North Carolina Shale Gas: Dan River Basin, Stokes and Rockingham Counties*

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Search and Discovery Article #80199 (2011)
Posted November 7, 2011

*Adapted from oral presentation at AAPG Eastern Section meeting, Washington, DC, September, 25-27, 2011

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Abstract

The Dan River Basin is an approximately 93-mile-long, northeast-trending half-graben Triassic rift basin with a steeply dipping western border fault in north-central North Carolina (NC) and Virginia. The basin is filled with ~6,600 feet of Triassic strata that dip at about 30° west toward the border fault. The Triassic is divided into the following three formations in descending stratigraphic order: (1) Stoneville Formation (red and gray siltstone and shale); (2) Cow Branch Formation (black shale, with some beds of gray shale, sandstone and very thin coal); and (3) Pine Hall Formation (gray sandstone and shale).

The Cow Branch Formation (CBF), the source rock in the Dan River Basin, is correlative to the Cumnock Formation in the Sanford sub-basin and, likely, to organic strata in the Wadesboro sub-basin, Deep River Basin, NC.

The CBF shale was deposited in fresh-water, shallow lakes similar to African rift valley lakes in a paleo-equatorial geographic location. The formation extends across ~65,000 acres in Stokes and Rockingham counties, North Carolina, and then northeastward into Virginia.

The CBF has been informally divided into lower-unnamed and upper-unnamed members. The lower member is late middle Carnian and is up to 540 feet thick. The upper member, early late Carnian in age, is up to 1050 feet thick near the state line in a quarry. Reconnaissance organic geochemistry and thermal maturation analyses indicate that the black shale in the lower member of the Cow Branch Formation is gas-prone, and that total organic carbon (TOC) averages 3.68% from two core holes (n = 43, min. = 0.17, max. = 27.68; std. dev. = 5.15). Sparse vitrinite reflectance data from these same two drill holes averages 2.07%Ro (n = 4). Additional vitrinite reflectance and TOC analyses are pending. Sparse TOC data reported in the literature are higher in the southern part of the basin than in the northern part of the basin. Temperatures in the northern part have been interpreted in the literature to be higher from either deeper burial or a paleo-hotspot.

The Dan River Basin contains systematic fractures that are observable in outcrop and on regional geologic maps superimposed on LiDAR data. The primary fractures trend northwest, whereas the conjugate fractures trend northeast. The Dan River Basin is an untested basin with
only three shallow core drill holes in the lower member of the Cow Branch Formation. No seismic lines are known. The gray shale of upper member of the Cow Branch Formation is mined for expanded and lightweight aggregate where 1500 feet of section are continuously exposed in a mine quarry. Additional organic geochemical sampling is in progress.

Selected References


Website

NORTH CAROLINA SHALE GAS: DAN RIVER BASIN – STOKES AND ROCKINGHAM COUNTIES

Jeffrey C. Reid, Kenneth B. Taylor, and James D. Simons
North Carolina Geological Survey
919.733.2423
Dan River Basin overview including:
- New TOC data, and
- Synthetic gamma-ray study (mimics horizontal hole)

Legislative update for North Carolina
Mesozoic rift basins in NC
Triassic paleogeography ~210mya, from Ron Blakey, NAU Geology.
Dan River Basin synopsis

- Half-graben, hanging wall on west
- 64,000+ acres in North Carolina, more north in VA
- Original basin depth estimates of 15,000 ft.; now 0 to 5500 ft.
- Width ranges from pinch-out (Stokes Co., NC) to 6 miles (Rockingham Co., NC) – NC portion
- Two organic lacustrine members:
  - Lower member - ~450 ft. thick, 22 miles long (deeper water lakes); TOC mean = 3.12 (n = 63)
  - Upper member - ~1500 ft. thick, 6 miles in NC, continues northward into Virginia (shallower water lakes); TOC mean = 1.38 (n = 42)
- Post-Triassic cover (Stoneville Fm.) is estimated from 0 to 4100 ft.
- Thin, persistent coal present (Stone, 1910)
- Some oil reported in thin sections (Robbins, 1982)
- %Ro avg. = 2.07; min. = 1.23, max. 3.02 (four data points – one drill hole) – Lower member; additional %Ro work pending
- Three shallow vertical core holes in Lower member
### Figure 5. Exploration overview - North Carolina on-shore Triassic lacustrine rift basins

