Field Laboratory for Emerging Stacked Unconventional Plays (ESUP)

ESUP Project Update – 10/15/2020
Acknowledgments

- Financial assistance for this work was provided by the U.S. Department of Energy through the National Energy Technology Laboratory’s Program under Contract No. DE-FE0031576.

- Robert Vagnetti, U.S. DOE/NELT Project Officer
Outline

- Research Team
- Objectives
- Timeline
- Accomplishments
- Remaining Work
*2 research associates and 5 graduate students supported
Advisory Stakeholder Group (ASG)
(Updated individually throughout negotiation Phase)

**TECHNICAL EXPERTS**

- **Randy Albert**
  Owner and CEO, Shale Advisory Group, Bluefield, West Virginia

- **Ed Diminick**
  Petroleum Engineer at Appalachian Energy, Inc

- **Jerry Grantham**
  Vice President, Southern Appalachian Division, Range Resources (retired), Abingdon, Washington County, Virginia

**COMMUNITY LEADERS**

- **Shannon Blevins**
  Associate Vice Chancellor for Economic Development and Engagement, The University of Virginia's College at Wise, Wise County, Virginia

- **Freddie Mullins**
  Freddie Mullins, Esq, Clintwood, Dickenson County, Virginia

- **John Schoolcraft**
  Board of Supervisors, County of Wise District III

**ENVIRONMENTAL LEADERS**

- **Leon Boyd**
  Virginia District Chair and Chair of the Southwest Virginia Coalfields Chapter, Rocky Mountain Elk Foundation, Buchanan County, Virginia

**STATE GOVERNMENT**

- **William Clear**
  Director of Finance and Project Administration, Virginia Department of Mines, Minerals and Energy, Big Stone Gap, Wise County, VA
Objectives

- Investigate and characterize the resource potential for multi-play production of emerging unconventional reservoirs in Central Appalachia.
  - Drill and selectively core a vertical Basement Test well, drilled to approximately 15,000 ft., through the Conasauga-Rome Petroleum System
  - Well logging, core analysis, reservoir testing and production information will be integrated with reservoir simulations to develop an assessment of the multi-play resource potential
  - An assessment will be made of the multi-play resource potential and a recommended strategy advanced for prudent development that considers regional environmental and socioeconomic impacts.
Historic Conasauga / Rome Tests and Producers vs. Recent Rogersville Shale Activity

**White #529**
Inland Gas Co
Drilled 1967
Maryville Ls. Producer
- 90 MCFD / 32 BOPD
- 10,000 BO Produced
- Oil sourced from Rogersville Sh.

**McCoy #1**
EXXON
Drilled 1975
Maryville Ls. Producer
- 6 – 9 MMCFD Natural
- .5 BCF Produced in 6 mo.
- Plugged: 9/9/1978
- Rogersville TOC: .29-.57

**Smith JP #1**
EXXON
Drilled 1974
- Excellent hydrocarbon shows
- Analysis indicates Rogersville is likely oil source for the White #529
- Rogersville TOC: 1.2-4.4

**Williams E #1**
Ashland Exploration
Drilled 1985
- Nolichucky Sh. Producer
- Fractured Shale Reservoir
- 1.2 BCF / 42,000 BBL Condensate

**Amherst Industries #50**
Cabot Oil & Gas
Vertical Rogersville Test
TD Date: 10/27/2014
- Maryville Ls. Producer
- 2.2 MMCFD (1st Month Avg.)
- CUM: 339,819 MCF

**JH Northrup Estates #LAW 1**
Chesapeake Appalachia
Vertical Strat Test
TD Date: 9/3/2015
- Excellent hydrocarbon shows in Maryville Ls., Rogersville Shale, Pumpkin Valley Shale & Rome Fm

**Price #1**
Gulf Oil
Drilled 1977
- Indicates the presence of both Rogersville Shale and Pumpkin Valley Shale south of the proposed Characterization Well

**EQT Prod Co #572360 H**
Horizontal Tech Energy Co (EQT)
Horizontal Rogersville Test
TD Date: 6/7/2015
Fm @ TD: Rogersville Shale
Shut In

**Walbridge Holdings #1H**
Bruin Exploration (Cimarex)
Horizontal Rogersville Test
TD Date: 2/23/2017
Fm @ TD: Rogersville Shale
Temporarily Abandoned
The Magnetic and gravity anomalies are proxies for Rome Trough and Precambrian structure.

