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PS Porosity, Permeability, and Pore Characterization of the Triassic Cumnock Formation: A Continuous Gas Assessment Unit, Sanford Sub-Basin, Deep River Basin, Lee County, North Carolina, USA, Part 2*

Jeffrey C. Reid[1], Kenneth B. Taylor[1], and Michael M. McGlue[2]

Search and Discovery Article #10662 (2014)
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*Adapted from poster presentation given at AAPG Eastern Section 43rd Annual Meeting, London, Ontario, Canada, September 27-30, 2014. See Part 1 of the article, Search and Discovery Article #10612 (2014)

[1]North Carolina Geological Survey, Raleigh, NC, USA (jeff.reid@ncdenr.gov)
[2]University of Kentucky, Lexington, KY, USA

Abstract

The Deep River basin is a continuous gas assessment unit (AU) and a total petroleum system (TPS). The Cumnock Formation source rocks are grey and black freshwater shales with thin basal coals. This formation is early Norian Age of 225-227Ma, and was deposited in a lacustrine rift near the paleo-equator after the onset of the breakup of Pangaea. The Deep River Basin Continuous Gas AU has an estimated mean gas content of 1,660 BCFG and an estimated mean natural gas liquids content of 83 MMBNGL (USGS Fact Sheet 2012 – 3075). The reservoir is being characterized using: 1) high pressure air / mercury infusion capillary pressure (MICP), 2) pore characterization using scanning electron microscopy (SEM) with argon-ion beam milled samples, 3) geomechanical analyses for triaxial shear, Poisson's ratio, Young's modulus accompanied by whole rock XRD mineralogy of core through the entire vertical extent of the „sweet spot" and basin center of the Cumnock Formation, and 4) light microscopy using ultrathin thin sections. Multiple porosity types were identified from argon-ion beam milled samples using SEM. Porosity types include: 1) intergranular (particularly between clay particles), 2) intragranular (especially in phosphate grains), 3) diagenetic growth of pyrite, and 4) pore development from the consumption of kerogen during hydrocarbon generation. Combinations of these porosity types were observed. The Cumnock Formation's average porosity in the "sweet spot" (drill hole CH-C-1-45) is 2.28%; the minimum is 0.44%, the maximum is 6.43%, and the standard deviation is 1.46%. The average permeability in the "sweet spot" (drill hole CH-C-1-45) is 1.75×10^{-5} md. The minimum is 0.090×10^{-5} md, the maximum is 7.11×10^{-5} md, and the standard deviation is 1.77×10^{-5}. Porosity near the basin center (V.R. Groce #1) averages 1.58%; the minimum is 0.24%; the maximum is 3.74%, and the standard deviation is 1.03%. Average permeability near the basin center is 1.61×10^{-5} md; the minimum is 0.05×10^{-5} md, the maximum is 6.68×10^{-5} md, and the standard deviation is 1.99×10^{-5} md. Molecular chemistry and stable isotopes of the gas from two shut-in wells have been obtained. Helium (~0.21%) is present in both wells. These data provide comprehensive, integrated and robust characteristics of one continuous gas reservoir of the Triassic continental rift / lacustrine basins in North Carolina.

Porosity, permeability, and pore characterization of the Triassic Cumnock Formation: A continuous gas assessment unit, Sanford sub-basin, Deep River basin, Lee County, North Carolina, USA

by Jeffrey C. Reid*, Kenneth B. Taylor*, Michael M. McGlue**

* North Carolina Geological Survey, **University of Kentucky, Lexington

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The Deep River basin is a continuous gas assessment unit (AU) and a total petroleum system. The Cumnock Formation source rocks are grey and black freshwater shales with thin basal coals. The Cumnock Formation (early Norian Age of 225-227Ma) was deposited in a lacustrine rift near the paleo-equator after the onset of the breakup of Pangea. The Deep River Basin Continuous Gas AU has an estimated mean gas content of 1,660 BCFG and an estimated mean natural gas liquids content of 83 MMBNGL (USGS Fact Sheet 2012 - 3075).