As of September 9, 2011

<table>
<thead>
<tr>
<th>Basin name = sub-basin name</th>
<th>Liner live</th>
<th>Drill live</th>
<th>Triassic</th>
<th>Cretaceous</th>
<th>Astoria County</th>
<th>Atlantic coastal plain basin</th>
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</thead>
<tbody>
<tr>
<td>Sanford sub-basin</td>
<td>140,250</td>
<td>405,356</td>
<td>205,005+</td>
<td>64,317</td>
<td>-3,952</td>
<td>0,283</td>
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<td>Surface area (acres)</td>
<td>8,765</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<td>Total pressure</td>
<td>Yes (BHP)</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Yes (BHP)</td>
<td>No</td>
<td>No</td>
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<td>SCI (core or cuttings)</td>
<td>0.02 - 0.01 (range)</td>
<td>n/a</td>
<td>n/a</td>
<td>3.19 - 27.08 (range)</td>
<td>unknown</td>
<td>n/a</td>
</tr>
<tr>
<td>LEC (core or cuttings)</td>
<td>0.8 - 1.3</td>
<td>n/a</td>
<td>n/a</td>
<td>3.29 - 3.0 (avg)</td>
<td>2.07</td>
<td>n/a</td>
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<tr>
<td>Wilo (core and cuttings)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>1.04 (n=344)</td>
<td>unknown</td>
<td>unknown</td>
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<td>Wilo (surface samples)</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<td>0</td>
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<td>Source rock thickness (feet)</td>
<td>up to 8000</td>
<td>unknown</td>
<td>unknown</td>
<td>NCGS study in progress</td>
<td>n/a</td>
<td>n/a</td>
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<td>Targets</td>
<td>Tight gas (Shafe gas and CBM)</td>
<td>Tight gas (Shafe gas and CBM)</td>
<td>Tight gas (Shafe gas and CBM)</td>
<td>Tight gas (Shafe gas and CBM)</td>
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<td>Quadrant</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>Geophysical logs available</td>
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<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>None</td>
<td>Yes</td>
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<tr>
<td>Depth to basement (feet)</td>
<td>-7,100</td>
<td>-3,500 to 4,200</td>
<td>Unknown but likely similar to Sanford and Durham sub-basins</td>
<td>5,500 ft. (est.)</td>
<td>Probably very shallow</td>
<td>200 ft. maximum depth</td>
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<tr>
<td>Shown (gas, oil, saline)</td>
<td>Numerous</td>
<td>None</td>
<td>None</td>
<td>Some, poorly known in thin sections</td>
<td>None known</td>
<td>None known</td>
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<td>Wet pressures (psi)</td>
<td>600,250</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<td>n/a</td>
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<td>n/a</td>
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<td>Light gas</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Previous drilling (gas and oil)</td>
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<td>No - water well</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Previous drilling (gas)</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Core available</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Cutting available</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Paleic lake water depth</td>
<td>Shallow - subject to currents action</td>
<td>Shallow - subject to currents action</td>
<td>Likely shallow - subject to currents action</td>
<td>Shallow and deep lakes</td>
<td>No lake facets present</td>
<td>No lake facets present</td>
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<tr>
<td>Counties</td>
<td>Lee, Chatham, Moore</td>
<td>Durham, Chatham, Orange, Wake, Granville</td>
<td>Union, Amran, Richmond, Montgomery</td>
<td>Stokes, Rockingham (continues into north into VA)</td>
<td>Danville</td>
<td>Richmond</td>
</tr>
<tr>
<td>Comments</td>
<td>Quarries and railroad cuts provide additional exposures</td>
<td>Quarries and railroad cuts provide additional exposures</td>
<td>Quarries and railroad cuts provide additional exposures</td>
<td>Quarries and railroad cuts provide additional exposures</td>
<td>Likely once part of the Dan River Basin</td>
<td>Likely once part of the Wadesboro sub-basin</td>
</tr>
<tr>
<td>Key stations</td>
<td>Reid and others, 2011; Reid and MFTid, 2008; Reid and Taylor, 2008-2010 - multiple reports - refer to stations in this guidebook</td>
<td>NC Geological Survey studies in progress</td>
<td>NC Geological Survey studies in progress</td>
<td>Thayer and Robbins, 1892; Whiteside, 1984; Stein, 1970; Kirstin in Thayer and others, 2010; Robbins, 1892</td>
<td>Thayer, 1990</td>
<td>Dinners, 1992</td>
</tr>
</tbody>
</table>
Dinosaur tracks
From Whitehead and others, May 2011.
Correlation between the Cumnock Fm., Deep River Fm., in cores MO-C-4-81, MO-C-2-81, and CH-C-1-81, the lower member of the Cow Branch, and the Newark-APTS.

