Shale Gas Potential in Triassic Strata of the Deep River Basin, Lee and Chatham Counties, North Carolina, USA*

Jeffrey C. Reid[1] and Kenneth B. Taylor[1]

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[1]North Carolina Geological Survey (NCGS), Raleigh, North Carolina 27699-1612 (jeff.reid@ncdenr.gov, kenneth.b.taylor@ncdenr.gov)

Abstract

The Deep River Basin is a 150-mile long northeast-trending half-graben with a steeply-dipping eastern border fault in central North Carolina. The basin is filled with ~7,000 feet of Triassic strata, which are divided into the following three formations in descending stratigraphic order: (1) Sanford Formation (red and gray siltstone and shale); (2) Cumnock Formation (black shale, with some beds of gray shale, sandstone, and coal); and (3) Pekin Formation (gray sandstone and shale). The Cumnock Formation includes a ~400-foot-thick interval of Upper Triassic (Carnian) organic-rich black shale. This shale extends across ~25,000 acres, at depths of less than 3,000 feet in Lee and Chatham counties. Organic geochemistry and thermal maturation analyses indicate that the black shale in the Cumnock Formation is gas-prone, and that values of total organic carbon (TOC) exceed 1.4% in places. The Cumnock Formation contains systematic fractures that are observable in outcrop, in drill cores, and on 1:24,000-scale geologic maps superimposed on LiDAR data. The primary fractures trend northwest, whereas the conjugate fractures trend northeast. In some places along the west side of the basin, the primary fractures are filled with diabase dikes (that locally heated the Cumnock Formation), although mapping in underground coal mines (now closed) has shown that the diabase dikes do not extend far into the basin. Six of the 28 wells that have been drilled in the Cumnock Formation have reported natural gas and oil shows, and two shut-in wells have reported pressures of 900 psi and 300 psi.

References

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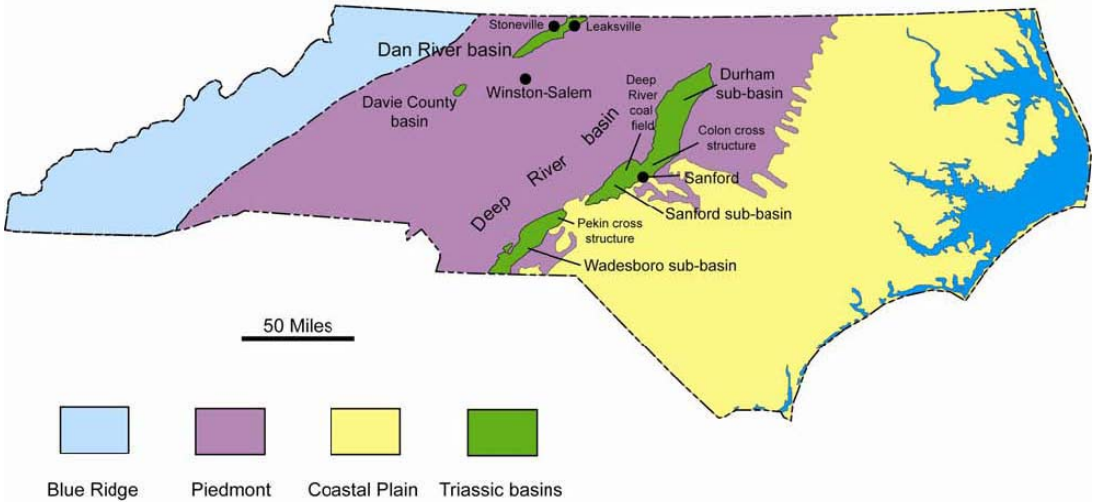
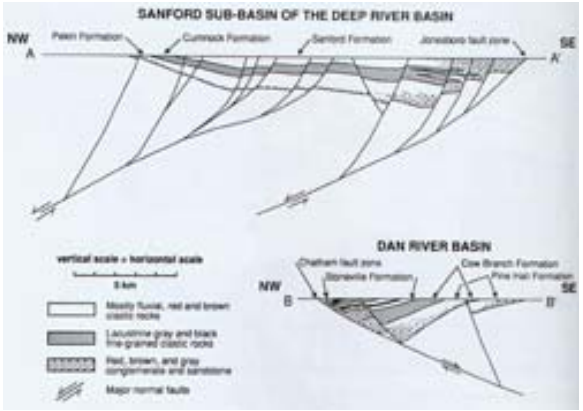


Shale Gas Potential in the Triassic Strata of the Deep River Basin, Lee and Chatham Counties, North Carolina USA

AAPG Eastern Section
Evansville, Indiana
Tuesday, September 22, 2009



Historical timeline – Deep River

- 1775 – Revolutionary War era, coal exploration for iron and munitions
- 1776 – N.C. Colonial Records mentioned “Pit Coal” …in good quantities….
- 1820’s – 1850’s – Coal reports ‘rediscovered’
- 1861 – 1873 – Civil war and post-war coal production
- 1920’s – 1940’s – Underground coal mining, exploration and 1925 coal mine explosion (killed 53 workers)
- ~ 1 million short tons coal produced – 1700’s–1930’s; (1980’s effort)
- 1980’s – 1990’s – Petroleum drilling (preceded seismic – vertical holes);
- 2008 – Organic geochemical data published (Reid and Milici)
- Thick section of organic shale recognized as a potential gas resource
- 2008 (Reid and Taylor) – Initial industry presentation (AAPG-Eastern)

Why Now?

New emphasis

- Industry largely unaware of basins in North Carolina
- USGS emphasis on Mesozoic basin energy systems
- Thick organic-rich shale section previously not considered to be of interest
- Similarity to other unconventional organic shale resources

Why Now?

Compilation of data

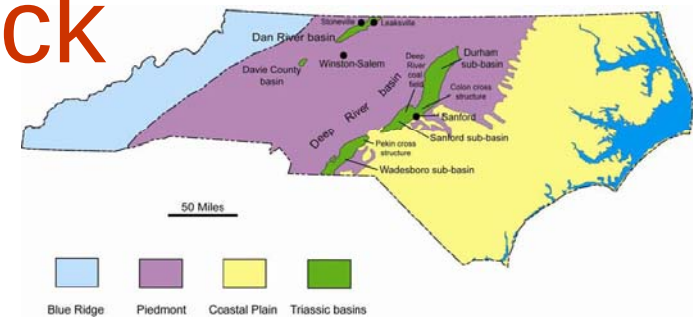
- Years of scholarship locating and compiling data
- Paper data converted to digital formats
- Organic geochemistry data collected and interpreted for first time
- Focus was shallow coalbed methane, not shale gas
- Wells drilled BEFORE seismic lines were run
- Relatively shallow well depths; wells did not target seismic features of potential interest as they were unknown then

Why Now?

New techniques / interpretation

- New gas chemistry and gas quality data
- Seismic lines interpreted
- Use of LiDAR to delineate geologic structures
- Directional drilling
- Recognition of a total petroleum system
- New gas pipelines and nearby users
- Rural area compared to other East Coast rift basins

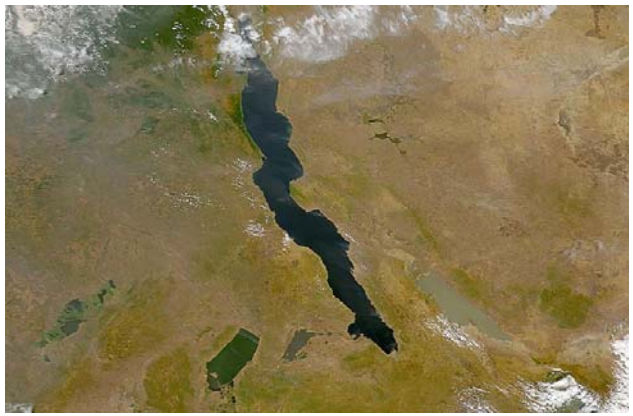
Basin and Source Rock Overview



Map showing the distribution of Mesozoic basins in North Carolina (from Reid and Milici, 2008).

Map showing the distribution of Mesozoic basins in the eastern United States (from Robinson and Froelich, 1985). Lee and Chatham counties are located inside the red box.

- Deep River Basin – 150-mile-long northeast-trending half-graben (rift basin) with a steeply dipping eastern border fault in central North Carolina
- Basin filled with ~7000 feet of Triassic strata
- Old lakes – similar to African rift valleys forming today
- ~25,000-acre area in Lee and Chatham counties, NC
- Viewed as total petroleum system – elements are:
  - Source rock
  - Seal
  - Traps
  - Porosity and permeability
- Significant exploration prospect
- Frontier exploration area

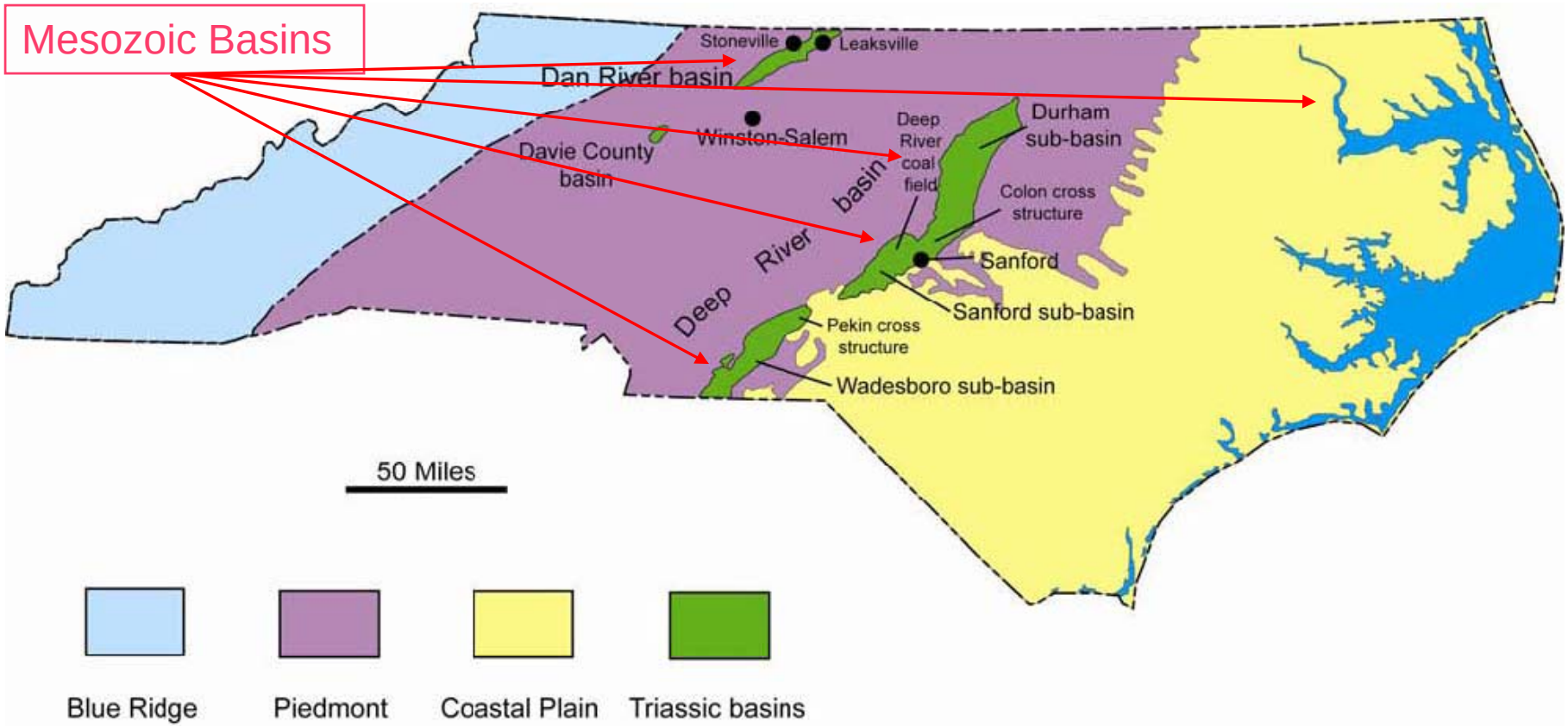


From left to right, Lakes Upemba, Mweru, Tanganyika and Rukwa – Image spans the SE corner of the Democratic Republic of the Congo, NE Zambia and southern Tanzania. Image courtesy of SEAWiFI, NASA/Goddard Space Flight Center and ORBIMAGE →

