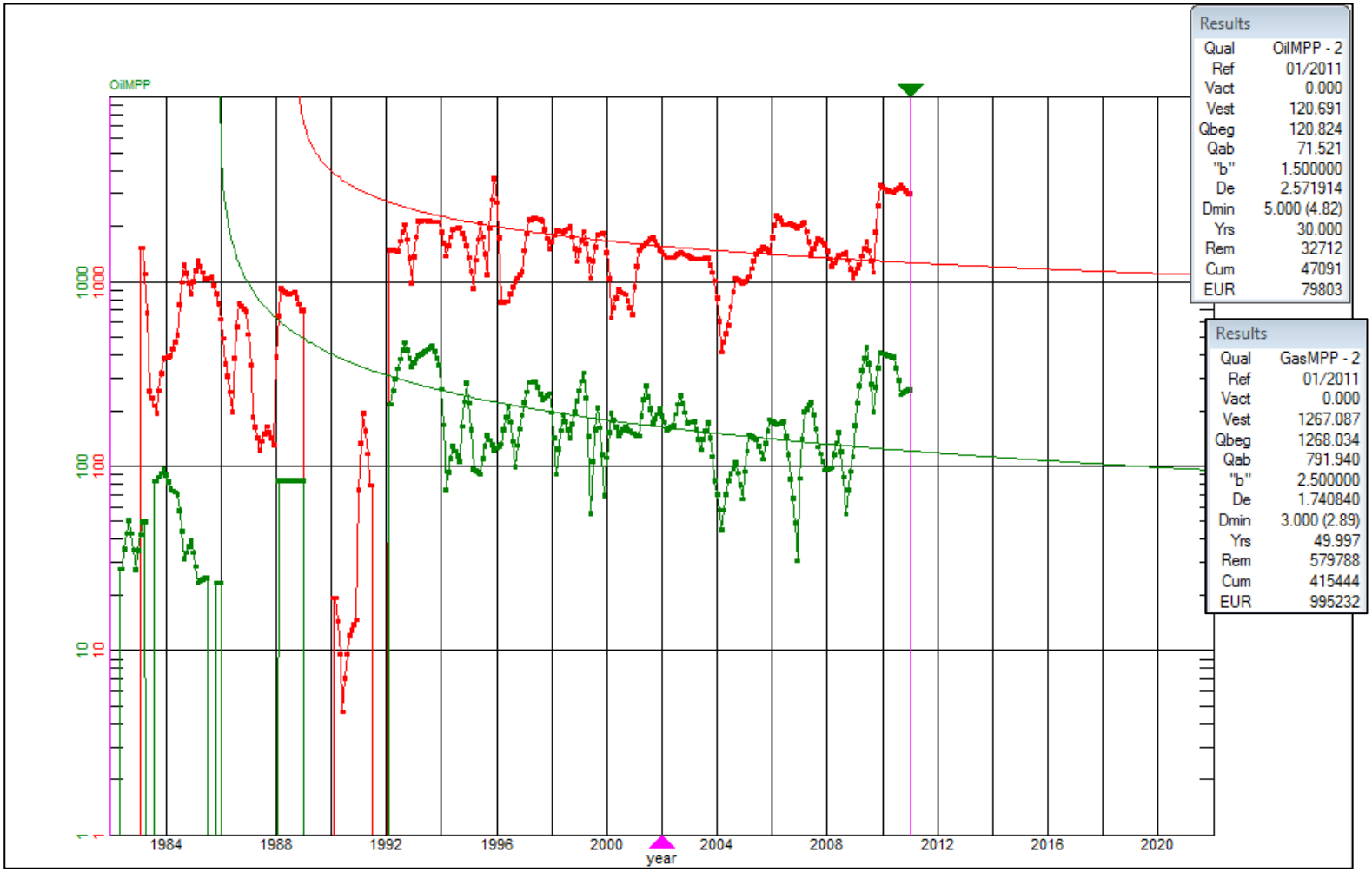
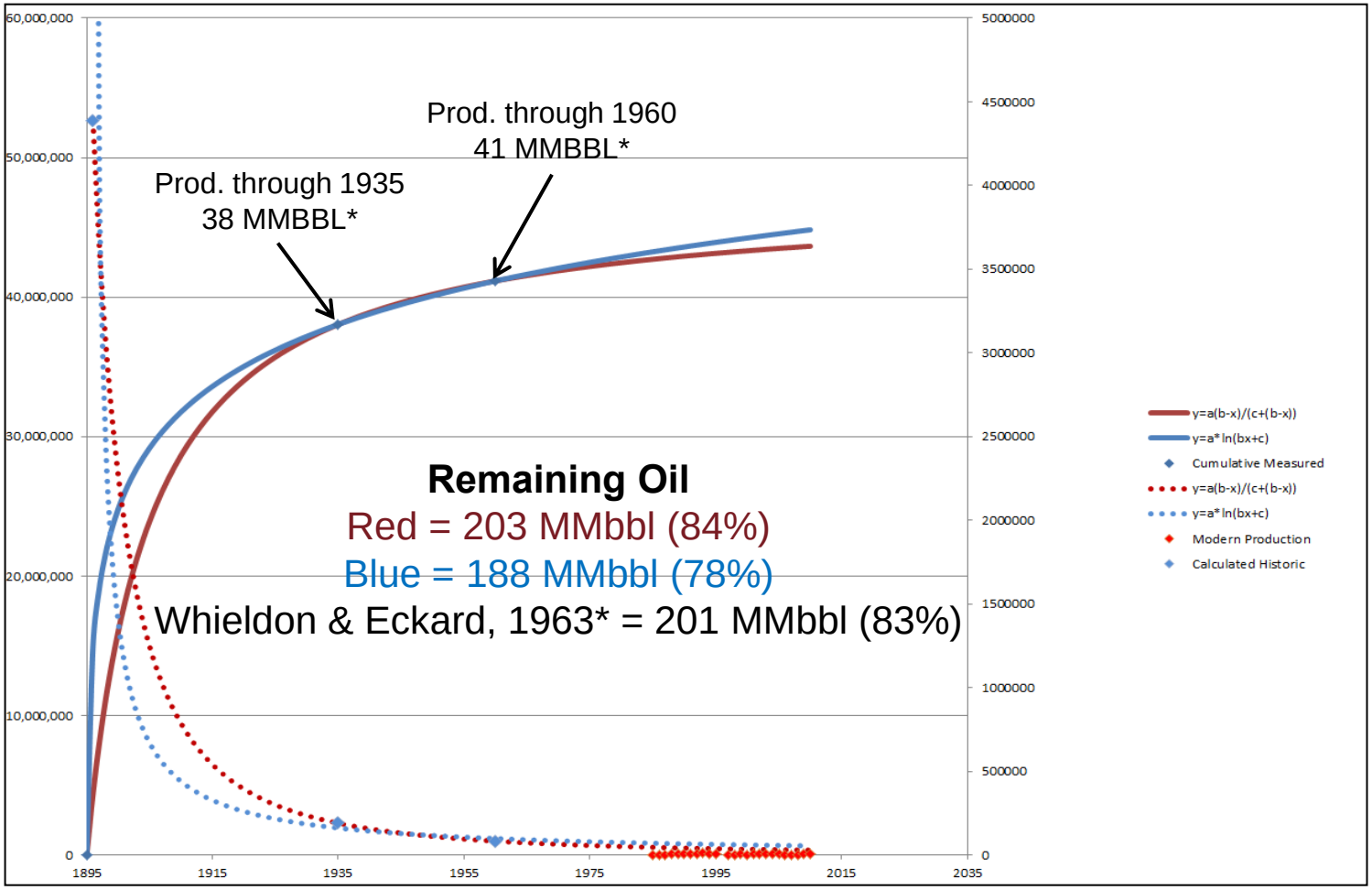
## Production for all 14 modern wells in Salem-Wallace Field