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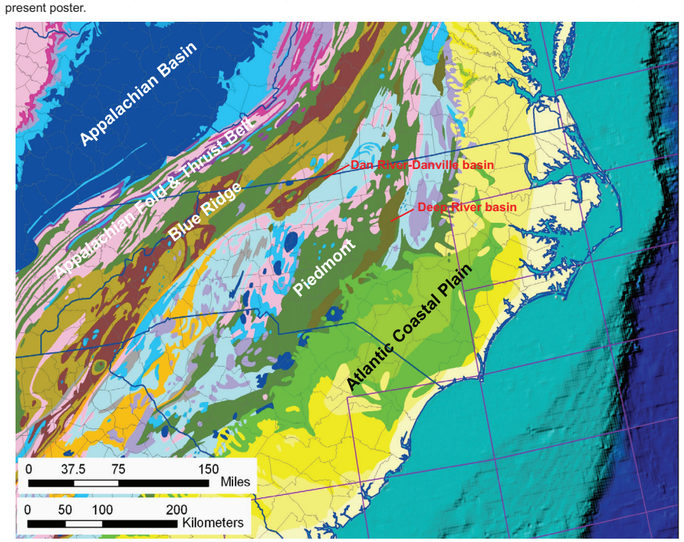
The Cumnock Formation's average porosity in the "sweet spot" (drill hole CH-C-1-45) is 2.28%; the minimum is 0.44%, the maximum is 6.43%, and the standard deviation is 1.46%. The average permeability in the "sweet spot" (drill hole CH-C-1-45) is 1.75 x 10-5 md. The minimum is 0.090 x 10-5 md, the maximum is 7.11 x 10-5 md, and the standard deviation is 1.77 x 10-5. Porosity near the basin center (V.R. Groce #1) averages 1.58%; the minimum is 0.24%; the maximum is 3.74%, and the standard deviation is 1.03%. Average permeability near the basin center is 1.61 x 10-5 md; the minimum is 0.05 x 10-5md, the maximum is 6.68 x 10-5 md, and the standard deviation is 1.99 x 10-5 md.

Molecular chemistry and stable isotopes of the gas from two shut-in wells have been obtained. Helium (~0.21%) is present in both wells. These data provide comprehensive, integrated and robust characteristics of one continuous gas reservoir of the Triassic continental rift / lacustrine basins in North Carolina.

Special note: This is a companion poster to AAPG 'Search and Discovery' contribution #1841705 by Reid and others (2014). That poster contains SEM pore images and additional mineralogy data from the Cumnock Formation. It should be viewed in conjunction with the present poster.

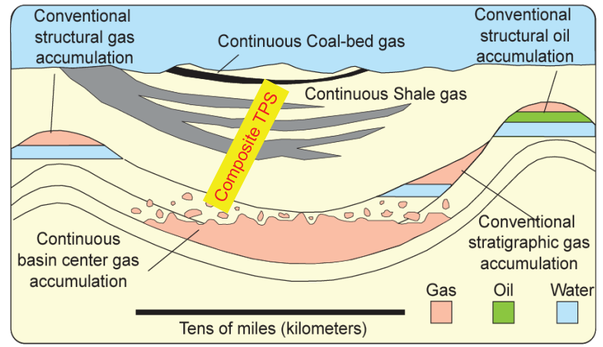


The geology of eastern North Carolina consists of a relatively thin to increasingly thick veneer of coastal plain sediments and sedimentary rocks of the Atlantic Coastal Plain, which range in age from Upper Jurassic(?) to Recent. These strata overlie a complex folded and faulted geology of metaigneous and metasedimentary rocks of Early Paleozoic to Late Proterozoic age, which in turn are punctuated in places by narrow Late Triassic(?) to Early Jurassic(?) rift basins. The stratigraphic geology of the Atlantic Coastal Plain section is composed of Mesozoic and Cenozoic siliciclastic and carbonate sedimentary rocks. This coastal plain has a relatively simple structural geology, with few faults and structures, other than those associated with the rift basins.

