Acknowledgements

- Larry Wickstrom, Matt Erenpreiss, Ron Riley, Dean Martin, Greg Schumacher, Joe Wells, Lisa Van Doren, Chuck Salmons
  - Ohio Geological Survey
- Geological Surveys of PA, WV, & NY
- Jackie Reed – Reed Geochemical Consulting
- USGS – Bob Ryder, Sue Tewalt, Bob Milici, Jingle Rupert
Talk Outline

Important Concepts:
- Source and Reservoir Rocks
- Porosity & Permeability
- Conventional vs. Unconventional Reservoirs
- Paradigm Shift
- Vertical vs. Horizontal Drilling

- Utica Shale Geology
- Status of Utica Shale Play
- Brine Disposal & Water Usage
- Impacts & Potential of the Utica Shale Play
Ohio currently has in excess of 63,000 producing oil & gas wells.

Historically, over 250,000 wells have been drilled.

Production has been established in 66 of our 88 Counties.

The Lima-Indiana Trend of NW Ohio was one of the first true giant fields produced in the U.S. (1884-1934)

Thus, oil & gas is not new to Ohio.
Sandstone: A Conventional Reservoir Rock
A porous sandstone prepared for viewing under a microscope reveals pore spaces (blue areas).
Shale: A Typical Unconventional Reservoir Rock

Above: Natural fractures ("joints") in Devonian-age shale, typical of fractures in Marcellus Shale. Image from Geology.com (2010).
Shale is extremely fine grained with many very small pore spaces and very low permeability.

Above: Secondary electron image of nanopores in the Barnett Shale. Nanopores are so small (20 nanometers [nm]) that they impact the passage of methane molecules. Figure attributed to Reed and others (2008) from Jarvie (2009).

Above: Secondary electron image of a human hair with a nanowire loop sitting on it. The diameter of the nanowire is equivalent to the scale in the shale picture to the left. The hair is about 60,000 nanometers in diameter.
Organic Porosity Development

Loucks et al., 2009
Recent technological innovations allow some shales to be considered “unconventional” reservoirs.
Many shale gas plays are now developing throughout the United States and Canada.

Source: ALL Consulting, Modified from USGS & other sources
Late Ordovician with hypothetical currents

Mitchell and Bergström, 1991; and Ettensohn, 1999

Facies map of Trenton/Point Pleasant time

- Clean carbonate grainstones, packstones, and wackestones with sharp upper contact
- Argillaceous carbonate grainstones, packstones, and wackestones with sharp upper contact
- Argillaceous carbonate grainstones, packstones, and wackestones with gradational upper contact
- Shale
- Calcareous shale and interbedded limestone

15° south Paleo latitude
Depositional Model Profile
Idealized Platform & Sub-Basin model with facies
(transect from NW Ohio to WV)
INTERVAL-THICKNESS MAP OF THE UTICA
(top of Trenton to top of Utica; includes the Point Pleasant and Antes Shale.)
The extent of the Utica and the Point Pleasant are also shown.

EXPLANATION
- Trenton-Black River outcrop area
- fault
- Utica extent
- Point Pleasant extent
- data point (oil and gas well)
- data points not corrected for structural dip

Recommended bibliographic citation:
Map modified by Powers, D.M., and Martin, J.L.
Utica/Point Pleasant core map for Ohio and surrounding region

36 cores

- Full diameter
- Sidewall
The presence, thickness, fracability, and source-rock-richness, of the Point Pleasant Formation in Ohio are what make this state the center of this play.