# Production

## Salem-Wallace cumulative and decline curves on historical production with modern production data




*Data obtained from Rietz Tucker – Assistant State Geologist of West Virginia

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# Volumetric Oil in Place Calculations

$$OIP\ (STB) = \frac{7{,}758\ A \bullet h \bullet \varphi \bullet (1 - S_{wg})}{B_o}$$

Where:
A = drainage area (acres)
h = net pay thickness (ft.)
Φ = porosity, fraction of rock volume available to store fluids
$S_{wg}$ = volume fraction of porosity filled with interstitial water and gas
$B_o$ = formation volume factor (reservoir Bbl/STB)
This is a dimensionless factor for the change in oil volume between reservoir conditions and std. conditions at the surface due to solution gas evolving out of the oil.
7,758 = constant converting acre-feet to STB (API Bbl/acre-ft.)

# The Gordon Sandstone In Salem-Wallace Field
## Gordon Sandstone – Mapping – Net Pay

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## All Gordon

- **Up to 89 ft. of pay**
- **4% to 20% Porosity**
  - 10.25% average where pay > 10 ft.

$$OIP\ (STB) = \frac{7{,}758\ A \cdot h \cdot \varphi \cdot (1 - S_{wg})}{B_o}$$

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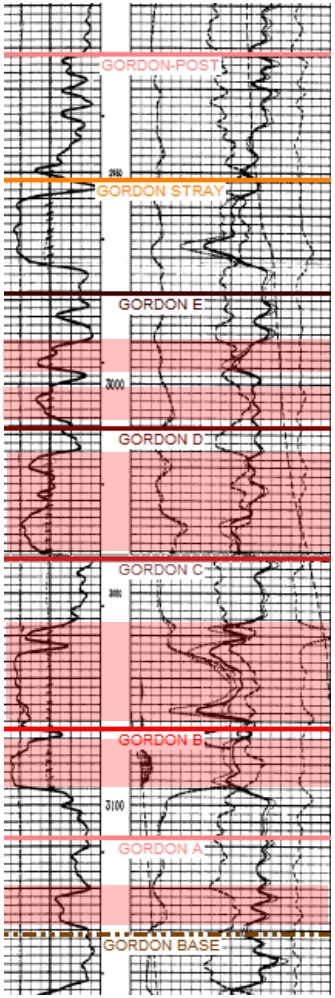