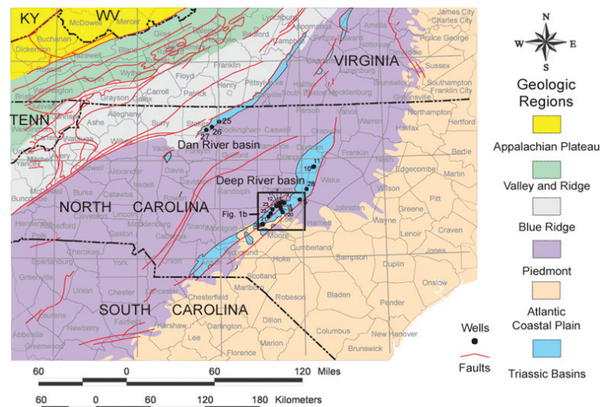
Identified and possible Triassic - Jurassic rift basins are not present in easternmost North Carolina based on drilling, seismic, and potential fields geophysical information. A hypothesized and undrilled Triassic-Jurassic rift basin (Cumberland-Marlboro basin) may be present beneath a thin coastal plain veneer. The basin is recognized by a large aeromagnetic low located parallel to, and seaward of the Deep River basin. (modified and adapted from Schruben and others, 1998).

Acknowledgements: The authors thank Ms. Katherine J. Marciniak, Mr. Walter T. Haven, and Mr. Ryan A. Channell for assisting with field work and sampling, and also with core sampling. Their assistance and fellowship is much appreciated.

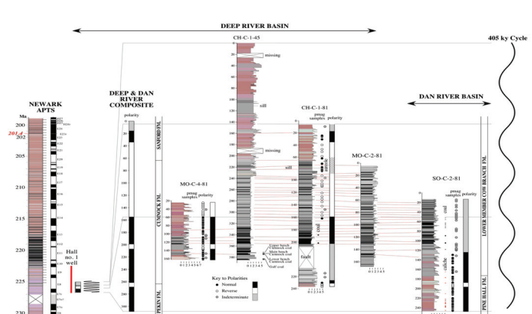
PANEL #1 - Overview and setting



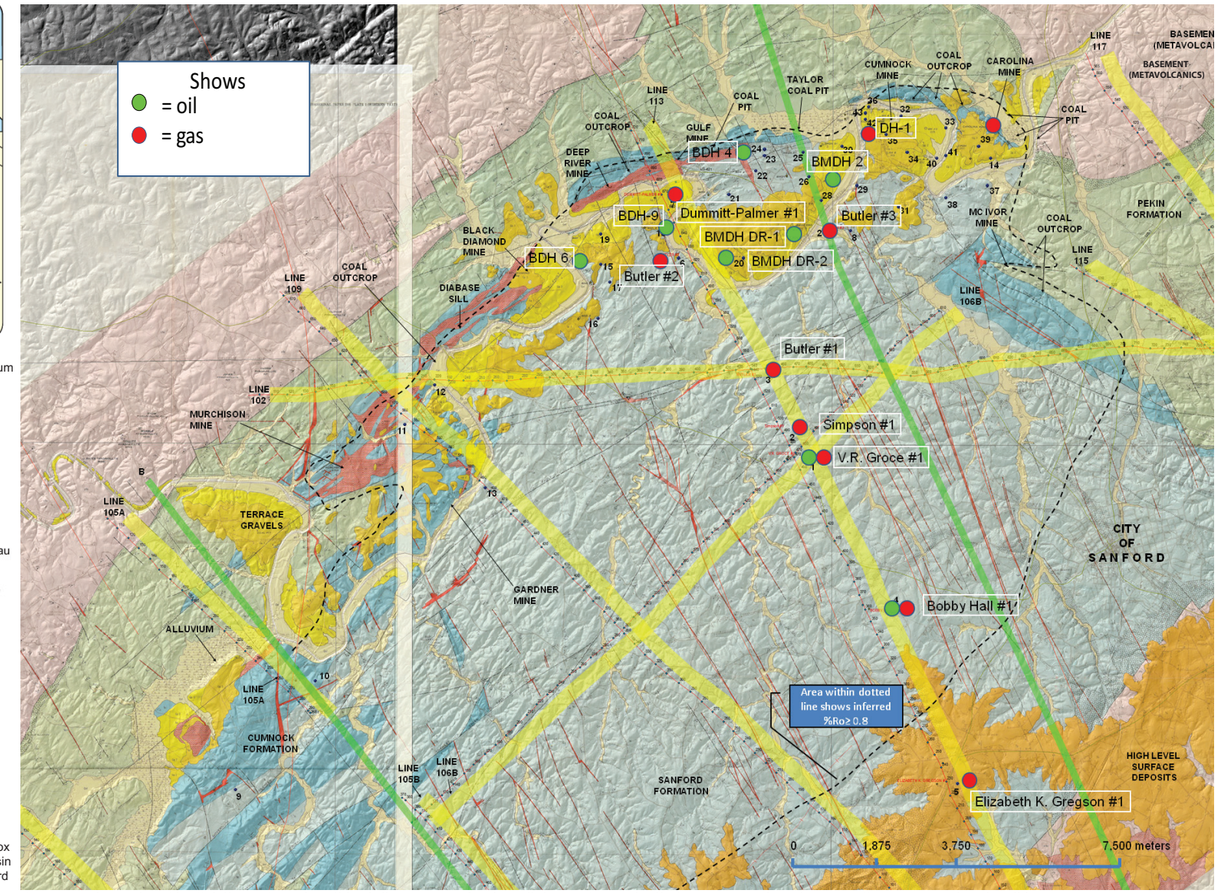
Geologic setting of continuous gas and oil accumulations relative to discrete accumulations in structural or stratigraphic traps (modified and adapted from Schmoker and others, 1995).The elements of a total petroleum system (TPS) shown in this diagram are present in both the Deep River and Dan River-Danville basins.