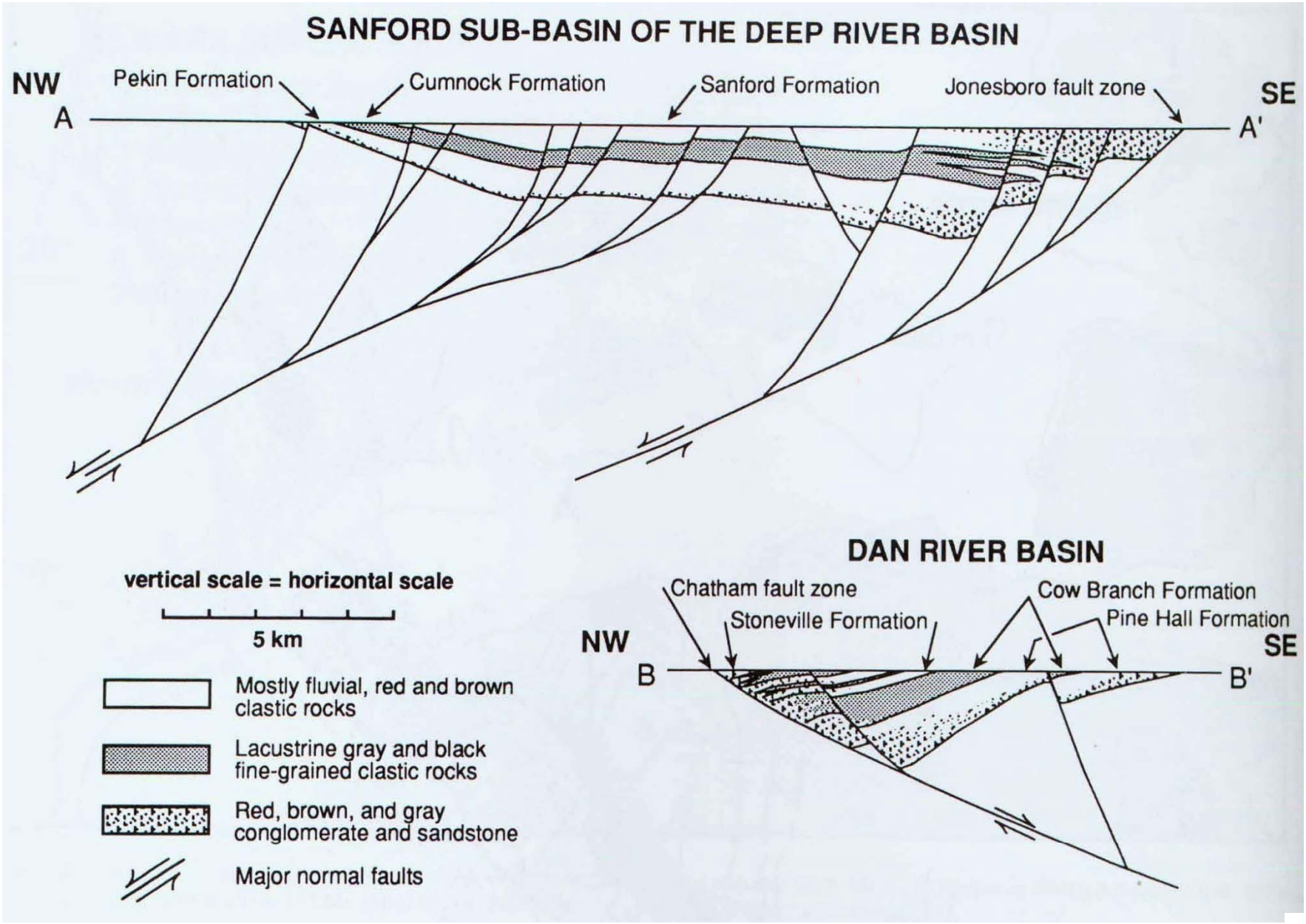
Basin Basics and Location

- Prime area covers ~1.5 counties (Lee and Chatham counties, North Carolina)
- ~25,000 acres underlain by ~110 million tons of coal (Reinemund, 1949 [24k geologic map]; 1955 [USGS Professional Paper])
- Coal reserves measured, indicated, and inferred to a depth of less than 3000 feet - two coal beds
- Thick (~400 feet) fractured, organic shale section – entire formation up to 800 feet thick
- Two shut-in wells with significant gas pressures (Simpson #1, Butler #3) – confirmed and sampled for molecular composition, stable isotopes, and BTU content in March 2009
- Known natural gas and oil shows (6 of 28 wells); oil retorted from shale (“shale oil”)
- Good bet that organic-rich shale follows the coal distribution in basin