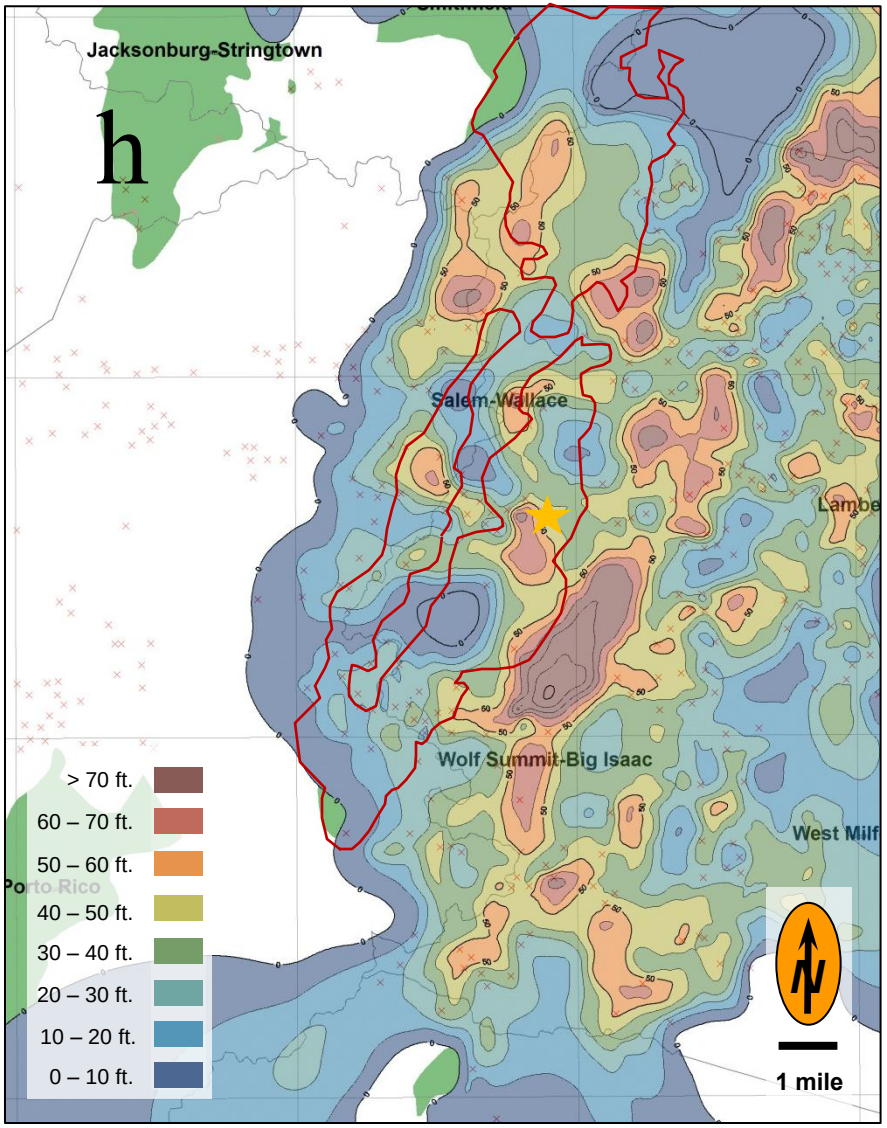

# Volumetric Oil in Place Calculations
# Average Porosity

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## Log Porosity
## All Gordon

$$OIP\ (STB) = \frac{7{,}758\ A \cdot h \cdot \varphi \cdot (1 - S_{wg})}{B_o}$$

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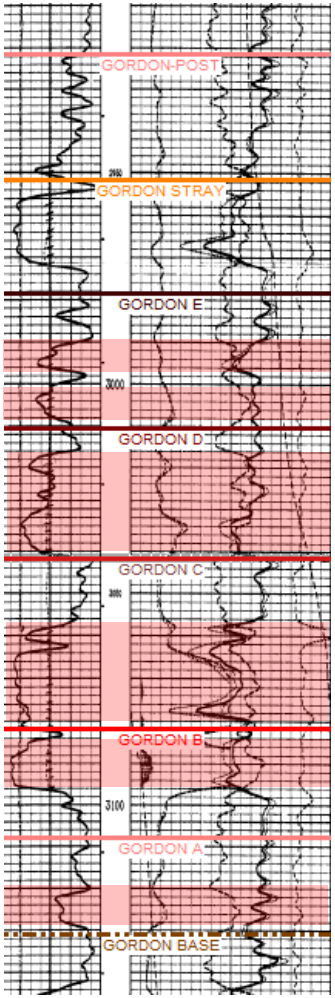
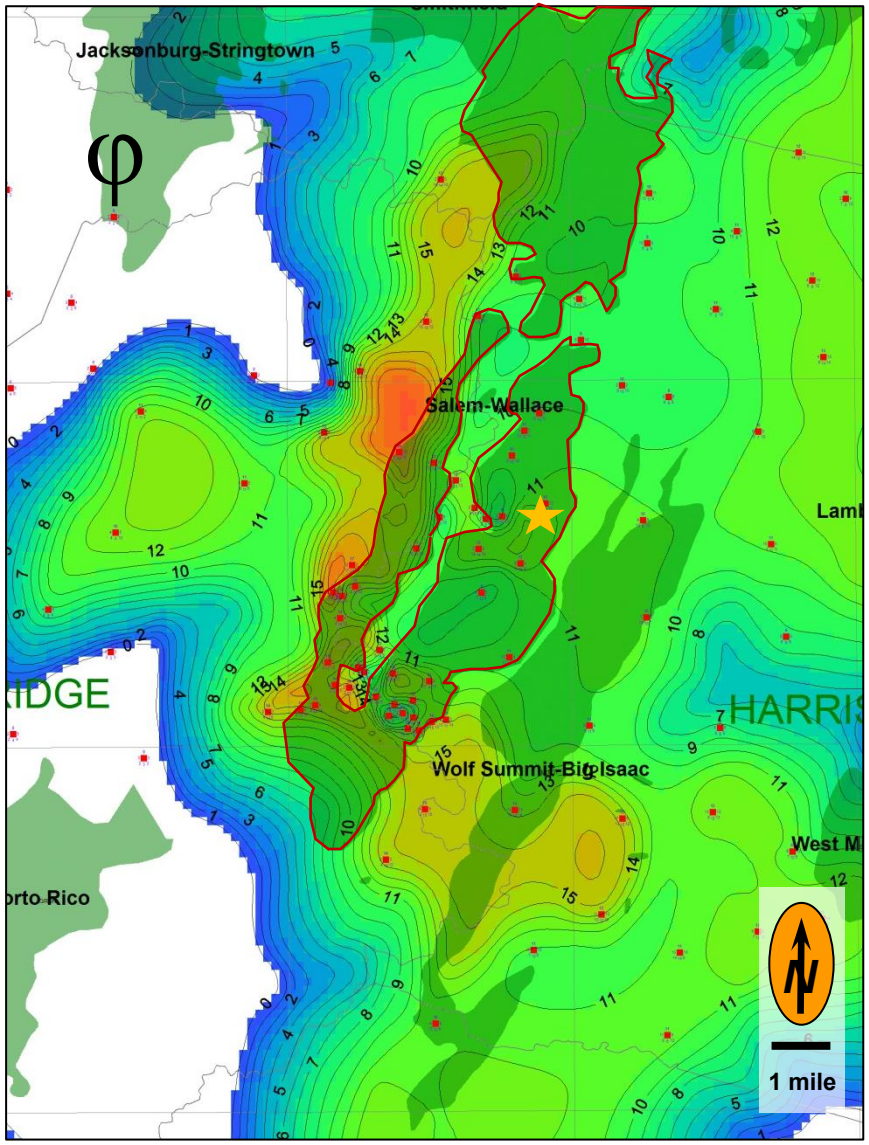
CNG - 1987