The borders of the Floyd Embayment are ambiguous and are poorly constrained in Virginia.

Gravity and magnetic data suggests that the Floyd Embayment may intersect western portions of EnerVest acreage.
**Project Timeline**

<table>
<thead>
<tr>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
<td>Q4</td>
<td>Q1</td>
</tr>
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<tr>
<td></td>
<td></td>
<td>Budget Period 1</td>
<td>Budget Period 2</td>
<td>Budget Period 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Site Selection Planning</td>
<td>Drilling Operations Coring Operations Data Analysis Evaluation</td>
<td>Post-operations Data Analysis Report Generation</td>
</tr>
</tbody>
</table>

- **4/28/2020** – Spud deep well

- **11/20/2019**: Pad construction completed
- **3/20/2020**: Top hole completed
- **4/28/2020**: Drilling Commenced
- **6/12/2020**: Finished Logging and Coring
- **6/15/2020**: Production Casing Set
V- 530555 Basement Test
Wellbore Schematic

Elevation: 2426' GL
KB: 25'

10" hole
65' KB 26" Conductor (0.375" wall)

24" hole
350' KB 18-5/8" 87.5# J-55 BTC

17-1/2" hole
LEE SANDSTONE
RAVENCLIFF SANDSTONE
AVIS LIMESTONE
MAXTON SANDSTONE
3425' KB 13-3/8" 61# / 68# J-55 BTC

12-1/4" hole
LITTLE LIME
BIG LIME
WEBER SALE
BEREA SANDSTONE
CLEVELAND SHALE
UPPER/LOWER HURON
MIDDLE/LOWER HURON
"LOVER" LOWER HURON
GLENTANY SHALE
MONDAGA LIMESTONE
LOCKPORT
BIG SIX
ROSE HILL SHALE
CLINTON SANDSTONE
ANDAYA FORMATION
8100' KB 9-5/8" 47# HCL-80 LTC

8-1/2" hole
TRENTON LIMESTONE
BLACK RIVER LIMESTONE
GULL RIVER LIMESTONE
GLENWOOD SHALE / LIMESTONE
KNOX UNCONFORMITY
BEDROCK/DOLOMITE
ROSE RUN SANDSTONE
TREMPEALEAU / COPPER RIDGE
LOWER COPPER RIDGE
RAYNARDVILLE LIMESTONE
MOLICHAYSHALE
MARYVILLE LIMESTONE
ROGERSVILLE SHALE
RUTLEDGE LIMESTONE
PUMPKIN VALLEY SHALE
ROME FM
SHADY DOLOMITE
BASEL SANDSTONE
GRANITE WASH
PRECAMBRIAN BASEMENT

15,500' KB 5-1/2" 23# P-110 MS1 LT&C
V- 530555 Basement Test Pad and Drilling Operations
Target of Pre-Cambrian basement for full section characterization successfully reached.

Time required to reach target formation was less than forecasted.
  - AFE’d @ 48 days, but completed in 42 days. (Inclusive of NPT time in previous slide).

Accurately identified and predicted geo-hazards, though some still gave us trouble.

Successfully completed operations without any injury, illness, or environmental issues.
  - Over 30,000 man hours worked
V-530555 Geological Update
## Wireline and Mud Logging Data Gathered from the 530555

### Openhole Logs

<table>
<thead>
<tr>
<th>Formation</th>
<th>Lithology</th>
<th>Top (MD)</th>
<th>Mud Log</th>
<th>Gamma</th>
<th>Neutron</th>
<th>Density</th>
<th>PE</th>
<th>Induction</th>
<th>Dipole Sonic</th>
<th>LithoScanner</th>
<th>Spectral Gamma</th>
<th>QuantaGeo</th>
<th>LithoScanner Analysis</th>
<th>Shear Anisotropy Analysis</th>
<th>Geomechanical Properties Advisor</th>
<th>Petrophysical Analysis (QELAN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAVENCLIFF SANDSTONE</td>
<td>AVIS LIMESTONE</td>
<td>MAXTON SANDSTONE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LITTLE LIMESTONE</td>
<td>BIG LIMESTONE</td>
<td>WEB</td>
<td>4,043</td>
<td>4,260</td>
<td>4,667</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| BREA SANDSTONE | CLEVELAND SHALE | LOWER BURON | OLENTANY SHALE | RHINESTREET SHALE | ONGNDAGA LIMESTONE | LOCKPORT | 6,000 | 6,260 | 6,600 | 6,647 | 6,678 | 7,000 | 7,212 | 7,400 | 7,900 | 8,350 | 8,958 | 9,425 | 9,851 | 10,637 | 10,817 | 11,395 | 11,737 | 11,812 | 12,144 | 12,288 | 13,314 | 14,372 | 15,019 | 15,144 |}