Location of Mesozoic Basins

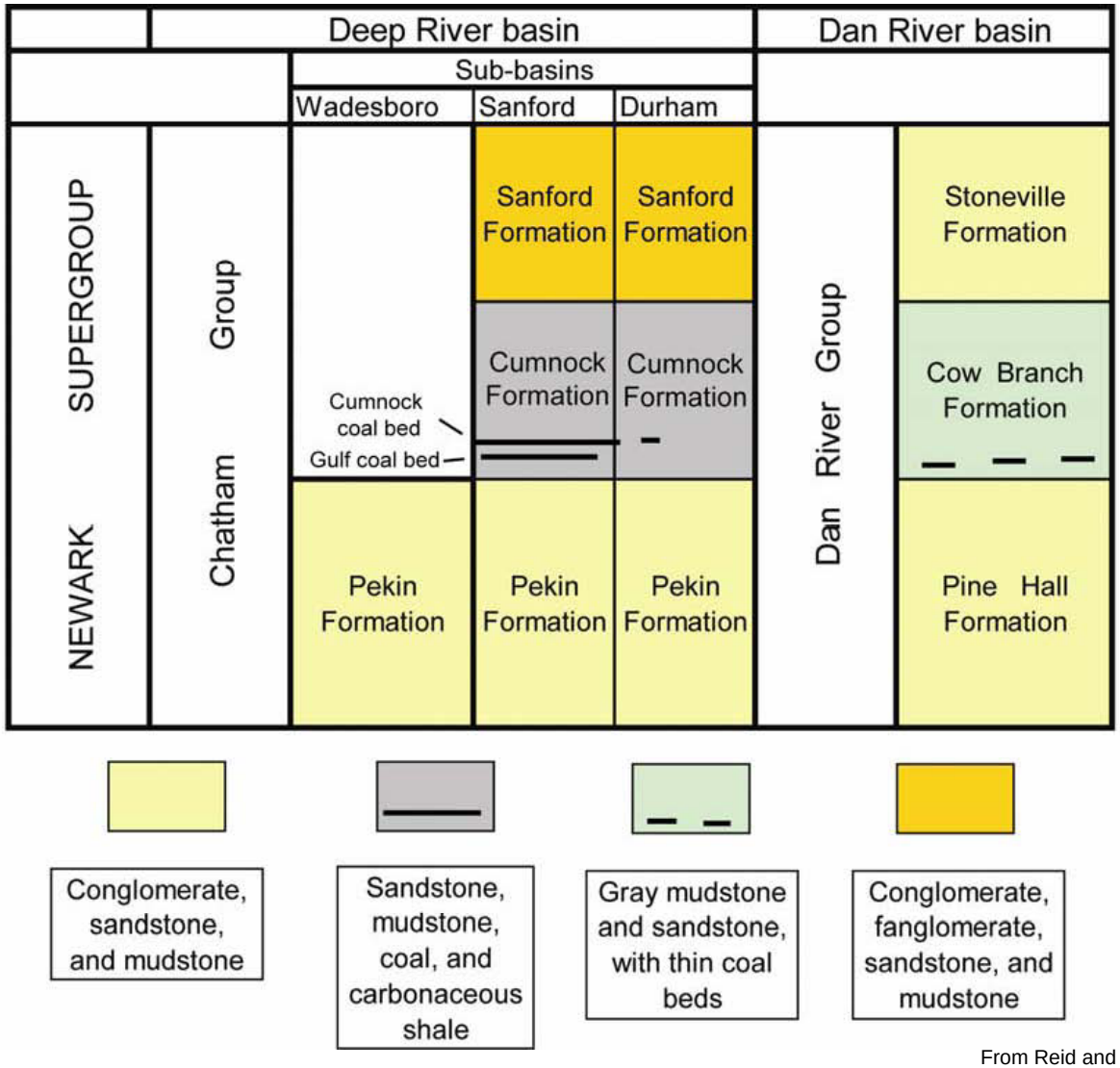


From Reid and Milici, 2008, USGS Open File Report 2008-1108



From Olsen and others, 1991

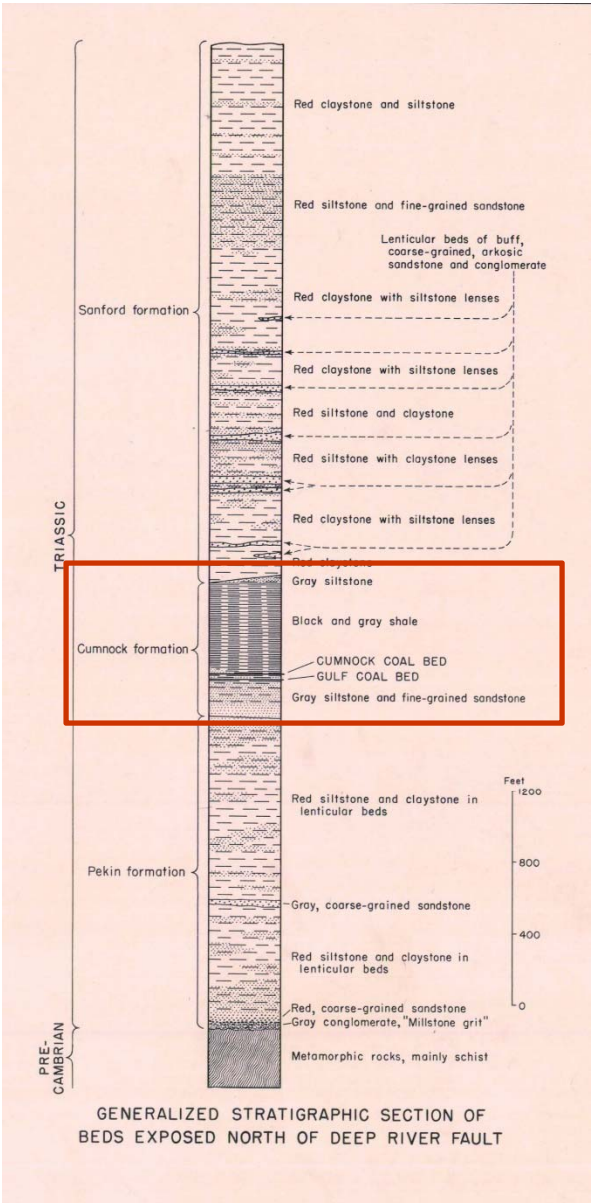
Stratigraphy



From Reid and Milici, 2008

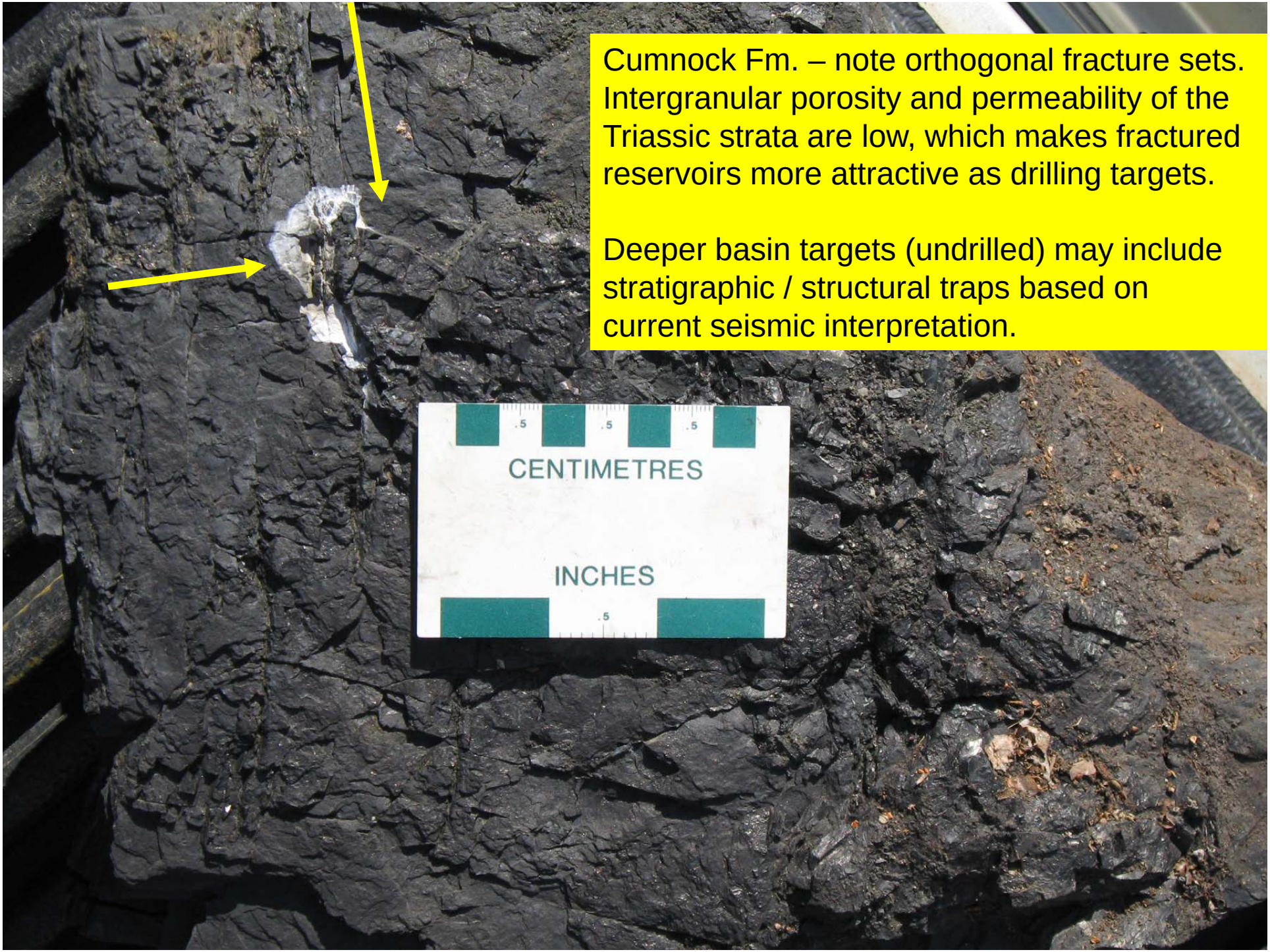
Shale thickness

- Cumnock Fm. Is up to 400 ft thick at the Egypt (Cumnock) coal mine. Overall formation thickness is ~800 feet
- Previous work focused only on relatively thin coals discussed in the geologic literature
- Organic-rich shales are far thicker than generally realized (400+ feet) and cover multiple counties



GENERALIZED STRATIGRAPHIC SECTION OF BEDS EXPOSED NORTH OF DEEP RIVER FAULT

From Reinemund, 1955

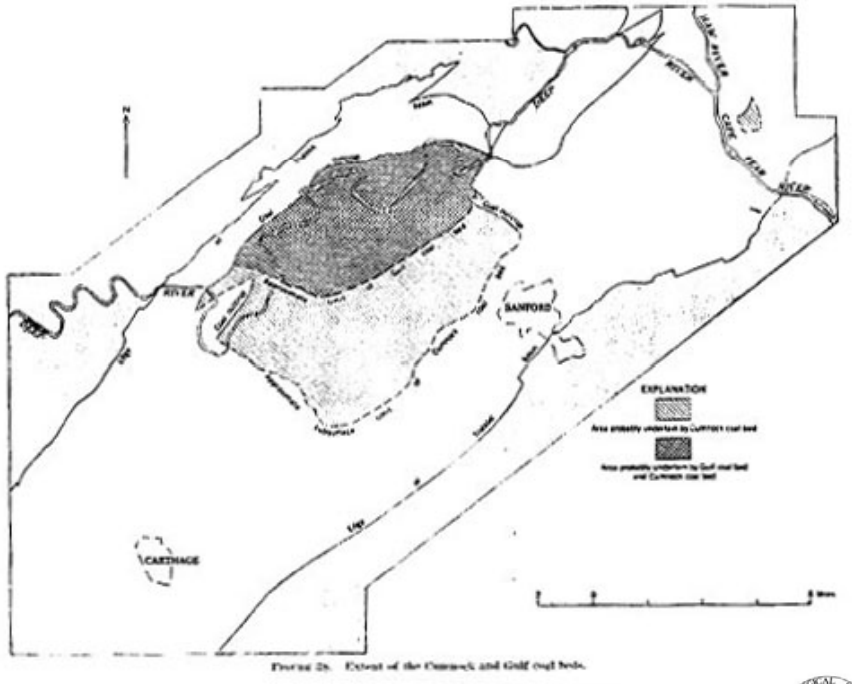


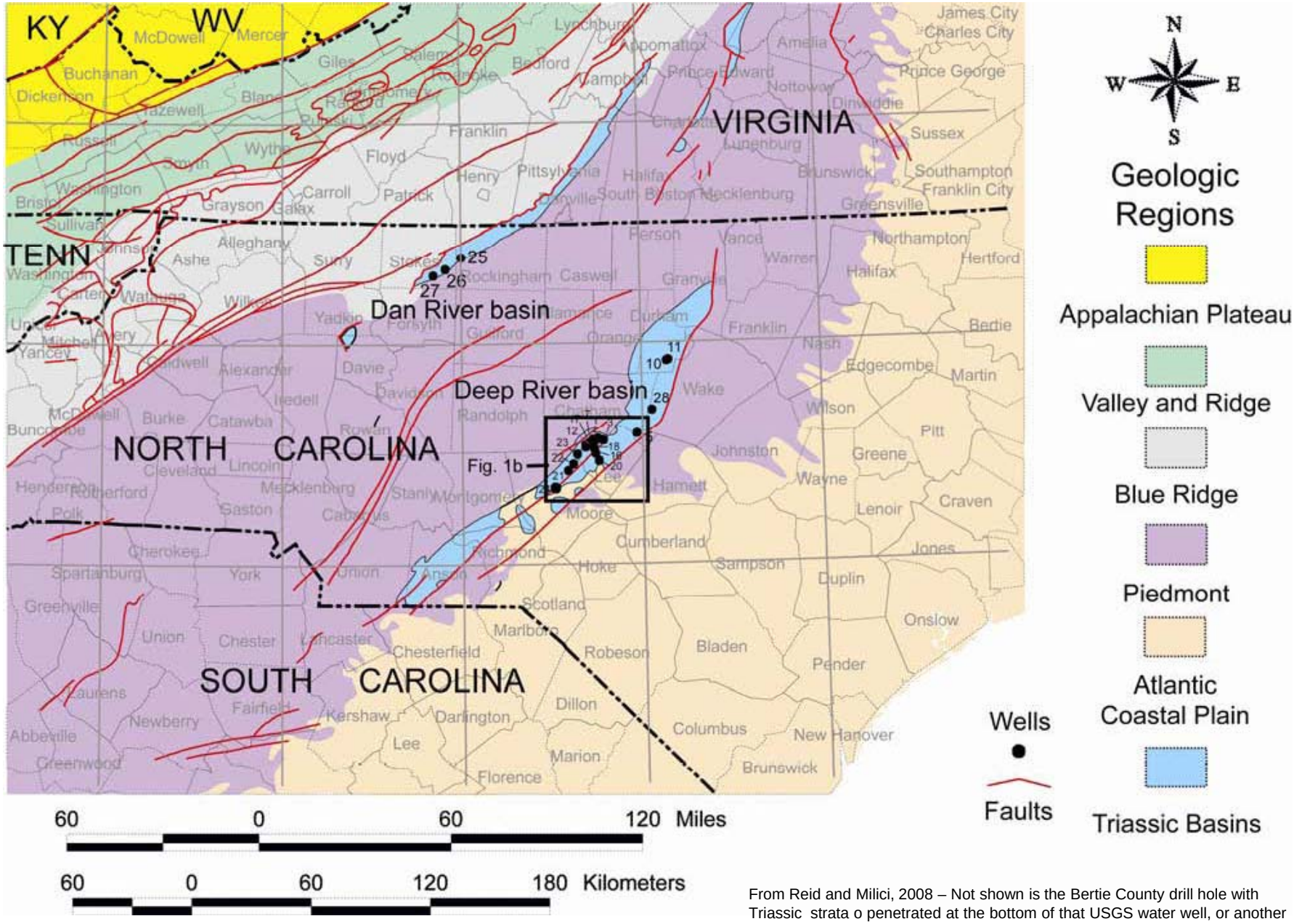
Cumnock Fm. – note orthogonal fracture sets. Intergranular porosity and permeability of the Triassic strata are low, which makes fractured reservoirs more attractive as drilling targets.

Deeper basin targets (undrilled) may include stratigraphic / structural traps based on current seismic interpretation.

Coals and their extent

- Extent = 26 square miles (mostly Lee Co., N.C.)
- There are two coals:
  - Cumnock (thickest and most extensive)
    - ave. 3-4 feet thick
  - Gulf (smaller area) –
    - 25 to 45 feet stratigraphically below the Cumnock Formation
    - a few inches to 3 feet thick
    - “black band” (an iron-rich, ammonia-sulphate rock) –
  - “Black band” produced oil when retorted





From Reid and Milici, 2008 – Not shown is the Bertie County drill hole with Triassic strata o penetrated at the bottom of that USGS water well, or another well in far northeastern NC. Airborne geophysical basin interpretations not shown.

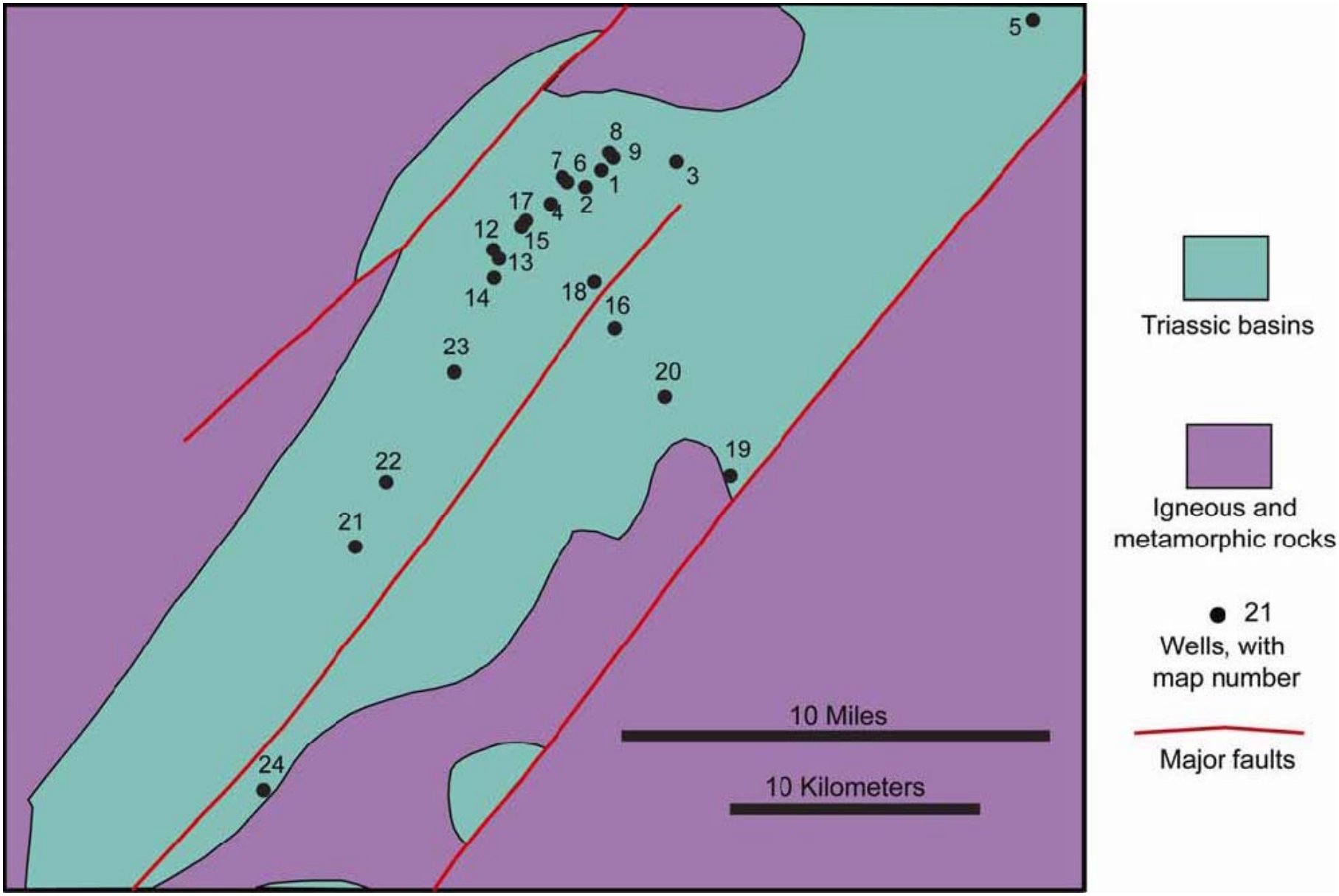
Gas and oil shows

Six of 28 drill holes (including old coal holes) have shows of gas, oil or both and some ‘asphalt’

Two wells are shut-in and have significant current pressure (March 2009)

- Butler #3 (upper right) – with pressure of 900 psi
- Simpson #1 (lower left) – with pressure of 250 psi
- Butler #1 (lower right) – small amount high paraffin oil (low flow temperature; (hand warming) was recovered.