# Volumetric Oil in Place Calculations
# OIP – Oil Feet

- **Volumetric OIP for the Salem Wallace Field**
  - Assumes $S_w$ = 0.7 based on previous work done in Jacksonburg-Stringtown field.
  - $B_o$ = 1.1 – typical value used for WV oil fields near the end of primary production.
  - **273 MMbbl**

$$OIP\ (STB) = \frac{7{,}758\ A \cdot h \cdot \varphi \cdot (1 - S_{wg})}{B_o}$$

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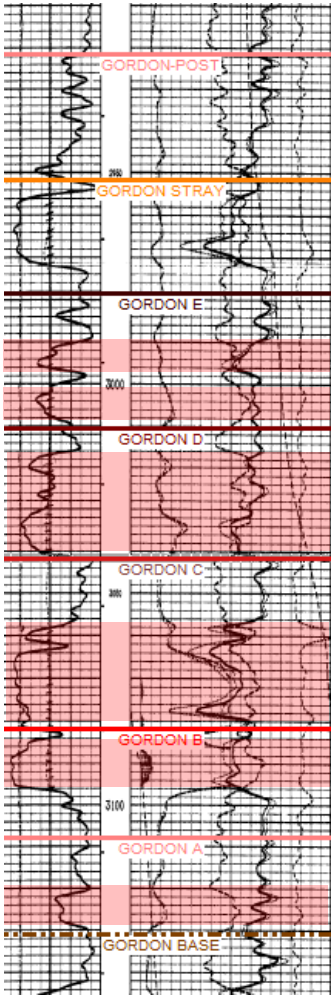
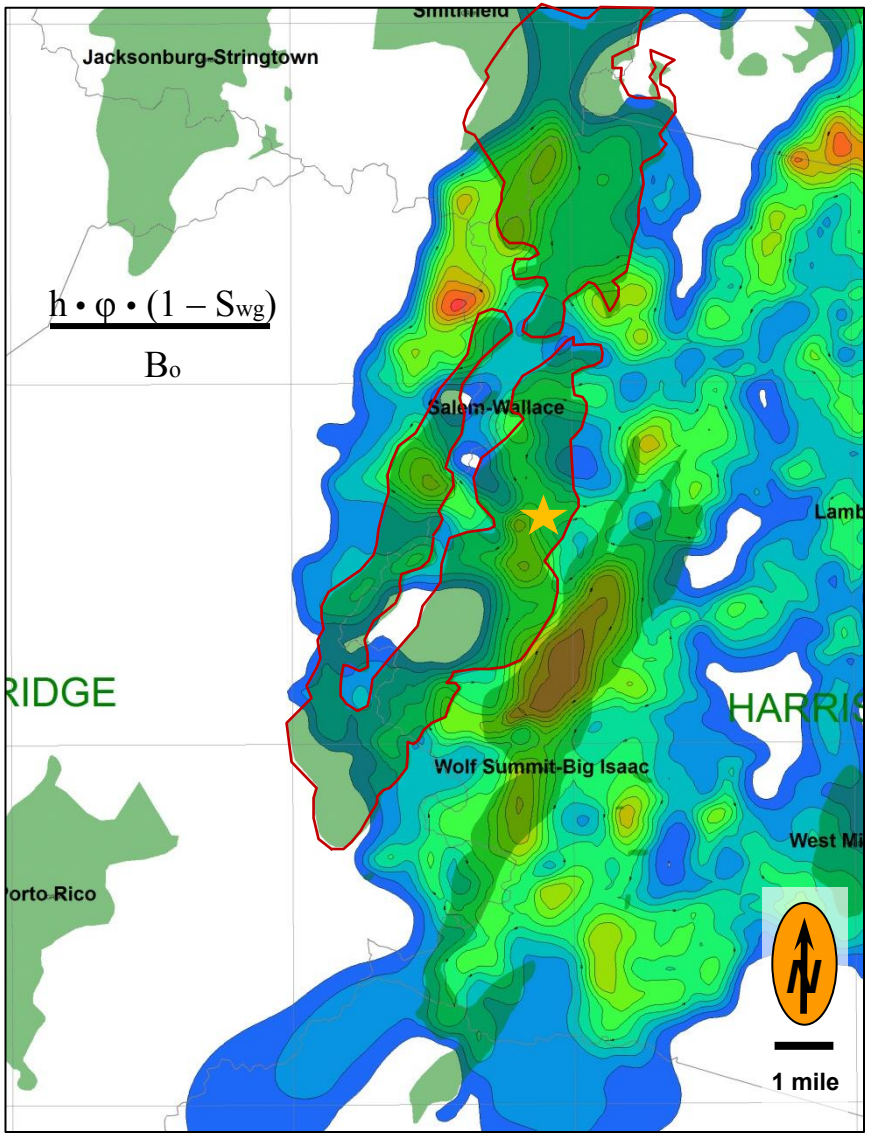
CNG - 1987