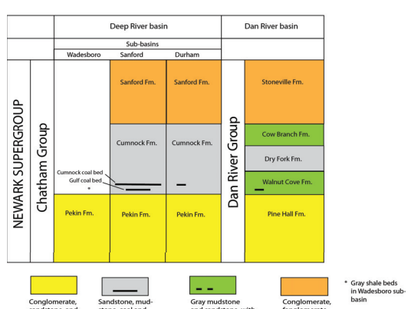
Location of the Deep River basin composite TPS (central North Carolina) and the Dan River-Danville basin composite TPS (north central North Carolina and south central Virginia). From Reid and Milici, 2008. The box in the central part of the Deep River basin is the location of the Sanford sub-basin. The Wadesboro sub-basin is located southwest of the Sanford sub-basin, and the Durham sub-basin is located northeast of the Sanford sub-basin.



Above -- Shows the correlation of drill hole CH-C-1-45 (USBM DH2) with cores from the Sanford sub-basin of the Deep River basin and the Dan River-Danville basin. Correlation prepared by P.E. Olson using magnetic polarities (adapted from Fig. 26 in Reid and others, 2011).



Map showing the location of the V.R. Groce #1 well, the USBM DH2 drill hole, and the Dummitt-Palmer #1 well in the Sanford sub-basin, Deep River basin. Yellow lines denote vintage 2D seismic lines. Green lines are cross section lines in Reinemund. Unlabled map area that is pink or uncolored is metavolcanic Paleozoic bedrock (adapted from Reid and others, 2010).



Stratigraphy - Deep River stratigraphy from Reinemund, 1955.
Dan River basin stratigraphy from Olsen, Reid, Taylor and Kent, 2014.