Low density shale
- AVG TOC = 2.78
- High TOC = 4.85
- High carbonate %
- Responds to HCL
- Interbedded limestone and black shale

J. Wicks, 2011
CO$_2$ No. 1 Well
Tuscarawas County, Ohio
Point Pleasant

Depth: 6282.0 FEET

Permeability (Klink.): 0.0003 mD
Porosity: 4.2%
Grain Density: 2.70 gm/cc

Lithology: Fossiliferous, slightly dolomitic mudstone (shale) to argillaceous skeletal wackestone

Framework Grains: Minor fine silt-sized to medium silt-sized quartz and mica; abundant calcareous fossil fragments (typically concentrated in layers), including bivalves, echinoderm fragments ostracods, rare phosphatic shell fragments and brachiopod spines, common organic particles

Matrix: Abundant detrital clay
STRUCTURE MAP ON TOP OF THE TRENTON LIMESTONE IN OHIO

EXPLANATION
- data points (oil and gas well)
- fault
- 500-ft contour
- 2500-ft contour

Elevation in feet

Modified from Fitchen and others, 2006.
Respected Geochemists: Utica Source Rock Potential

Utica-Point Pleasant

- Organic content in eastern Ohio is very high
- Organic matter is very rich and oil prone
- The maturity ranges from dry gas in the east to early oil west, to the central part of the state over about 100 mile distance
- Significant hydrocarbon generation has occurred across the area and the hydrocarbon content is quite high
- The majority of the hydrocarbons are being generated in the Point Pleasant, but the overlying Utica is also prospective
- The high carbonate content of the entire section suggests fracing could be very effective for production
Ohio Geological Survey Core and Sample Repository

- **Number of Visitors** using OGS’ sample repository
  - 2006 thru 2008: 134 visitors/yr (avg)
  - 2009: 439 (Utica-Pt.Plnt sampling began)
  - 2010: 456
  - 2011: 472
  - 2012: 91 (thru 3/15)

**Since Play’s Inception:**

- Total wells sampled (cuttings): 183
  - total samples analyzed: 4,143
- Total cores examined and sampled: 20
  - total core samples analyzed: 586
- One year confidentiality from date of sampling.
Wells with Utica-Point Pleasant Source Rock Analyses

EXPLANATION
- Wells sampled
  - Core
  - Core / Cuttings
  - Cuttings
  - Sidewall core / Cuttings

MAP OF OHIO WITH LOCATION MARKERS

- FRED BARTH # 3
- BELDEN BRICK UNIT
- POWER OIL COMPANY

ODNR GEOLOGICAL SURVEY
175 YEARS OF SERVICE 1837-2012

SCALE 0 10 20 30 40 50 MILES
0 10 20 30 40 50 KILOMETERS
Figure 8. Graph of subsurface processes, depths, temperatures, and vitrinite reflectance values associated with the conversion of organic matter to hydrocarbons in petroleum source rocks. Modified from Tissot and Welte (1984).

Source: Pennsylvania Geology, Spring 2010
Source Rock Maturation Status Based on Combined CAI to Ro Regression Equation (Hulver, 1997; Rowan, 2006)
Map of Core Productive Area Based on Initial Analysis of TOC, S1, S2, and Ro Data

EXPLANATION
Core Area & %Ro
10,830,209 total acres

% Ro data source
- Core
- Core / Cuttings
- Cuttings
- Sidewall core / Cuttings

% Ro contours
- Probable
- Inferred

% Ro maximum

MATURE
Ohio’s Utica-Point Pleasant Core Area With $S_1$ Maximum Color Ramp Superimposed

EXPLANATION
Play core area defined by TOC, $S_1$, $S_2$, and Ro

$S_1$ maximum
mg HC/g of rock
- Excellent >4
- Very Good 2–4
- Good 1–2
- Fair 0.5–1
- Poor 0–0.5
OIL AND GAS FIELDS MAP OF OHIO

EXPLANATION

OIL FIELD  GAS FIELD  COALBED METHANE  PRODUCING HORIZON(S) GROUPED BY STRATIGRAPHIC INTERVAL

Pennsylvanian undifferentiated sandstones and coals
Mississippian undifferentiated sandstones and Maumee Limestone
Devonian Berea Sandstone and Cuyahoga Sandstone
Devonian Ohio Shale and siltstones
Silurian-Devonian “Big Lime” interval
Silurian “Clinton-Medina” sandstone and “Pocker Shale”
Ordovician fractured shale, Trenton Limestone, Black River Group, and Wells Creek Formation
Cambrian-Ordovician Knox Dolomite