Black band rock retorted (1927) produced shale oil range of 3.6 – 12.4 gallons per ton



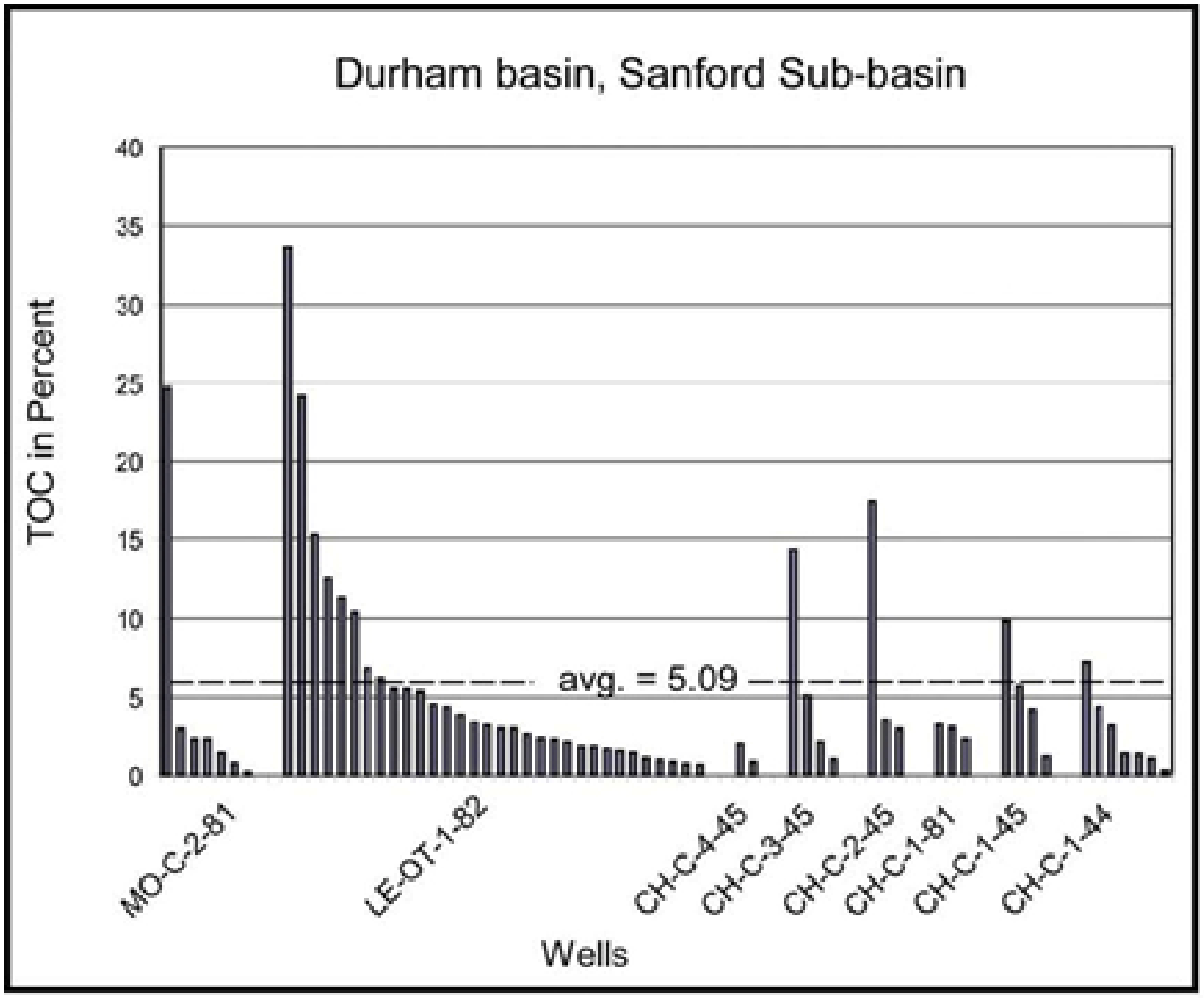
From Reid and Milici, 2008. Wells 17-19 follow trace of Seismic Line 113 (dip section); wells21-2 approximate the strike section of Seismic Line 106B.

Natural gas and oil shows (cont'd)

- Daily drilling reports provide additional data. Selected entries:
- Simpson #1 - ~250 psi and gas flow (3/2009)
  - 4/27/1998 – strong gas flow at 2033 feet in excess of 3000 mcfd. After 3 hours flow rate was 231 mcfd
- Butler #3 – ~900 psi and gas flow (3/2009)
  - 10/12/98 well head pressure 1200 psi
  - 10/15/98 well head pressure 570 psi, slight oil show
  - 10/26/98 well head pressure 600 psi, oil show

Organic geochemistry

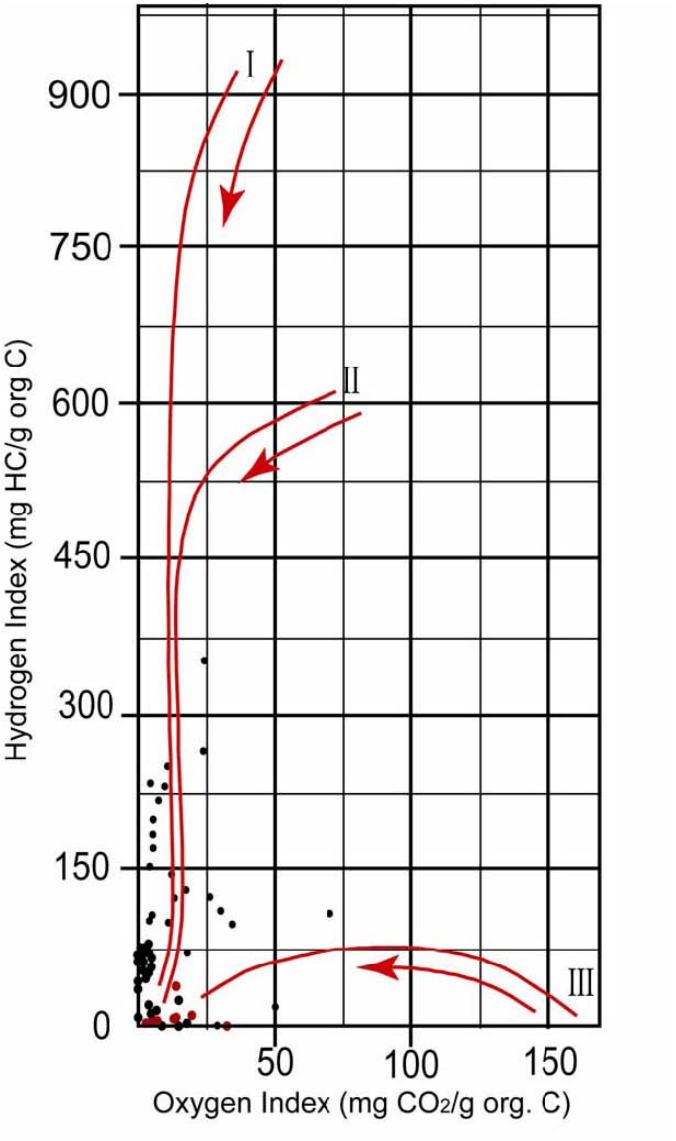
- Reid and Milici (USGS OFR 2008-1108) show that potential source rocks exist in the Sanford sub-basin and that the sediments are gas-prone, rather than oil-prone although oil source rock cannot be precluded.
- TOC data exceeds the conservative 1.4% threshold necessary for hydrocarbon expulsion.
- The organic matter in these formations was derived primarily from terrestrial Type III woody (coaly) material and secondarily from lacustrine Type I (algal material).
- Both the thermal alteration data (TAI) and vitrinite reflectance data (%Ro) indicate levels of thermal maturity suitable for the generation of hydrocarbons
- A new USGS grant provides funding to expand the database.



- Distribution of TOC data in wells in the Durham basin
- A threshold of 1.4% TOC is considered necessary for hydrocarbon expulsion.
- From Reid and Milici, 2008.

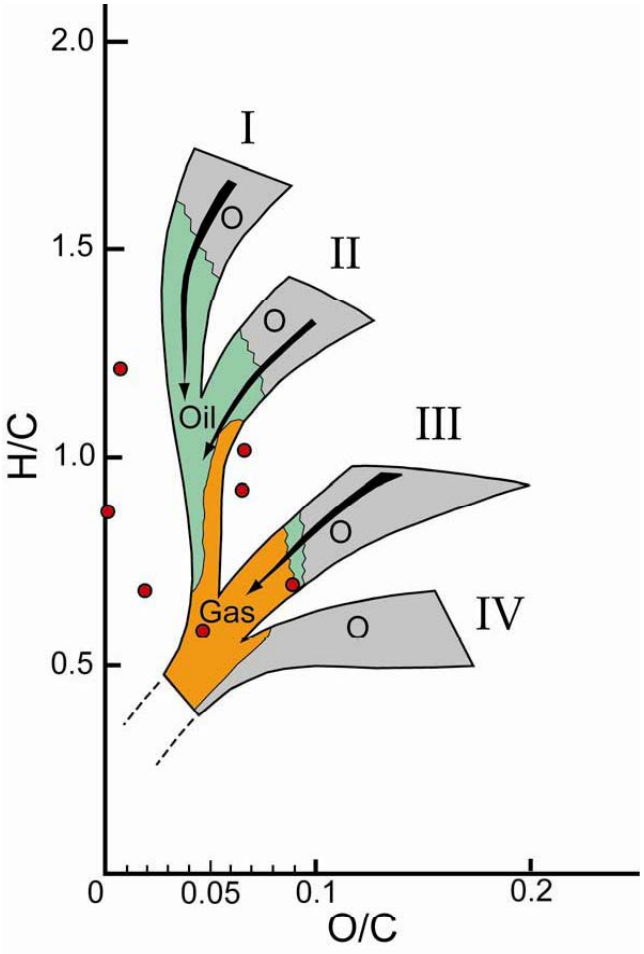
Hydrogen and oxygen indices

- Hydrogen and oxygen indices from Rock-Eval pyrolysis in relation to primary kerogen type
- The organic material in these formations was derived primarily from terrestrial Type III woody (coal) and secondarily from Type I (algal) matter.