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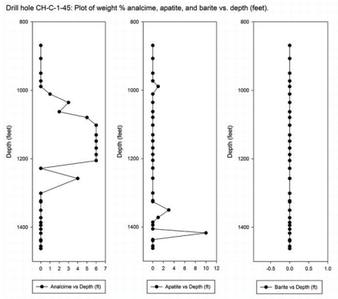
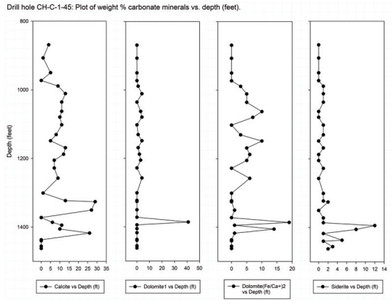
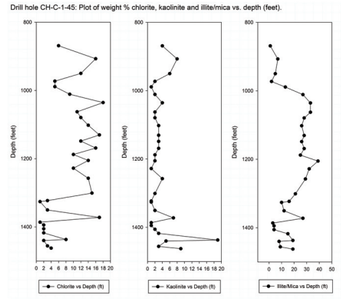
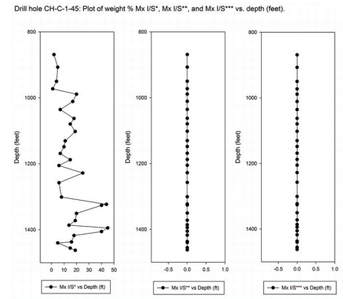
Down hole whole rock mineralogy by XRD

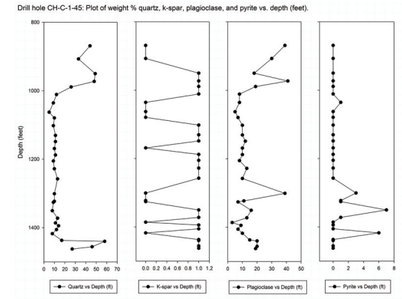
"Sweet spot" - Drill hole CH-C-01-45 (USBM DH2)

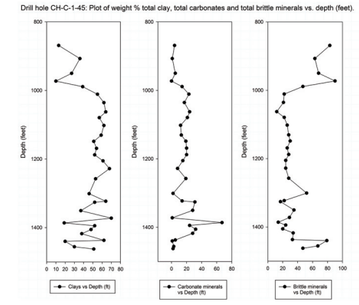




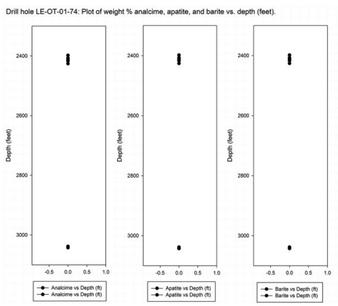


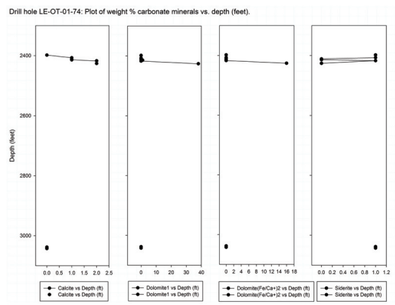


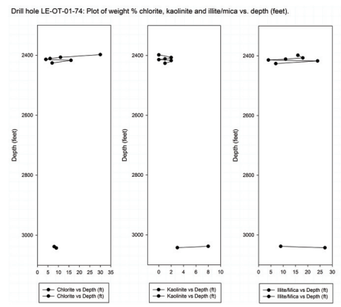


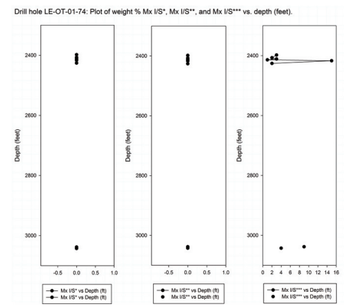


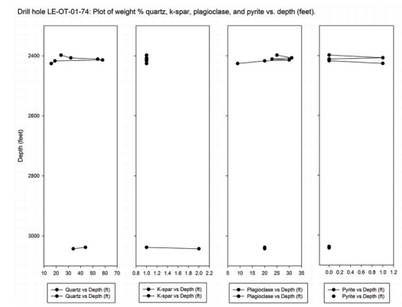
Basin center - Well LE-OT-01-74 (V.R. Groce #1)