### Cased Hole

- **RAVELL**
- **CLEVELAND**
- **TRENTON**
- **BLACK RIVER**
- **GULL RIVER**
- **GLENWOOD**
- **BEEKMANTOWN DOLomite**
- **ROSERUN SANDSTONE**
- **TREMPALEAU / COPPER RIDGE**
- **LOWER COPPER RIDGE**
- **MAYNARDVILLE LIMESTONE**
- **NOUCHUCKY SHALE**
- **MARYVILLE LIMESTONE**
- **ROGERSVILLE SHALE**
- **RUTLEDGE LIMESTONE**
- **PUMPKIN VALLEY SHALE**
- **ROEF OR**
- **SHADY DOLomite**
- **GRANITE WASH**
- **PRESUMPTIVE BASEMENT**  

## Diagrams

1. Openhole Logs
2. Cased Hole
3. Evaluation Logs
Core Point Determination

• A Heterogeneous Rock Analysis (HRA) was conducted to evaluate the variability of log responses based on Triple Combo data and identify packages (Facies) of like rock and ensure optimal distribution of the Rotary Sidewall Cores (RSWC).

• The HRA was performed on 10 individual formations of interest:
  - Trenton / Black River Ls
  - Glenwood through Rose Run
  - Nolichucky Shale
  - Maryville Limestone
  - Rogersville Shale
  - Rutledge Limestone
  - Pumpkin Valley Shale
  - Rome Fm
  - Shady Dolomite
  - Granite Wash
## Coring Summary

<table>
<thead>
<tr>
<th>FORMATION</th>
<th>UNIQUE CORE POINT ATTEMPTED</th>
<th>UNIQUE CORE POINT RECOVERED</th>
<th># OF RSWC RECOVERED</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>REEDSVILLE</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>TRENTON</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>BLACK RIVER</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>GLENWOOD / WELLS CREEK</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>BEEKMANTOWN</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>ROSE RUN</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>Duplicate core recovered at 10,708'</td>
</tr>
<tr>
<td>MAYNARDVILLE</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>NOLICHUCKY</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>MARYVILLE</td>
<td>17</td>
<td>15</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>ROGERSVILLE</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>RUTLEDGE</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>PUMPKIN VALLEY</td>
<td>16</td>
<td>15</td>
<td>17</td>
<td>Duplicate core recovered at 13,306' &amp; 13,312'</td>
</tr>
<tr>
<td>ROME</td>
<td>9</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>SHADY DOLOMITE</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>GRANITE WASH</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>102</strong></td>
<td><strong>87</strong></td>
<td><strong>90</strong></td>
<td></td>
</tr>
</tbody>
</table>

**RECOVERY RATE:** 85%
CT Scanning National Energy Technology Laboratory (NETL) work led by Dustin Crandall, NETL

- All 90 cores were scanned utilizing a Medical CT Scanner
  - Each core was scanned at two energies so that the dual energy density could be calculated

- 11 cores were selected to be scanned at high resolution with the Industrial CT Scanner
  - Additional cores can be scanned at high resolution if desired but was limited initially
Logging, Coring, and Analysis

Logging Job 1 (Intermediate Section)
- Quad Combo (G, N, D, Pe, LL)
- Dipole Sonic
- LithoScanner
- ELAN (Shale Evaluation)
- Mechanical Properties

Logging Job 2 (Deep Section)
- Quad Combo (G, N, D, Pe, LL)
- Dipole Sonic
- LithoScanner
- FMI / OBMI
- ELAN (Shale Evaluation)
- Mechanical Properties