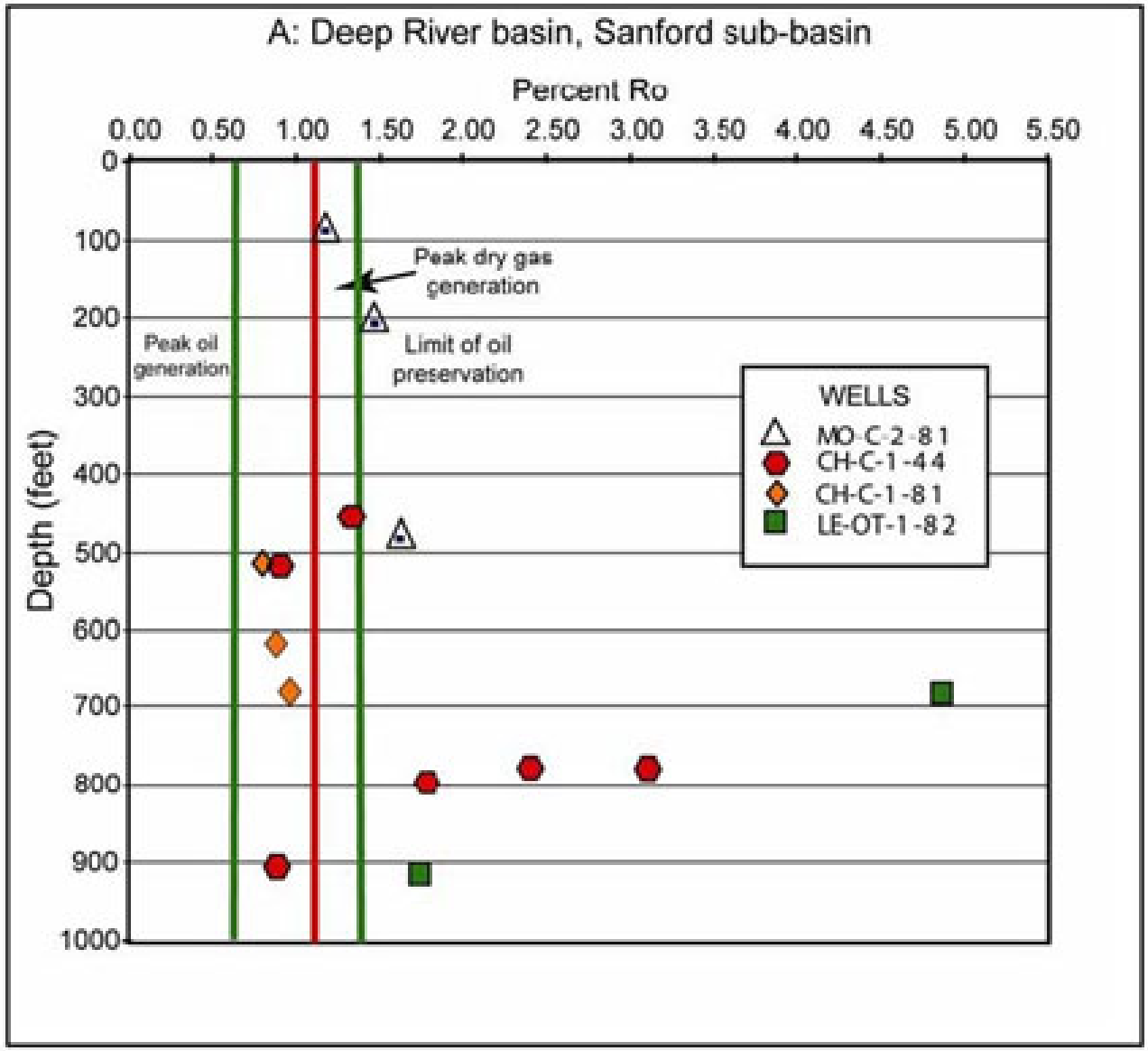
From Reid and Milici, 2008.

H/C and O/C ratios of kerogen types



- Data (red circles) are from well CH-C-1-44, Cumnock Fm., Sanford sub-basin of the Deep River basin (from Reid and Milici, 2008).
- The organic material in these formations was derived primarily from terrestrial Type III woody (coal) and secondarily from Type I (algal) matter.
- S1+S2 data (not shown) in the mid-20 mg HC/g sample range indicate considerably higher source-rock potential than the basin average.

From Reid and Milici, 2008.

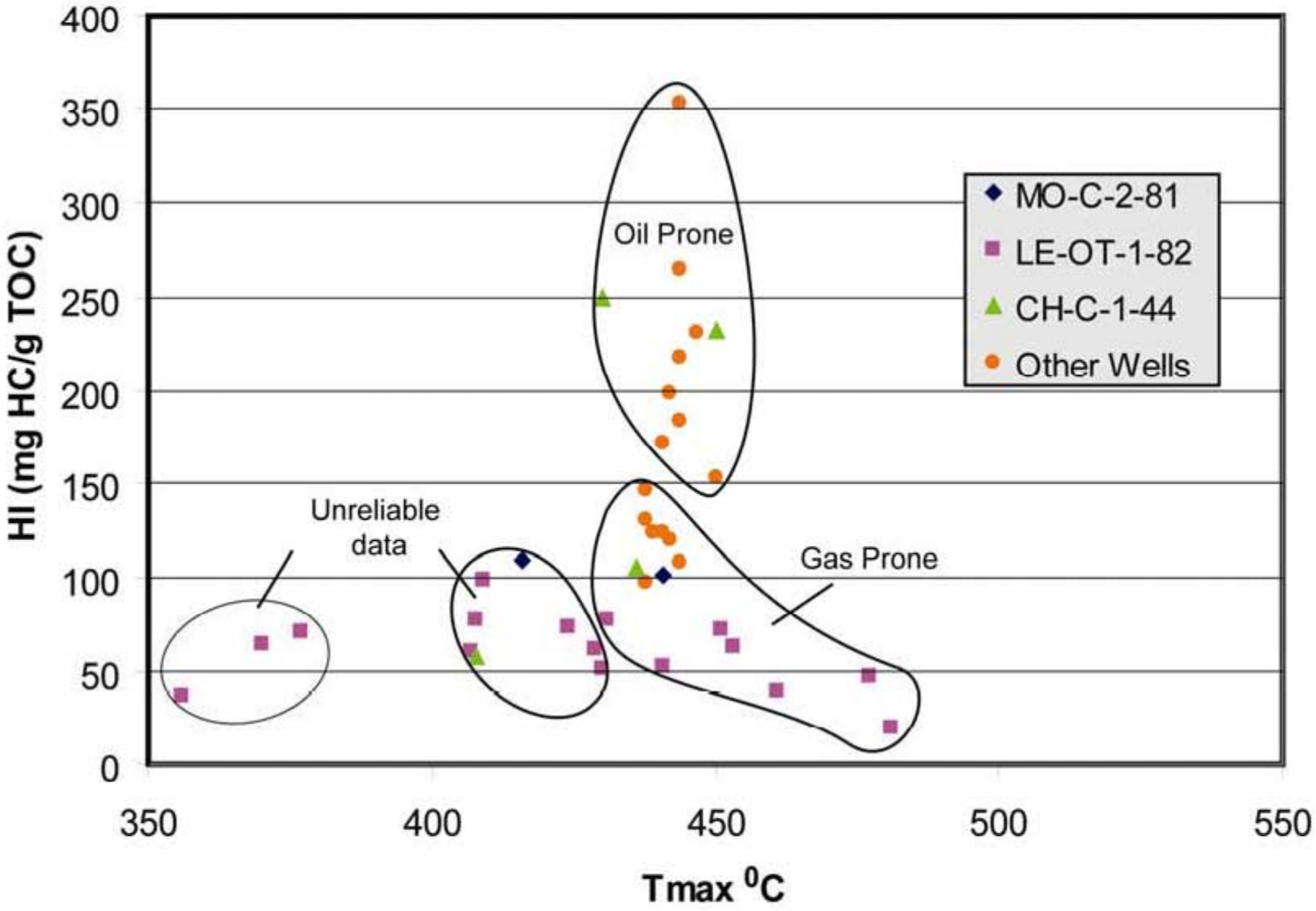


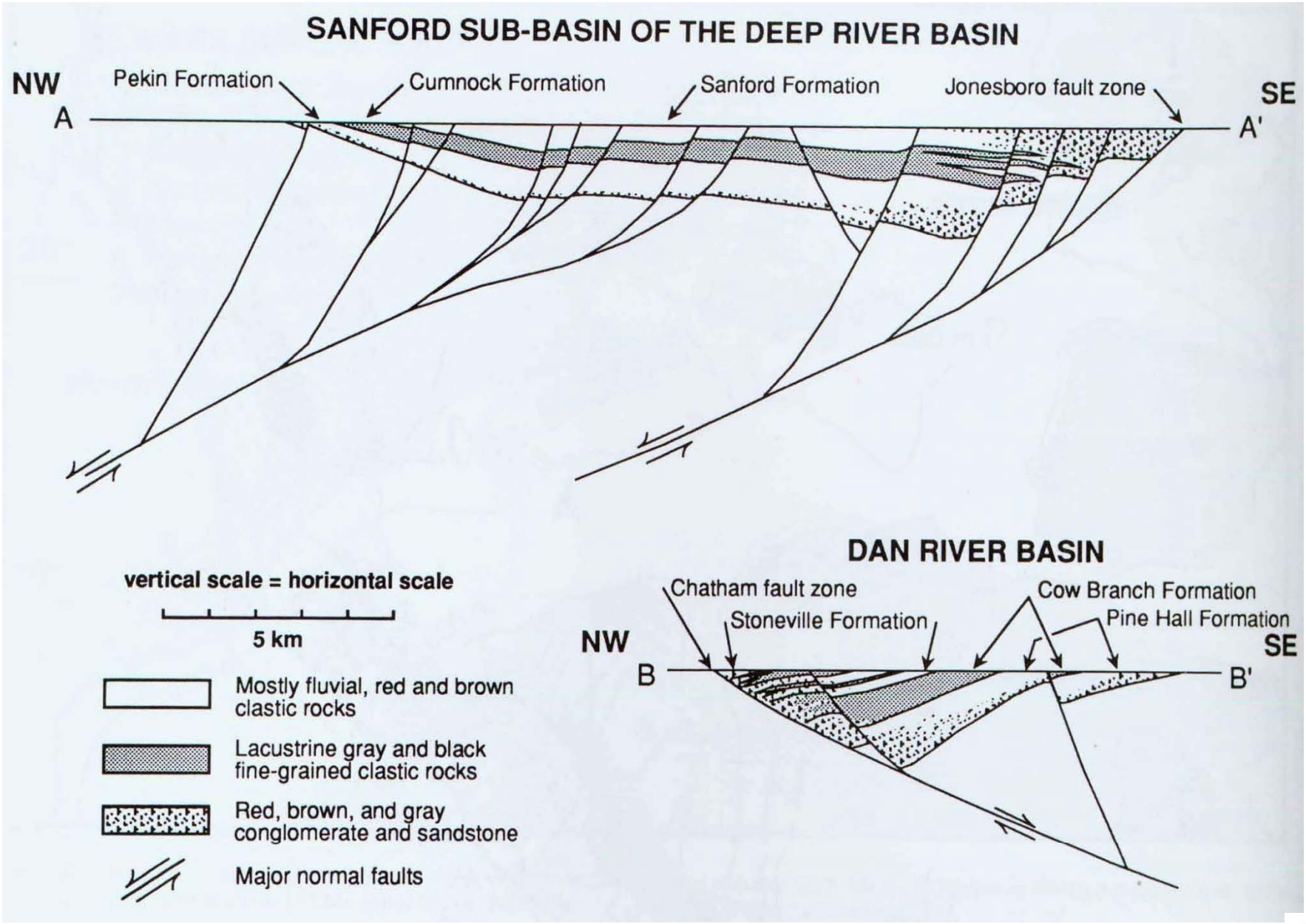
Plot of depth *vs.* %Ro for selected wells in the Deep River basin showing the relationship between thermal maturity, measured as %Ro, to depth.

Hydrocarbon generation and preservation limits from (Housekneicht and Spotl, 1993).

From Reid and Milici, 2008.