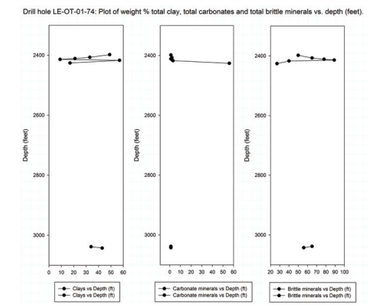




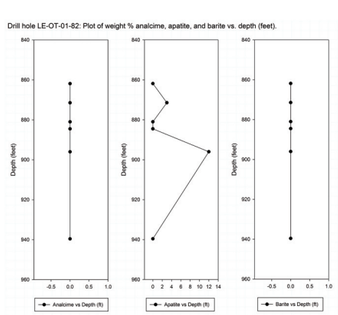


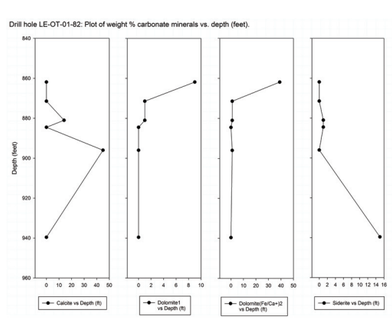


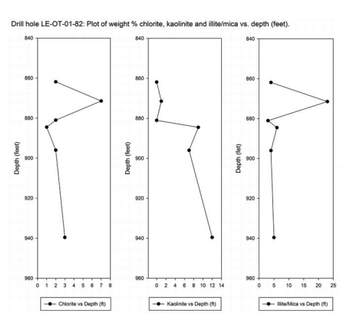


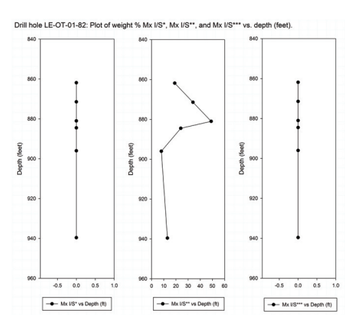


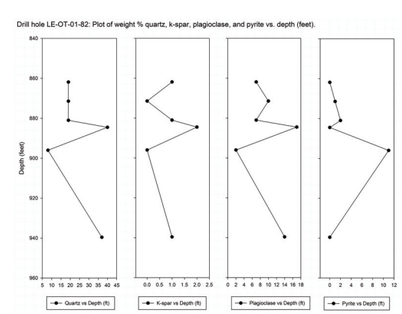
Coal bed methane (CBM) - Drill hole LE-OT-01-82 (Dummitt Palmer #1)

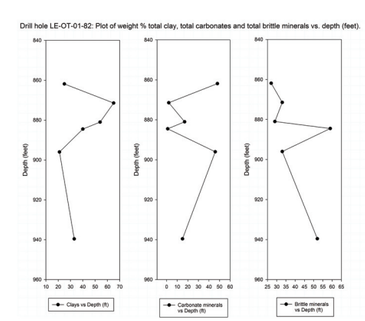












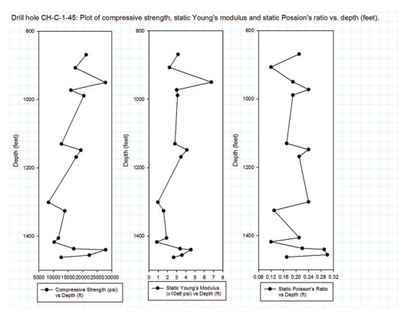
PANEL #2 - Down hole whole rock mineralogy by XRD

Porosity, permeability, and pore characterization of the Triassic Cumnock Formation: A continuous gas assessment unit, Sanford sub-basin, Deep River basin, Lee County, North Carolina, USA

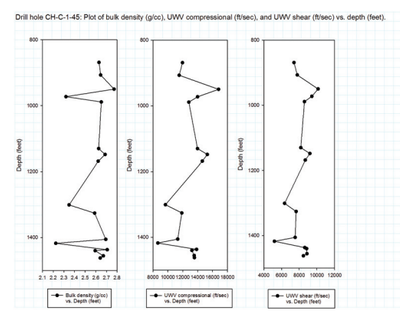
Rock mechanics data (static and dynamic) Poisson's ratio vs. Young's modulus, mineralogy and porosity-permeability summaries, and TOC and % porosity vs. depth (feet)