Recommended citation: Ohio Division of Geological Survey 2004, Oil and gas fields map of Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map PN-5, gymia hardcopy version with label. 28a, scale 1:200,000.
Gas-prone areas of Utica Shale found to be in the deeper portion of the basin. Much of Ohio may contain appreciable amounts of oil within Utica Wells, as illustrated by this schematic cross section by Ryder, (2008) which shows the results of geochemical analyses of well samples.
Acreage Positions

<table>
<thead>
<tr>
<th>Company</th>
<th>Net Acres</th>
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<tbody>
<tr>
<td>Chesapeake (CHK)</td>
<td>1,360,000</td>
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<tr>
<td>Chevron (CVX)</td>
<td>623,000</td>
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<tr>
<td>Range Res. (RRC)</td>
<td>357,000</td>
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<tr>
<td>(CNX/HES) JV</td>
<td>200,000</td>
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<tr>
<td>Anadarko (APC)</td>
<td>200,000</td>
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<tr>
<td>EVEP / Enervest</td>
<td>159,000</td>
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<tr>
<td>Devon Energy (DVN)</td>
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<tr>
<td>Hess (HES)</td>
<td>85,000</td>
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<td>Rex Energy (REXX)</td>
<td>58,900</td>
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<td>Gulfport (GPOR)</td>
<td>62,500</td>
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<td>PDC Energy (PETD)</td>
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<td>Magnum Hunter (MHR)</td>
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<td>Carrizo (CRZO)</td>
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<tr>
<td>ExxonMobil (XOM)</td>
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<tr>
<td>Shell (RDS-A)</td>
<td>Unknown</td>
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</tbody>
</table>

Source: Bodino, M., 2011, DUG East presentation

Source: Company Data, modified Gulfport map, GHS Research
HORIZONTAL UTICA-POINT PLEASANT WELL ACTIVITY IN OHIO

EXPLANATION
Horizontal well status
- Showing wells permitted 2010–Present
  - Producing (10)
  - Completed (15)
  - Drilled (35)
  - Drilling (21)
  - Permitted (124)
  - Plugged (1)

Well permit information from the ODNR
Division of Oil and Gas Resources Management

<table>
<thead>
<tr>
<th>OPERATOR NAME</th>
<th>MAP LABEL</th>
<th>COUNT</th>
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<tbody>
<tr>
<td>ANADARKO E &amp; P COMPANY LP</td>
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<td>ANTEAN RESOURCES CORP</td>
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<td>CHERISH EXPLORATION LLC</td>
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<td>DEVON ENERGY PRODUCTION CO.</td>
<td>DSV</td>
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<td>ECLIPSE RESOURCES LP</td>
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<td>R E G AS GAS DEVELOPMENT LLC</td>
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<tr>
<td>XTO ENERGY INC</td>
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</tbody>
</table>

Recommended citation: Ohio Department of Natural Resources, 2012, Horizontal Utica-Point Pleasant Well Activity in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, scale 1:1,250,000, revised 3/30/2012.
Current Horizontal Well Permit and Completion Activity Overlaid on Equivalent Ro Max Color Ramp And Defined Core Area

EXPLANATION
Core Area & %Ro
10,830,209 total acres

Horizontal well status
Showing wells permitted 2010–Present
- Permitted
- Drilling
- Drilled
- Completed
- Producing

% Ro maximum

MATURE

OPERATOR NAME | MAP LABEL | COUNT
--- | --- | ---
ANADARKO E & P COMPANY LP | APC | 10
C-ESAPESAKE EXPLORATION LLC | CHK | 103
CNX GAS COMPANY LLC | CNX | 5
DEVON ENERGY PRODUCTION CO | DVN | 4
ECLIPSE RESOURCES LP | ERI | 1
ENERVEST OPERATING L | EOS | 7
HESS OHIO RESOURCES LLC | HES | 1
HG ENERGY LLC | HGE | 5
XTO ENERGY INC | XTO | 138

Activity thru 2-27-12

Well permit information from the ODNR Division of Oil and Gas Resources Management