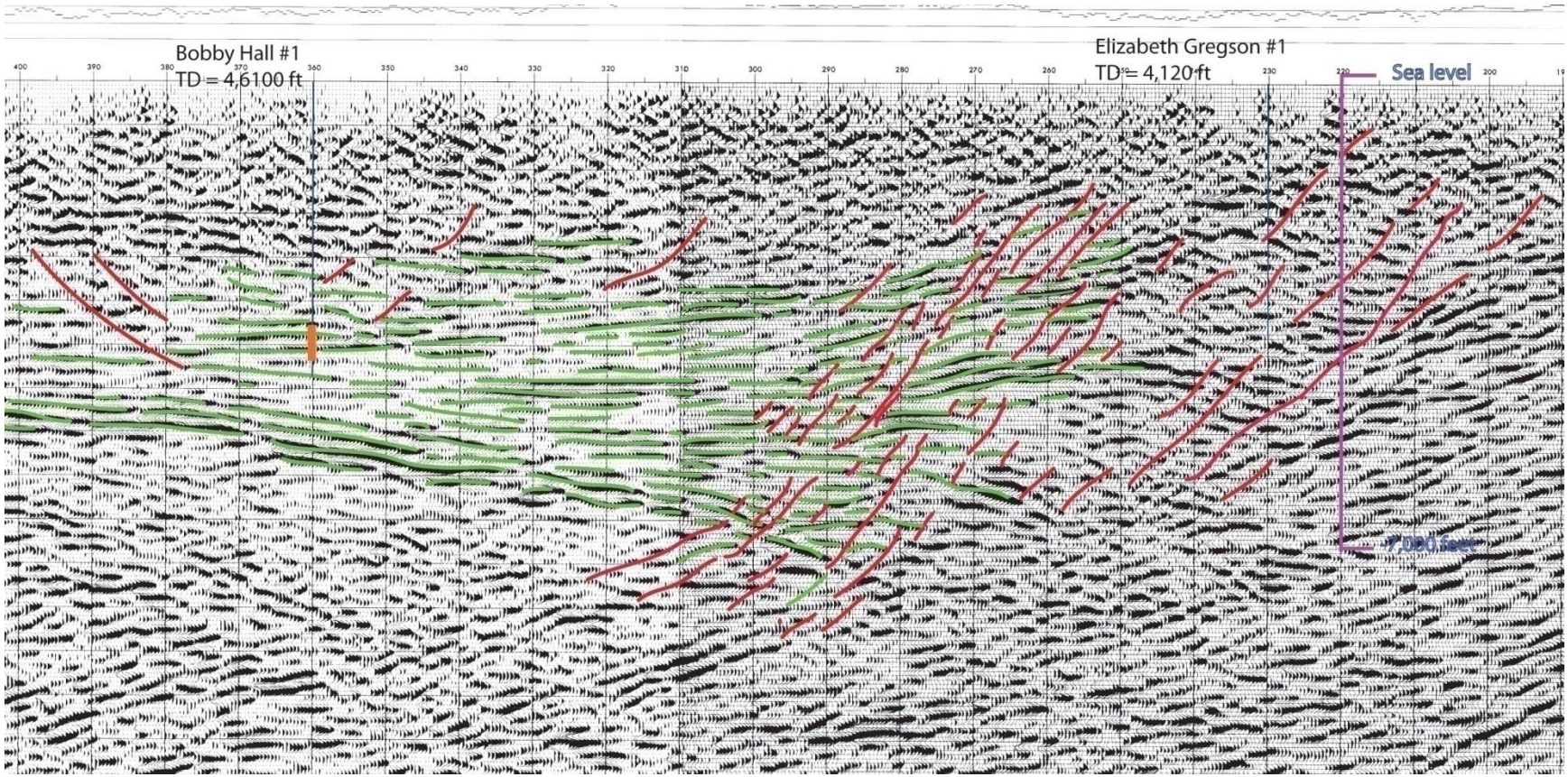
Comparison of Tmax and Hydrogen Index of samples from wells in the Durham Basin, Sanford sub-basin (from Reid and Milici, 2008).





From Olsen and others, 1991

Seismic Line 113



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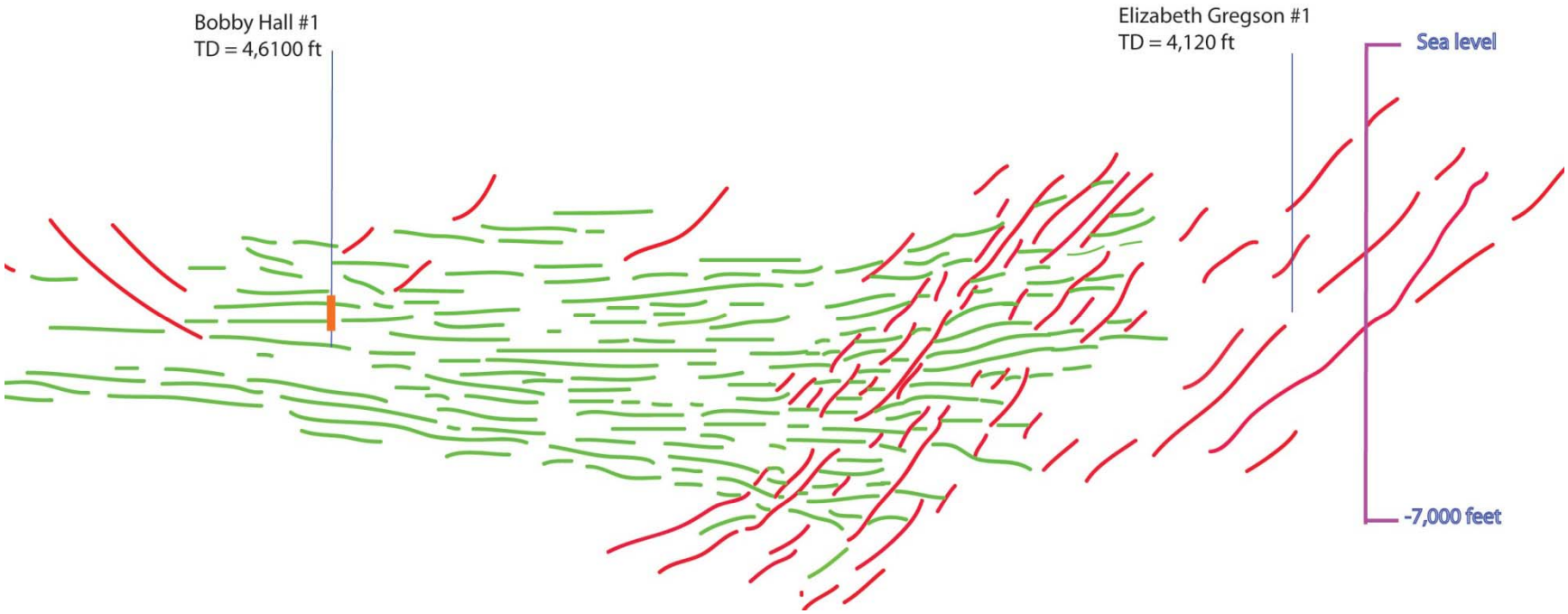
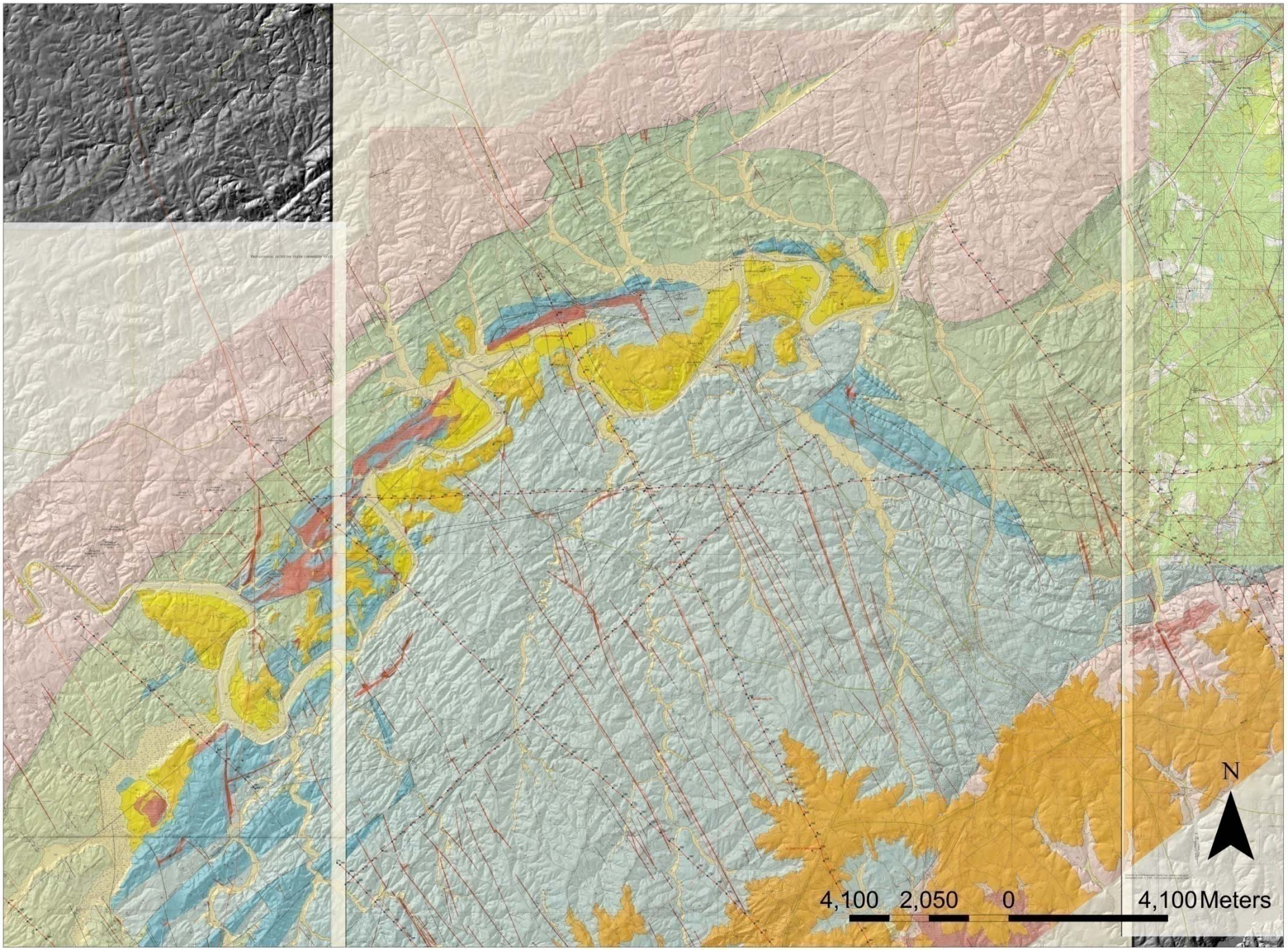