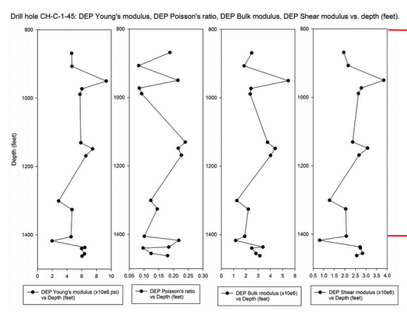
"Sweet spot" - Drill hole CH-C-01-45 (USBM DH2)

Static data

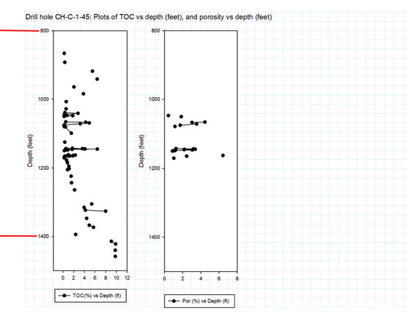


Dynamic data



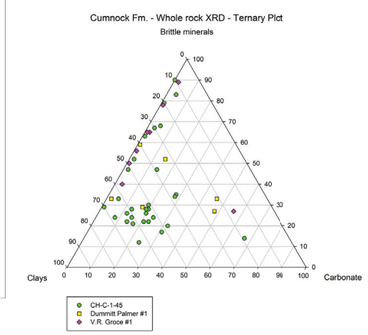


TOC and % Porosity vs. depth (feet)

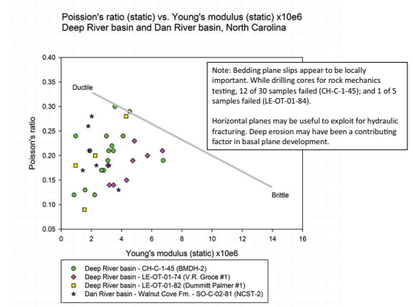


Note vertical scale change

Mineralogy summary - % Whole rock XRD

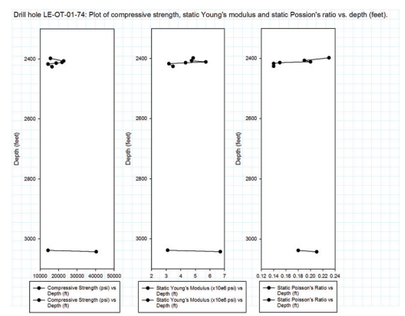


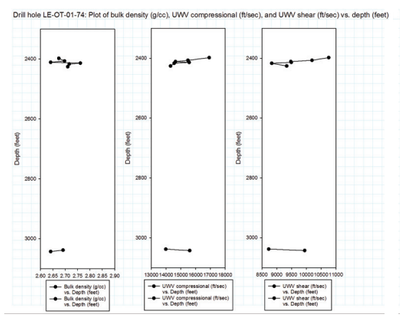
Poisson's ratio vs. Young's modulus plots

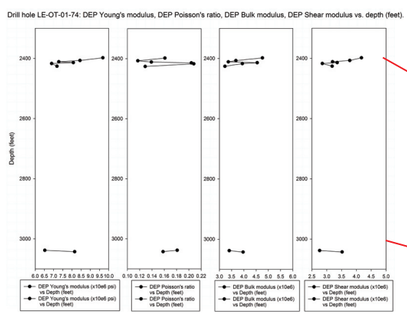


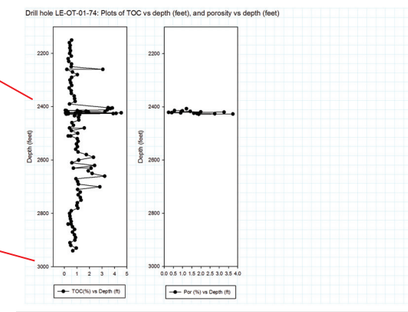
Static data

Basin center - Well LE-OT-01-74 (V.R. Groce #1)