# Volumetric Oil in Place Calculations
# OIP – Oil Feet

- **Volumetric OOIP for the Salem Wallace Field**
  - Assumes $S_{wg}$ = 0.7 based on previous work done in Jacksonburg-Stringtown field.
  - $B_o$ = 1.1 – typical value used for WV oil fields near the end of primary production.
  - **246 MMbbl**
- **Oil Produced from 1899 to present**
  - 39 – 54 MMbbl
- **Volumetric ROIP**
  - **192 – 207 MMbbl**

$$OOIP\ (STB) = \frac{7{,}758\ A \cdot h \cdot \varphi \cdot (1 - S_{wg})}{B_o}$$

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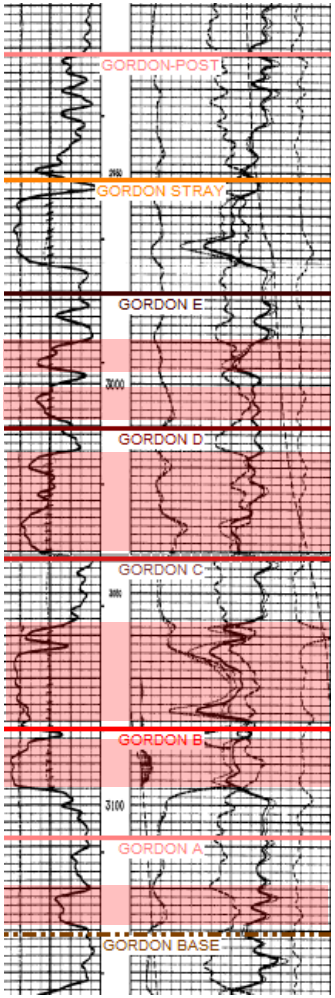
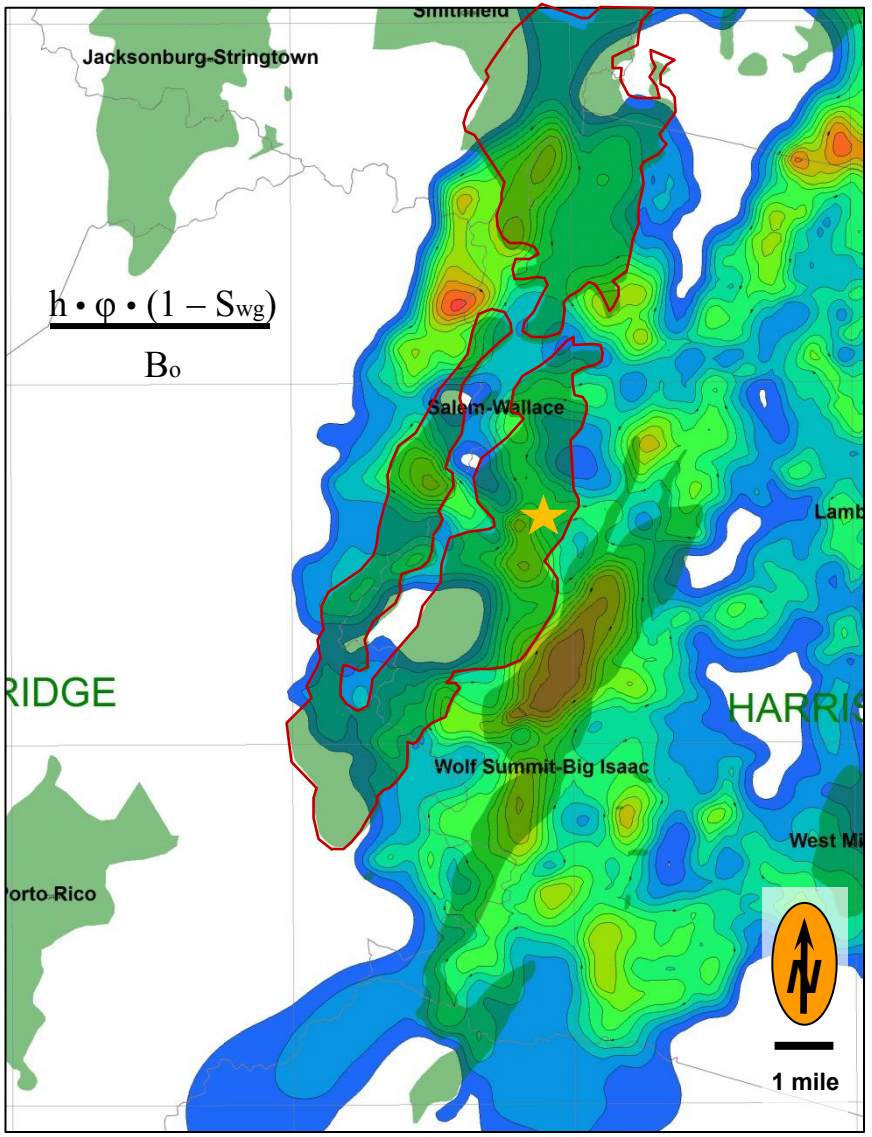
J Ritter #2896
CNG - 1987



# Venango Oil Fields of West Virginia
# Oil Production

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## POTENTIAL RESERVES IN VENANGO OIL FIELDS