LiDAR and fractures

- LiDAR shows structural patterns that can be traced to outcrop-scale, and likely to corresponding fractures in drill core.
- Fracture patterns are consistent in the Cumnock Fm. (shown in outcrop and samples) and underlying Pekin sandstones.
- LiDAR is a potential exploration tool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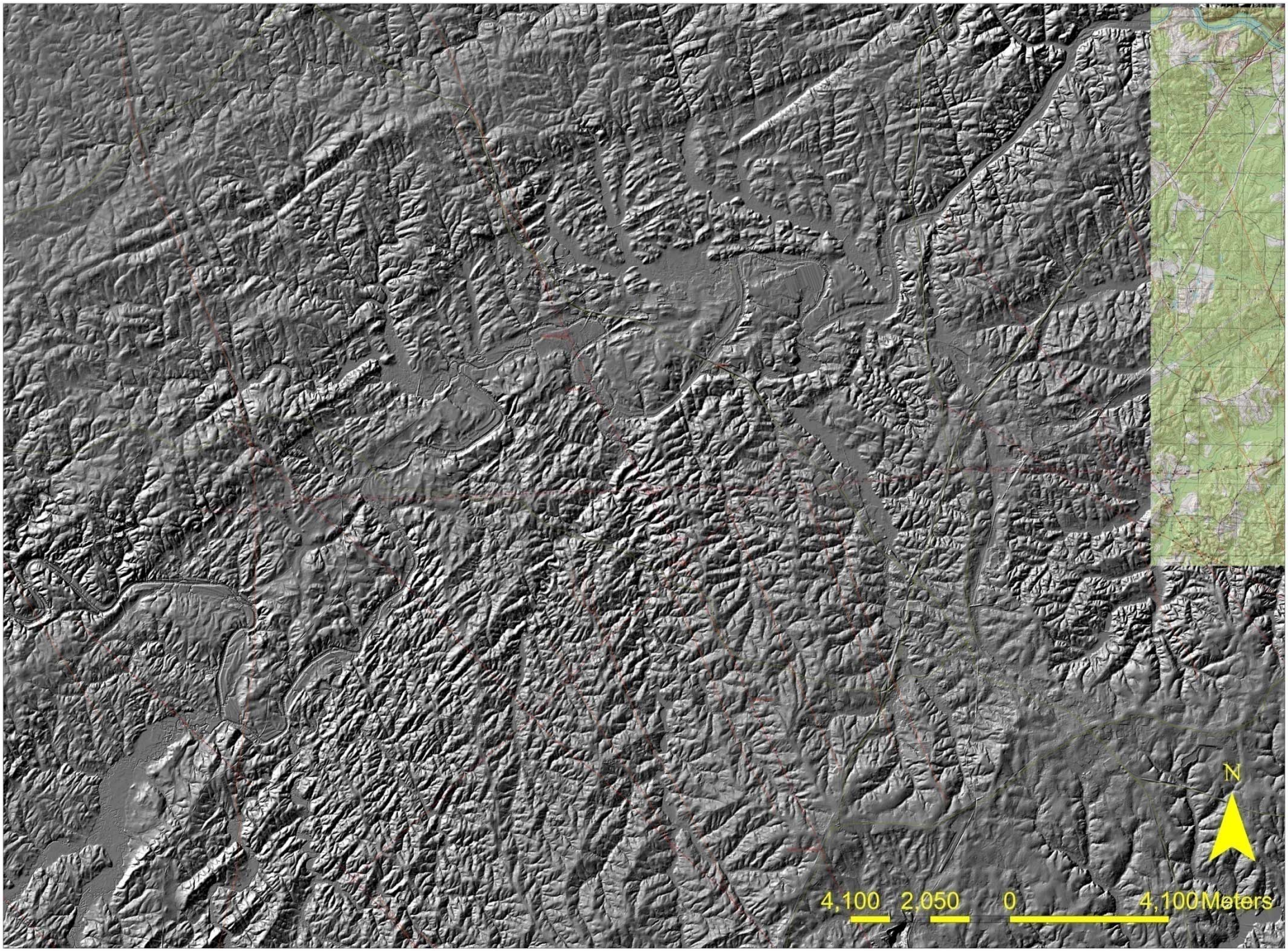
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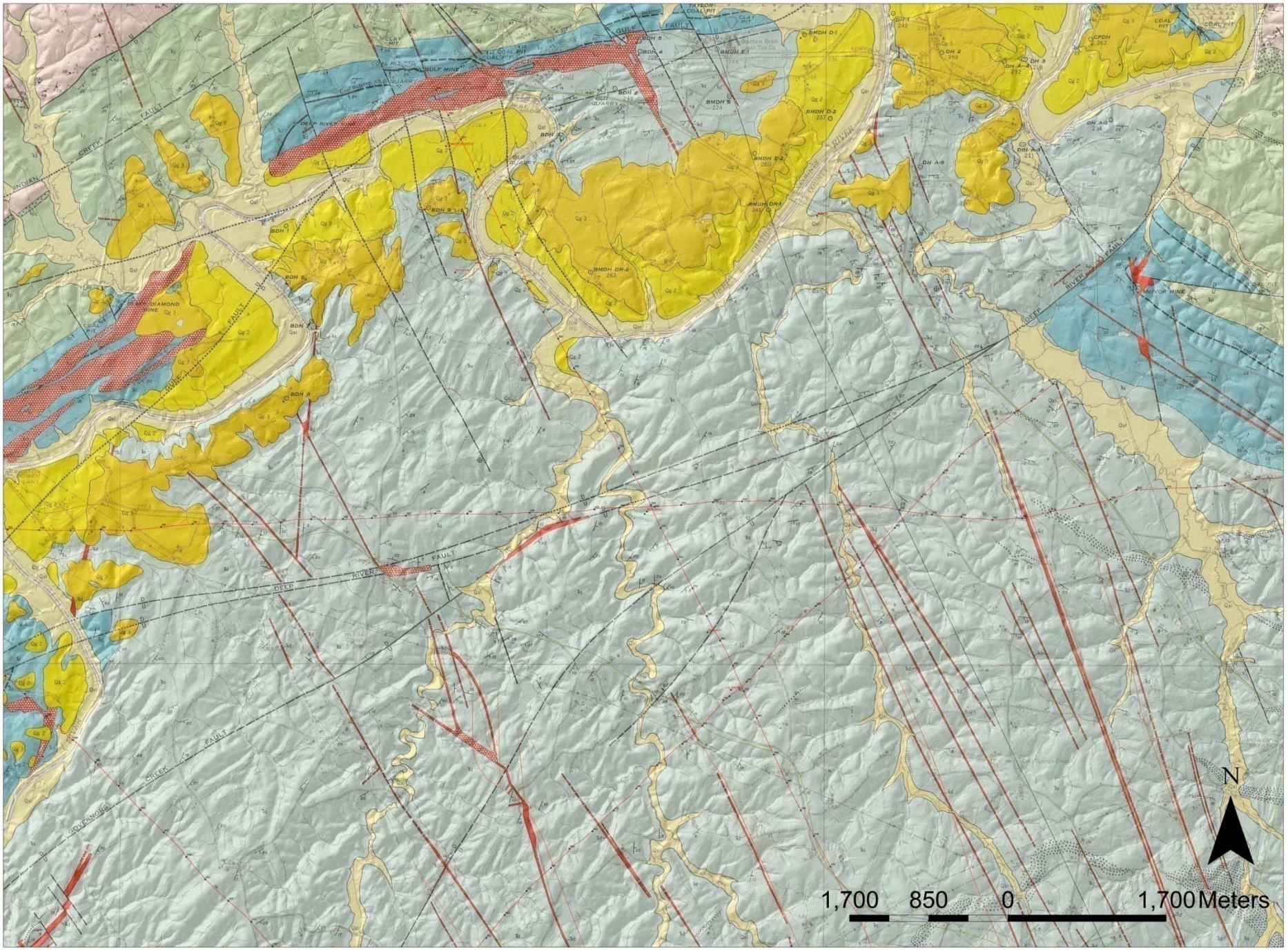
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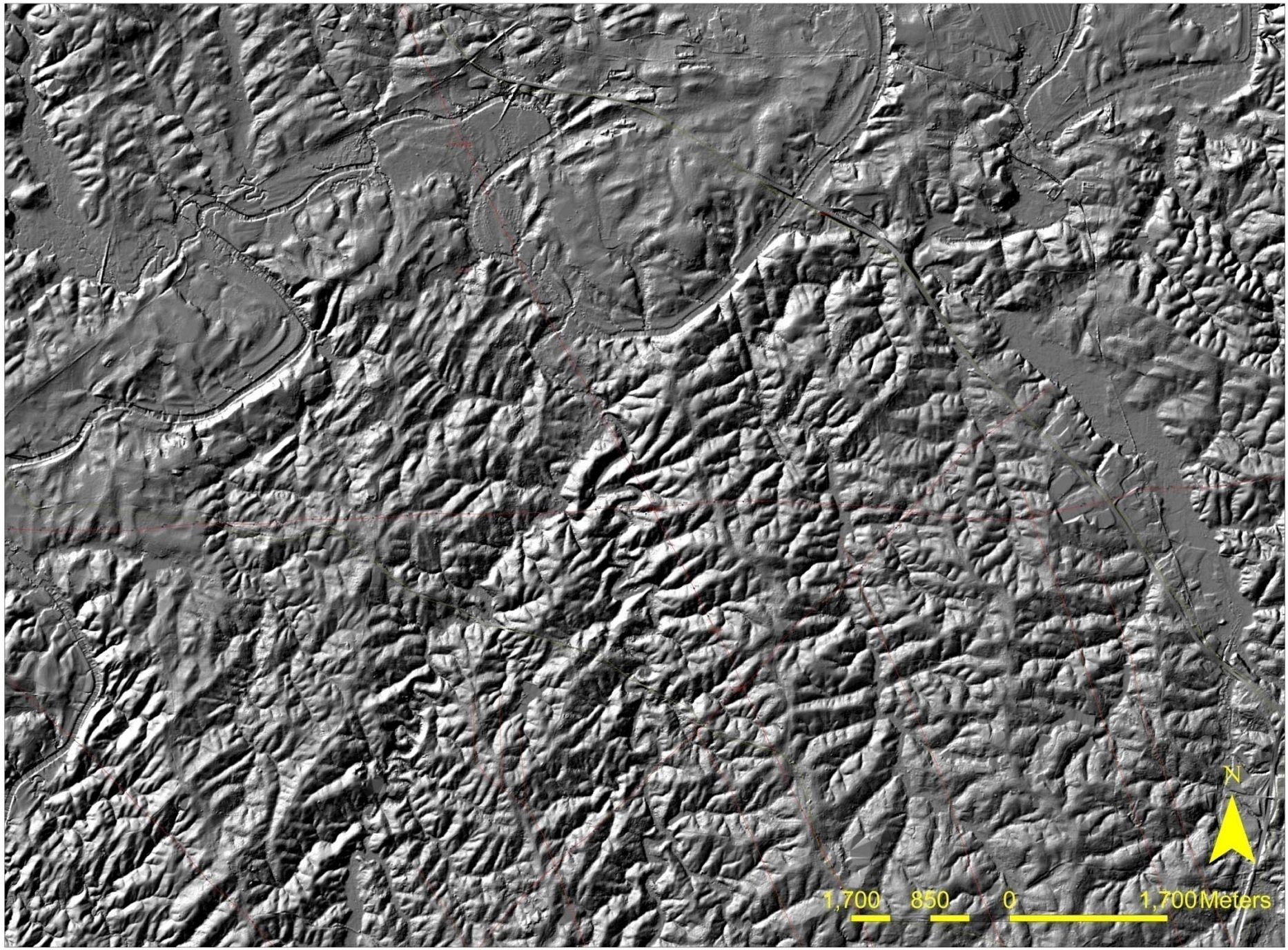
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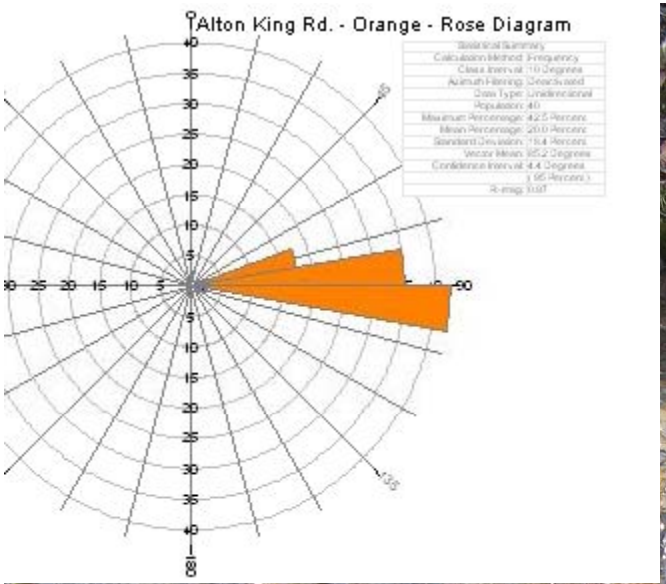
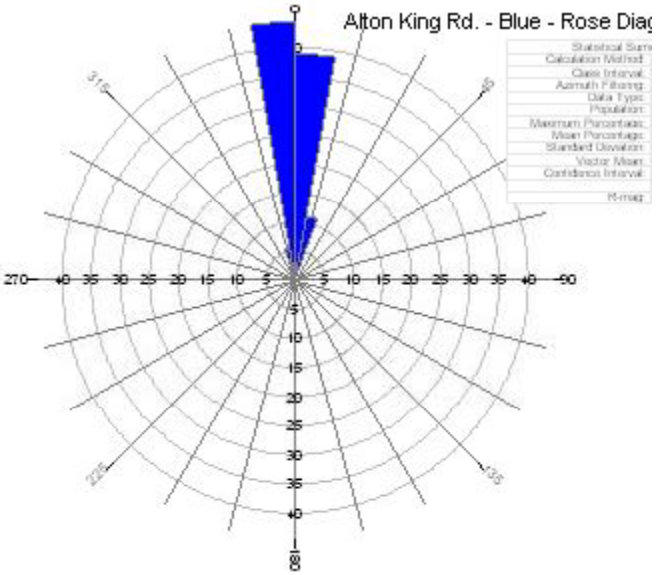