Recommended citation: Ohio Department of Natural Resources, 2012, Horizontal Utica-Point Pleasant Well Activity in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, scale 1:1,250,000, revised 2/27/2012.
HORIZONTAL UTICA-POINT PLEASANT WELL ACTIVITY IN OHIO

EXPLANATION
Horizontal well status
Showing wells permitted 2010-Present
- Producing
- Completed
- Drilled
- Drilling
- Permitted

Well permit information from the ODNR Division of Oil and Gas Resources Management

Recommended citation: Ohio Department of Natural Resources, 2012, Horizontal Utica-Point Pleasant Well Activity in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, scale 1:1,250,000, rockfile 12-2362.
Ohio Utica Overview

- Devon Acreage
- Oil Window: = 1/3 of JV Acreage
- Rich Gas Window: = 1/3 of JV Acreage
- Dry Gas
- Approximate Thermal Maturity Windows

<table>
<thead>
<tr>
<th></th>
<th>DVN (net)</th>
<th>JV (gross)</th>
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</thead>
<tbody>
<tr>
<td>Net acres</td>
<td>157,000</td>
<td>235,000</td>
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<tr>
<td>Unrisked res.</td>
<td>640 MMBOE</td>
<td>950 MMBOE</td>
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<tr>
<td>2012 capital</td>
<td>$26 MM</td>
<td>$100 MM</td>
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<tr>
<td>2011/12 plans</td>
<td>Drill = 15 wells</td>
<td></td>
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</tbody>
</table>

Attractive Attributes

- Positive industry results to date
- Conventional oil and gas area
- Abundant well control
- Favorable subsurface (TOC, porosity, perm)
Ohio Utica
Stratigraphic Section

- Hybrid unconventional resource
- Lithology consists of laminated limestone-mudstone
- In-situ fractures
- Frac barriers above and below (no wet zones)
- Prolific source rock and reservoir
- Potential upside from fractured Trenton/Black River
Ohio Utica
Type Log

- Point Pleasant primary reservoir
- Gross thickness: 100’ - 140’
- Consistent interval thickness
- Low structural relief
- Play spans dry gas to oil window
- Microdarcy permeability system
Ohio Utica
Permeability Analysis

- FIBSEM analysis enables imaging of connected pores
- Significant size pores present
- Indicates potential to move liquids
- Top-tier permeability:

<table>
<thead>
<tr>
<th>Permeability (microdarcy, µD)</th>
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<tbody>
<tr>
<td>DVN Harstine Well</td>
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<tr>
<td>Barnett Shale:</td>
</tr>
<tr>
<td>Marcellus:</td>
</tr>
<tr>
<td>Eagleford:</td>
</tr>
<tr>
<td>Bakken:</td>
</tr>
</tbody>
</table>

nm = nanometers
(Oil molecules range from 0.5 - 3.0 nm)
Ohio Utica
Results to Date & Targets

Target Well Economics
- Drill & complete cost: $3.0 - 5.0 million
- EUR: 200 - 300 MBOE (85% liquids)
- IP rate (1st month avg): 200 - 250 BOED
- Average royalty: 16%

Keys Going Forward
- Flow properties of oil window
- Variations in permeability
- Gas/oil ratio
- Maturity variation across position
- Overpressured trend
Generalized Geology and Profile of a Utica Shale Well Prototype in East Central Ohio
View of Current Horizontal permits in a Portion of Carroll & Jefferson Counties. From Ohio Geological Survey On-line Interactive Oil and Gas Well Information System
Ohio has regulatory primacy of its brine injection wells and adequate geologic capacity.
Water Usage

- Peak drilling activity not likely for nearly 10 years
- Peak water use may be on the order of 50 million gallons/day
- At peak, water use will remain less than ONE PERCENT of state’s daily water consumption
- MUCH less than the water used to irrigate Ohio golf courses
- BUT, LOCAL impacts can be significant, depending on source, time of year, etc.
References


EnerVest, 2011, Developing Unconventional Gas (DUG) East Conference, John Walker, Pittsburgh PA November 17

GHS Research, 2011, (Global Hunter Securities), DUG East Conference, Michael Bodino, Pittsburgh PA, November 17