Production data from Bureau of Mines Bulletin 607, 1963

| Field Name | Producing Formations | Geologic Age | OOIP (MBbl)* | Primary Oil Production (MBbl) | Remaining Oil (MBbl) | Primary Oil Recovery Factor (V/V) |
|---|---|---|---|---|---|---|
| Bellton | Fourth, Gordon | Upper Devonian | 1,920 | 541 | 1,379 | 0.28 |
| Brave | Gordon, Fourth, Big Injun | Upper Devonian, Mississippian | 11,443 | 3,360 | 8,083 | 0.29 |
| Cameron-Garner | Gordon | Upper Devonian | 25,160 | 5,975 | 19,185 | 0.24 |
| Campbells Run-Miracle Run | Fourth, Gordon, Gordon Stray, Fifth | Upper Devonian | 30,965 | 7,544 | 23,421 | 0.24 |
| Cappo Run(Hixenbaugh) | Fourth, Gordon | Upper Devonian | 4,708 | 1,353 | 3,355 | 0.29 |
| Condit-Ragtown | Fourth, Fifth, Gordon, Big Injun, Gordon Stray | Upper Devonian, Mississippian | 34,830 | 11,996 | 22,834 | 0.34 |
| Copley | Fifth, Gordon, Gordon Stray | Upper Devonian | 8,160 | 2,973 | 5,187 | 0.36 |
| Deep Valley | Big Injun, Maxton, Go | ylvanian | 9,502 | 2,084 | 7,418 | 0.22 |
| Dents Run | Thirty-Foot | | 21,912 | 5,049 | 16,863 | 0.23 |
| Falls Mill*6 | Gordon | | 1,750 | 345 | 1,405 | 0.20 |
| Follansbee | Berea, Hundred-Foot | | 1,152 | 333 | 819 | 0.29 |
| Jacksonburg-Stringtown | Gordon Stray | | 88,469 | 20,458 | 68,011 | 0.23 |
| Lambert Run*2 | Fourth | | 1,242 | 599 | 643 | 0.48 |
| Littleton | Gordon, Fourth, Fifth, | | 9,200 | 2,020 | 7,180 | 0.22 |
| Logansport*5 | Thirty-Foot | | 2,600 | 599 | 2,001 | 0.23 |
| Lucas and Lambert Run | Fourth | | 3,675 | 1,772 | 1,903 | 0.48 |
| Mannington-Mt. Morris | Big Injun, Gordon, Fif | | 127,617 | 32,017 | 95,600 | 0.25 |
| Mooresville | Fifth, Bayard | Upper Devonian | 10,496 | 2,575 | 7,921 | 0.25 |
| Pine Grove | Gordon Stray | Upper Devonian | 32,910 | 1,575 | 31,335 | 0.05 |
| Porters Falls(Maud) | Gordon, Big Injun | Upper Devonian, Mississippian | 7,580 | 1,522 | 6,058 | 0.20 |
| Porto Rico | Gordon, 1st Cow Run | Upper Devonian, Pennsylvanian | 36,315 | 6,791 | 29,524 | 0.19 |
| Pyles Fork*5 | Thirty-Foot | Upper Devonian | 3,916 | 902 | 3,014 | 0.23 |
| Rockport | Gordon | Upper Devonian | 6,144 | 1,469 | 4,675 | 0.24 |
| **Salem-Wallace** | **Gordon** | **Upper Devonian** | **242,440** | **41,162** | **201,278** | **0.17** |
| Sand Fork | Fifth Sand | Upper Devonian | 3,808 | 1,072 | 2,736 | 0.28 |
| Shinnston | Fifty-Foot | Upper Devonian | 10,800 | 5,144 | 5,656 | 0.48 |
| Smithfield | Big Injun, Gordon, Maxton | Mississippian, Upper Devonian | 83,392 | 11,646 | 71,746 | 0.14 |
| Steele Run | Gordon Stray, Gordon | Upper Devonian | 26,629 | 3,969 | 22,660 | 0.15 |
| West Milford | Gordon | Upper Devonian | 6,475 | 1,276 | 5,199 | 0.20 |
| Wolf Summit-Big Isaac | Fifth, Gordon, Gordon Stray | Upper Devonian | 68,919 | 12,629 | 56,290 | 0.18 |
| **Total** | | | **924,129** | **190,750** | **733,379** | **0.21** |

- **BOM 1963 estimation**
  - 201 MMbbl Remaining
- **Production Calculations**
  - 188 – 203 MMbbl Remaining
- **Volumetric Calculations**
  - 192 – 207 MMbbl Remaining

From Whieldon & Eckard, 1963

# Overview

- History of Oil Drilling In West Virginia
- Geology – the Venango Group Sandstones
- Overview of Salem-Wallace Oil Field
- The Gordon Sandstone In Salem-Wallace Field
- Calculating Remaining Oil In Place
- **Conclusions**

# Conclusions

- **The Gordon Sandstone in the Salem-Wallace field has been prolific in the past, but currently, very little oil is produced.**
- **Although production data for West Virginia oil fields is limited and difficult to find, it is possible to estimate remaining oil in place for specific oil fields, including Salem-Wallace.**
- **Using log derived pay and porosity maps, volumetric calculations can also be used to estimate remaining oil in place.**
- **Using the above two methods, it has been shown that between 188 MMbbl and 207 MMbbl of oil remain in the ground at Salem-Wallace.**
  - Comparable with Whieldon & Eckard's 1963 calculation of 201 MMbbl.
- **If this holds true for the other 29 Venango Group oil fields in West Virginia, then there could be as much as 733 MMbbl of oil remaining.**
  - Large unexploited resource waiting for the right technology to extract it.