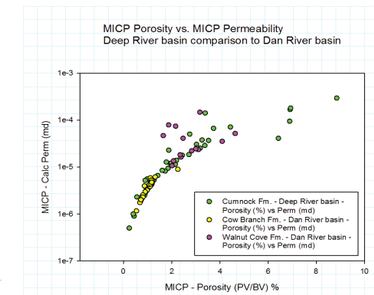


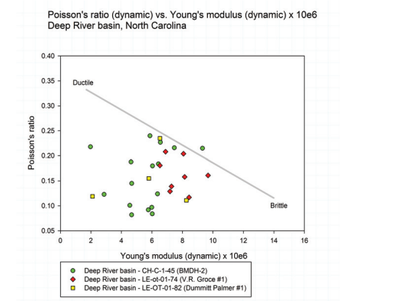




Note vertical scale change

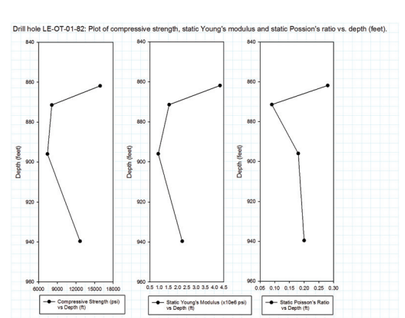
Porosity - permeability summary

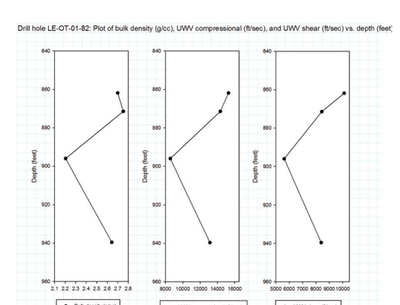


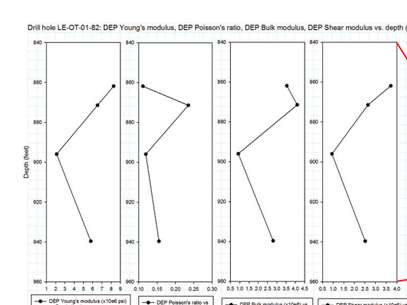


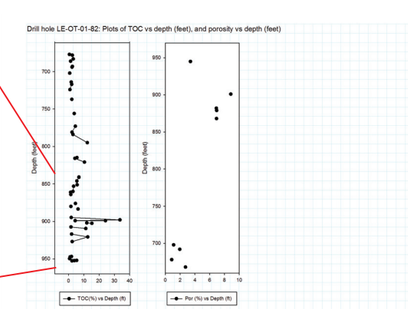
Dynamic data

Coal bed methane (CBM) - Drill hole LE-OT-01-82 (Dummitt Palmer #1)

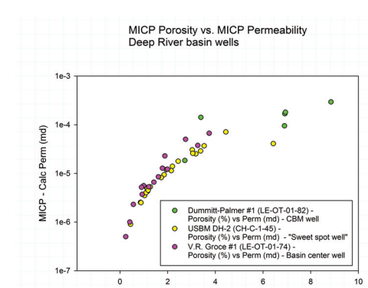






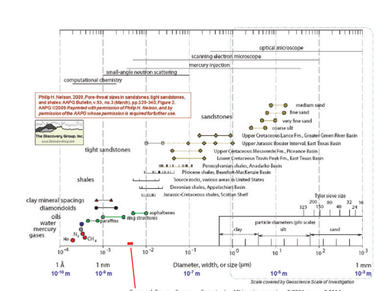


Note vertical scale change



Rock mechanics notes:
Note 1: Confining pressure was 800psi.
Note 2: Ultrasonic wave velocity = UWV.
Note 3: Dynamic elastic parameters = DEP.

Pore diameter range



PANEL #3 - Rock mechanics data (static and dynamic), porosity and permeability by high pressure mercury infusion, Poisson's ratio vs. Young's modulus and pore diameters.