Paleomagnetics and geography

Fig. S1. Main lacustrine sections analyzed with their frequency spectra. Colors in the sections are representative of, although shown here more saturated than the actual, rock color. MP, magnetic polarity (black is normal, white reverse); B-T, Blackman–Tukey spectrum.

Stratigraphy

From Reid and Milici, 2008
LiDAR and geology
LiDAR and geology

[Map showing geological features such as metamorphic and intrusive rocks, Stoneville Fm., Cemex, Pine Hall Fm., Spray cross structure, Dikes, Cow Branch Fm., and Metamorphic and intrusive rocks.]
Cross section A – A’
Pine Hall Formation
Cow Branch in outcrop – Lower member
Cow Branch in outcrop – Lower member
Drill Hole: NCST-2
NCGS No.: SO-C-2-81
Box No.: 19
From: 220 feet to 230 feet

Drill Hole: NCST-2
NCGS No.: SO-C-2-81
Box No.: 20
From: 230 feet to 240 feet

Lower member of the Cow Branch Fm.
Cow Branch Formation – Upper member

[Image of rock formation with a scale card]
Cow Branch Formation – Upper member
Cow Branch Formation – Upper member
Recent TOC results

Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>TOC(%)</th>
<th>TOC(%)</th>
<th>TOC(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Cow Branch - lower mbr</td>
<td>Cow Branch - upper mbr</td>
</tr>
<tr>
<td>Mean</td>
<td>2.428</td>
<td>3.124</td>
<td>1.364</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>3.612</td>
<td>4.481</td>
<td>.932</td>
</tr>
<tr>
<td>Std. Error</td>
<td>.352</td>
<td>.565</td>
<td>.144</td>
</tr>
<tr>
<td>Count</td>
<td>105</td>
<td>63</td>
<td>42</td>
</tr>
<tr>
<td>Minimum</td>
<td>.078</td>
<td>.106</td>
<td>.078</td>
</tr>
<tr>
<td>Maximum</td>
<td>27.677</td>
<td>27.677</td>
<td>3.615</td>
</tr>
<tr>
<td># Missing</td>
<td>34</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Results for totals may not agree with results for individual cells because of missing values for split variables.
Thin, persistent coal present (Stone, 1910)
Some oil reported in thin sections (Robbins, 1982) => reaching the oil window
%Ro avg. = 2.07; min. = 1.23, max. 3.02 (four data points – one shallow drill hole) – Lower member (data from one quarry)
Robbins (1982) suggests the basin area near the NC-VA line had elevated heat flow
RockEval and %Ro analyses in progress
Synthetic gamma-ray study

- Gamma-ray outcrop along mine face to mimic a horizontal hole
- Objective: insight to gamma-ray log variations
- Continuous fresh mine exposure, ~1500 feet exposed
- Upper member, Cow Branch Fm.
- Ludlum Model 19 – Micro R scintillometer used
- Re-occupied TOC sample stations
Synthetic gamma-ray study
Synthetic gamma-ray study
Dan River Basin is part of the USGS Mesozoic Basin assessment

Geologic presentations for the assessment were completed in July 2011

Numeric assessment and ‘Fact sheet’ are pending by the USGS
NC Oil & Gas Act of 1945

- Became law in 1945 – never updated
- Requires drill hole not to deviate more than 3° from vertical (e.g., no horizontal drilling)
- No fracking allowed because of groundwater quality rules
- Focus of interest in the 2011 General Assembly session resulting in much discussion and the passage of two bills (HB242, and SB709).
2011 General Assembly: Energy bills put ‘fracking’ on two tracks

HOUSE BILL – HB 242

- Increases the surety bond and permit fees applicable to drilling, establishes provisions for protection of landowners and directs the DENR to study oil and gas exploration, including horizontal drilling and hydraulic fracturing.
- Report due to the NC General Assembly on May 1, 2012

SENATE BILL – SB 709

- ‘Energy Jobs Act’
- Encourages increased energy production in the State, including inland shale gas exploration;
- Directs DENR to:
  - Inventory all water supplies and evaluate potential impacts on other water users;
  - Review existing laws and rules in NC and other states and recommend regulatory framework.
- Vetoed by Governor
Dan River Basin synopsis

- Half-graben, hanging wall on west
- 64,000+ acres in North Carolina, more north in VA
- Original basin depth estimates of 15,000 ft.; now 0 to 5500 ft.
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  - Lower member; RockEval and %Ro analyses in progress
- Three shallow vertical core holes in Lower member
Acknowledgements

- We thank:
  - CEMEX – mine access
  - Dr. Paul Olsen – field discussions
  - Ms. Elizabeth DePoy, REACH Intern 2011
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