Coring Operations (Deep Section)
- 90 RSWC (XL-Rock – 1 ½” x 3”) were retrieved

Core Analysis (Deep Section)
- Source Rock Analysis (SRA)
- Tight Rock Analysis (TRA) Porosity
- Tight Rock Analysis (TRA) Pressure Decay Permeability
- X-ray Diffraction Analysis (XRD)
- Scanning Electron Microscopy (SEM)
- X-ray CT Scanning - VT
- Adsorption Isotherms (CH₄, N₂, CO₂) - VT
- Desorption Isotherms (CH₄, N₂, CO₂) - VT
- Capillary Suction Clay Dispersion Analysis (CST)
- Proppant Embedment Test / Fracture Conductivity Analysis
- Multi Stress Compression Test
Sedimentology and Geochemistry Research
*led by Dr. Ben Gill in Geosciences*

- Conduct geochemical, sedimentological, and mineralogical examination of the Conasauga Shale units: Nolichucky, Rogersville, Pumpkin Valley Shales.
- Determine environmental controls on organic matter deposition in the Conasauga Shale units: Nolichucky, Rogersville, Pumpkin Valley.
- Characterize post-depositional processes that may effect source rock quality.
- Establish a model for organic matter deposition in the Rome Trough.
## Sedimentology and Geochemistry

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Environmental conditions/processes</th>
<th>Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOC, pyrite S, Organic sulfur contents</td>
<td>Source rock quality; diagenetic processes</td>
<td>TOC analysis completed on the cuttings from deep Cambrian Shales. SLB and VT Core Analysis</td>
</tr>
<tr>
<td>Carbon isotopes ($\delta^{13}C$)</td>
<td>Organic matter source and quality/alteration, well correlation</td>
<td>Completed on the cuttings from deep Cambrian Shales</td>
</tr>
<tr>
<td>Iron speciation</td>
<td>Local redox chemistry during deposition/early diagenesis</td>
<td>TBD</td>
</tr>
<tr>
<td>Redox sensitive trace metals (Mo, U, V)</td>
<td>Local redox chemistry during deposition/early diagenesis</td>
<td>TBD</td>
</tr>
<tr>
<td>Major elements (Al, Si, Ti, etc.)</td>
<td>Sediment source</td>
<td>TBD</td>
</tr>
<tr>
<td>Sedimentology</td>
<td>Sediment transport, diagenetic depositional processes; bioturbation</td>
<td>Thin section analyses started</td>
</tr>
<tr>
<td>Mineralogy</td>
<td>Sediment source; diagenetic processes</td>
<td>SLB Core Analysis</td>
</tr>
</tbody>
</table>
Pumpkin Valley – Rutledge Transition
Core Analysis and Modeling
Led by Dr. Cheng Chen, Mining Engineering

1. Shale sample sorting from the field based on the depth, and the performance testing of proppant in different sizes

2. Conductivity curve as a function of closure pressure in the non-smooth-surface shale sample

3. PDP permeability measurement for the shale samples from different formations, and a multi-physics shale transport model (MPST) developed using PDP data (published at Li et al 2020, JPSE)

4. Shale sample non-smooth-surface stitch scanned by profilometer
Modeling Tools and Approaches
led by Dr. Cidgem Keles

- **CMG**
  - Field scale reservoir simulator
  - Finite difference formulation

- **ABAQUS, XFEM**
  - Finite element formulation
  - Hydraulic fracturing modeling
  - Proppant embedment

- **Phase behavior model**
  - In-house Equation of State flash calculation

- In house fully compositional simulation model
Dissemination of Results

- Advisory Stakeholder Group includes community leaders
- Local outreach events completed, and future ones planned
- Multiple press releases by DOE and VT
- Project Website: www.esup.energy.vt.edu
- 1 MS and 1 PhD Degree completed
- 1 MS and 2 PhD Degrees in progress
- Multiple journal and conference publications
Summary

- 2nd deepest well drilled in Virginia
- Well Logs and Core obtained from reservoirs of interest
- Core and log analysis on-going
- Formation Testing Planned (DFIT)
- BP3 Plans
  - Core Analysis
  - Geologic Characterization
  - Reservoir Modeling
  - Data Analysis
  - Commercialization Plans
Contacts

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