Alton King Rd. - Orange - Rose Diagram


Alton King Rd. - Blue - Rose Diag


North


CENTIMETRES
INCHES

Pekin Fm. (fractured) as seen in clay pit below Cumnock

Gas pressures + sampling
Butler #3 and Simpson #1 wells

- Formation “Petrophysical Report” (September 1998)
- Nine-month pressure test
- Pressures maintained over six months:
  - Butler #3 - Tbg (560 psi); Csg (1,100 psi)
  - Simpson #1 Tbg (1200 psi); Csg (640-680 psi)
  - Pressure holding when wells sampled and pressured, measured in March 2009

Butler #3 well – shut-in

Molecular, stable isotope and BTU results (C1 = methane)

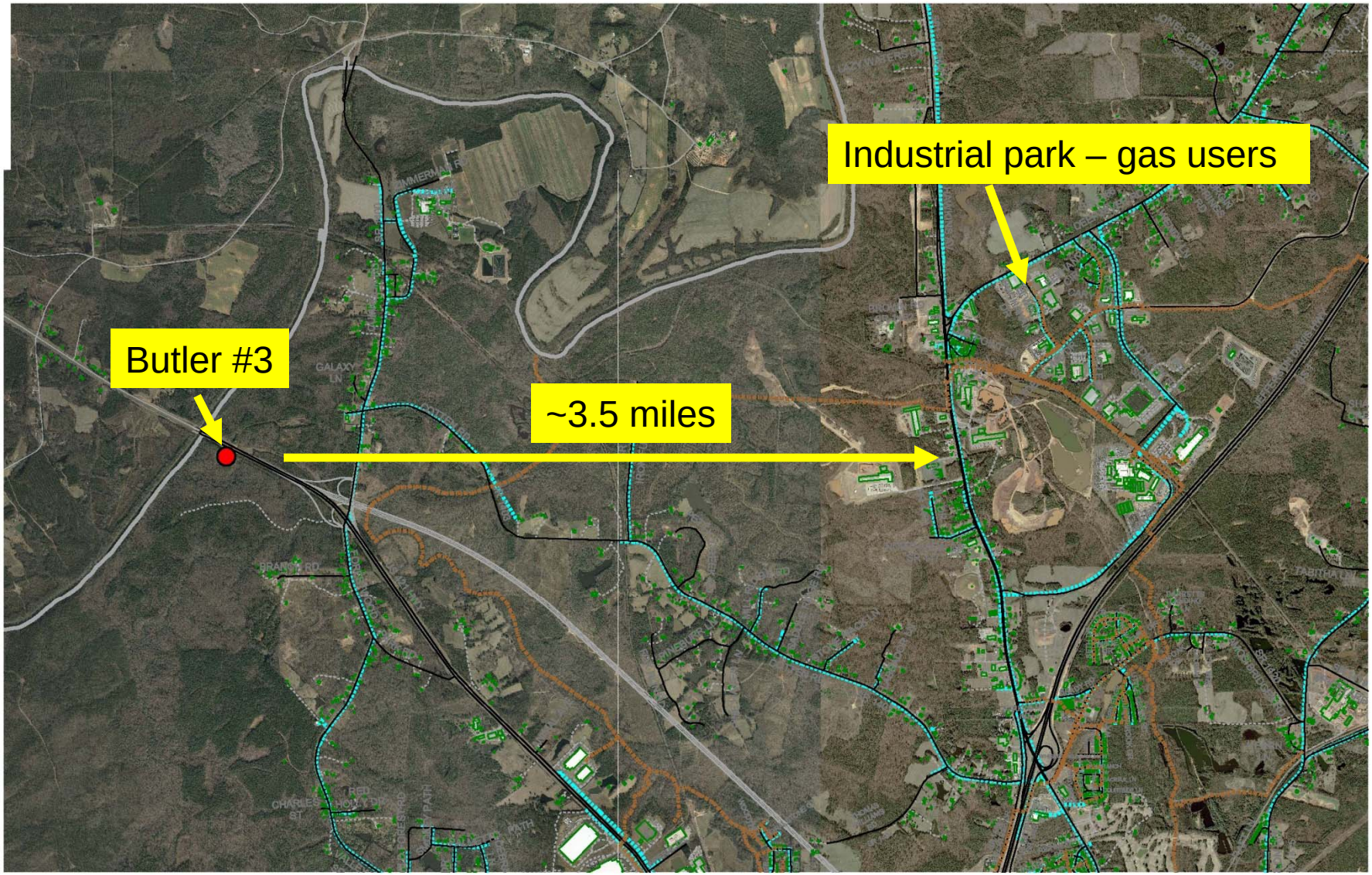
Well	PSI	C1 %	N2 %	CO2	C2H6	BTU (Dry)	Comment	Delta N Per mill	Delta C Per mill (C1)	Delta D Per mill (C1)
Butler #3 - 2009	900	48.78	45.60		3.86	605	Small amounts other gases	-3.32	-45.11	-178.5
Simpson #1 - 1998	640-680	70.074	29.603		0.117	712.920				
Simpson #1 - 2009	~250	51.65	45.49		1.89	577	Small amounts other gases	-3.23	-51.41	-174.8
Dummitt-Palmer #1 – 1991 - Cumnock		96.95	2.4	0.24	0.024	986.25				
Dummitt-Palmer #1 – 1991 – Gulf coal		96.40	3.05	0.16	0.27	976.45				
Dummitt-Palmer #1 – 1991 – Black shale		88.40	10.85	0.17	0.30	908.95				

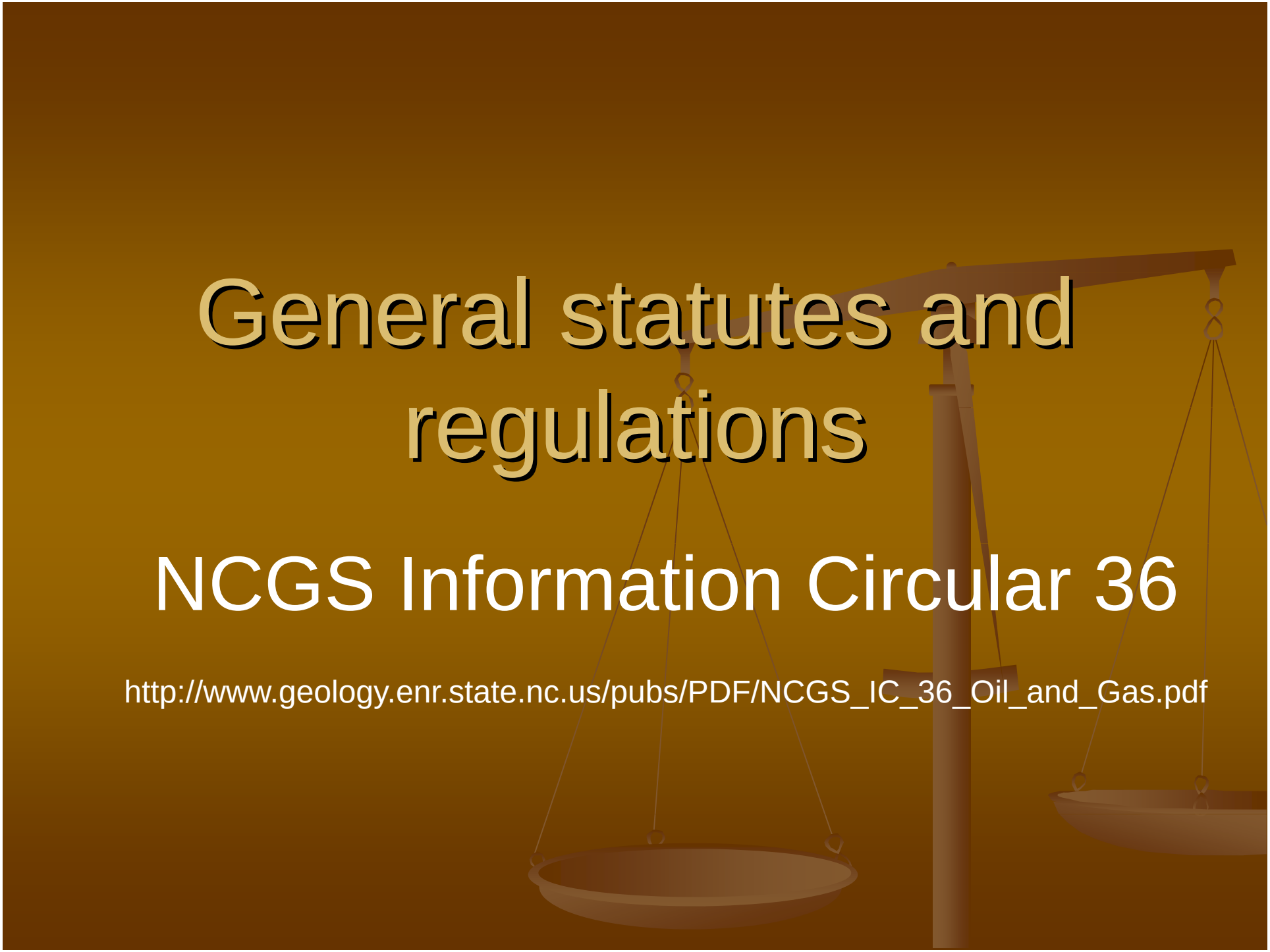
Note – Delta C and Delta D for light gases (ethane, propane, iso-pentane and N-butane along with specific gravity for 2009 analyses – not shown because of space)

Gas users near and new…

- Nearby Sanford Industrial Park
  - 3.5 miles from the nearest shut-in well (Butler #3), and
- Progress Energy announced a natural-gas fired plant and new pipeline to be constructed near Goldsboro, N.C. – about 85 miles east of Lee County. Plant would replace 3 aging coal-fired units in 2013.

Nearby gas users





General statutes and regulations

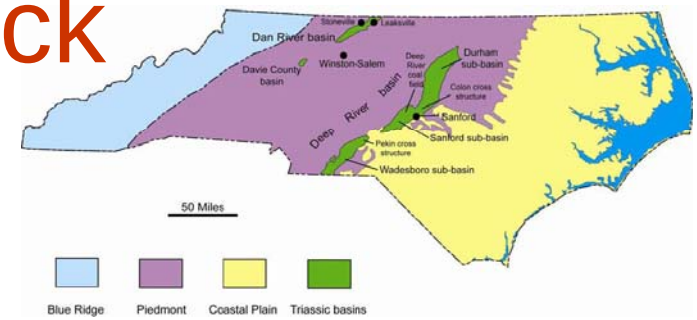
NCGS Information Circular 36

http://www.geology.enr.state.nc.us/pubs/PDF/NCGS_IC_36_Oil_and_Gas.pdf

NC Geological Survey Resources for Industry

- Drill core, logs and cuttings are available for examination in the NCGS repository (Raleigh, North Carolina) – loan agreements possible
- Limited covered thin sections available
- Our activities include: digitizing paper well logs (gamma, sonic, and neutron), seismic interpretation, additional organic geochemistry, core, and fracture studies, 3D seismic database, and field work.

Basin and Source Rock Summary



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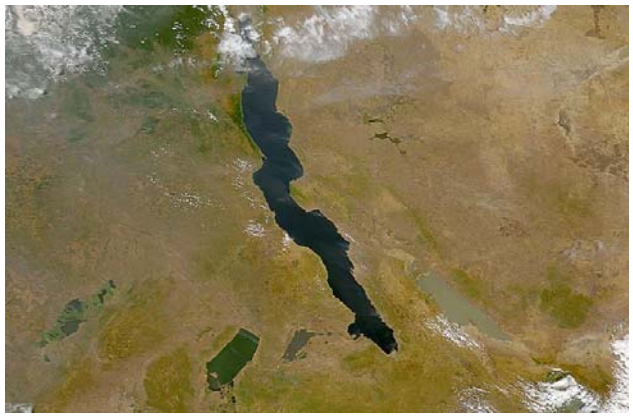
- Frontier exploration area



From left to right, Lakes Upemba, Mweru, Tanganyika and Rukwa – Image spans the SE corner of the Democratic Republic of the Congo, NE Zambia and southern Tanzania. Image courtesy of SEAWiFI, NASA/Goddard Space Flight Center and ORBIMAGE →

Contact information

- Dr. Jeffrey C. Reid

  North Carolina Geological Survey
  1612 Mail Service Center
  Raleigh, North Carolina 27699-1612
  Voice: 919.733.2423 x403
  Email: jeff.reid@ncdenr.gov, and

- Dr. Kenneth B. Taylor

  Same address
  Voice: 919.733.2423 x401
  Email: kenneth.b.taylor@ncdenr.gov