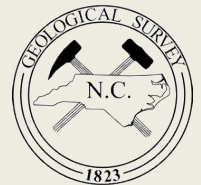
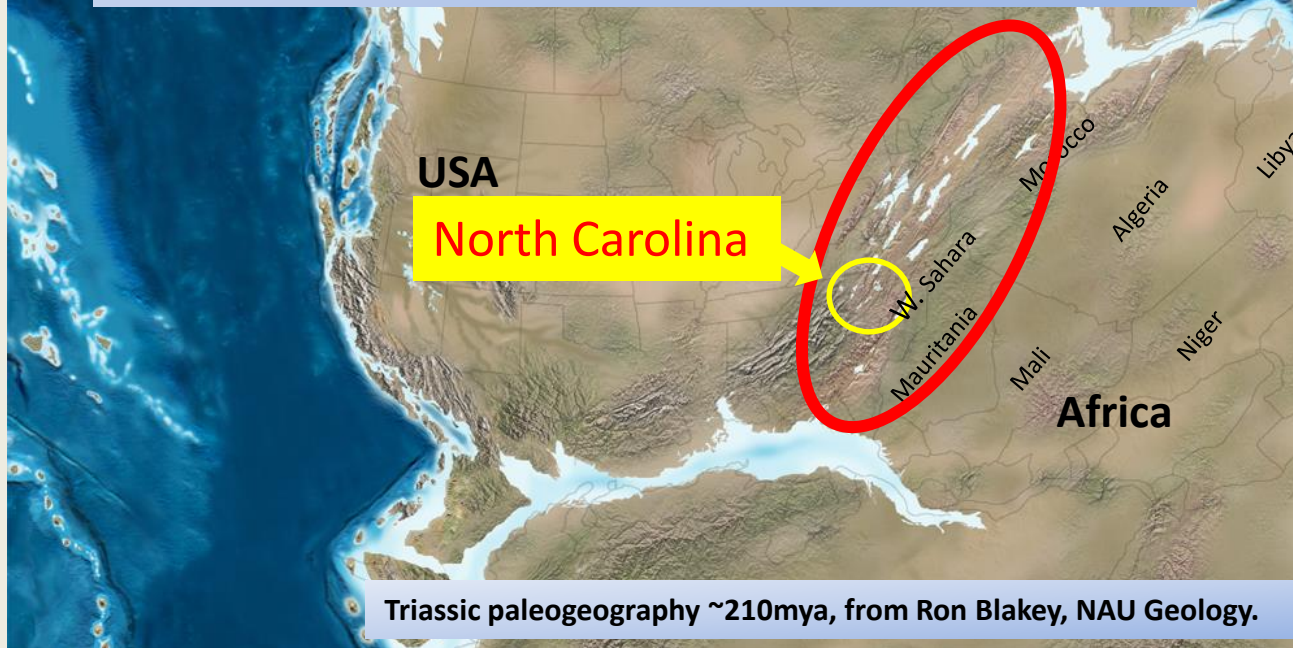


Triassic rift / lacustrine oil and gas in North Carolina and south-central Virginia: An unexplored US East Coast fairway

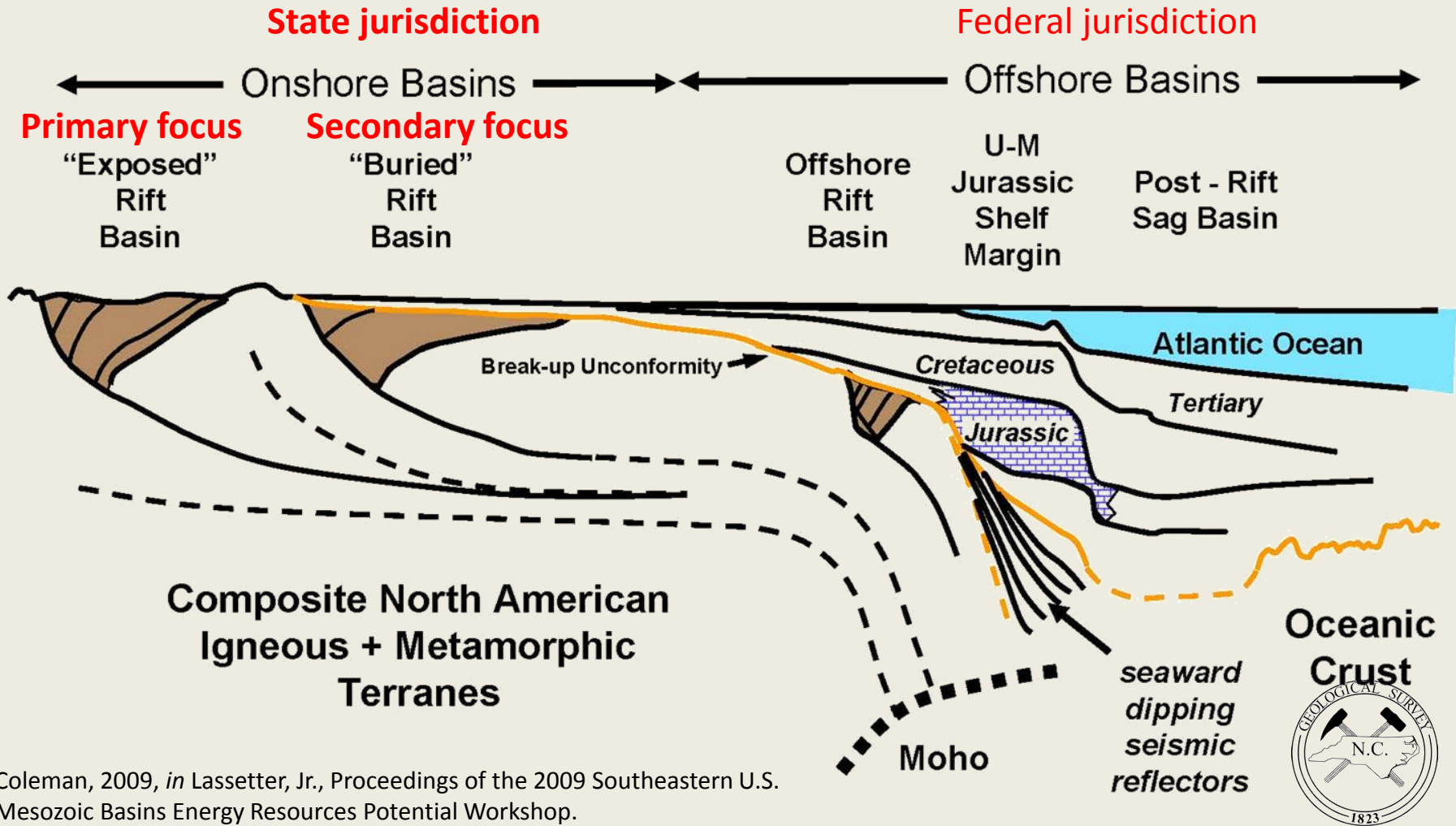


North Carolina (NC) - Overview

- NC is a highly technical and modern society right in the heart of the U.S. East Coast.
- NC is in the middle of a major unexplored rift / lacustrine oil and gas fairway stretching from Florida to NJ and until now, virtually no one has realized it.
- NC is right next to the NY market and can economically access the Marcellus generated oil field service industry in Appalachian basin.
- NC has spent a lot of time and effort getting the “social license” to drill and frack straightened out.

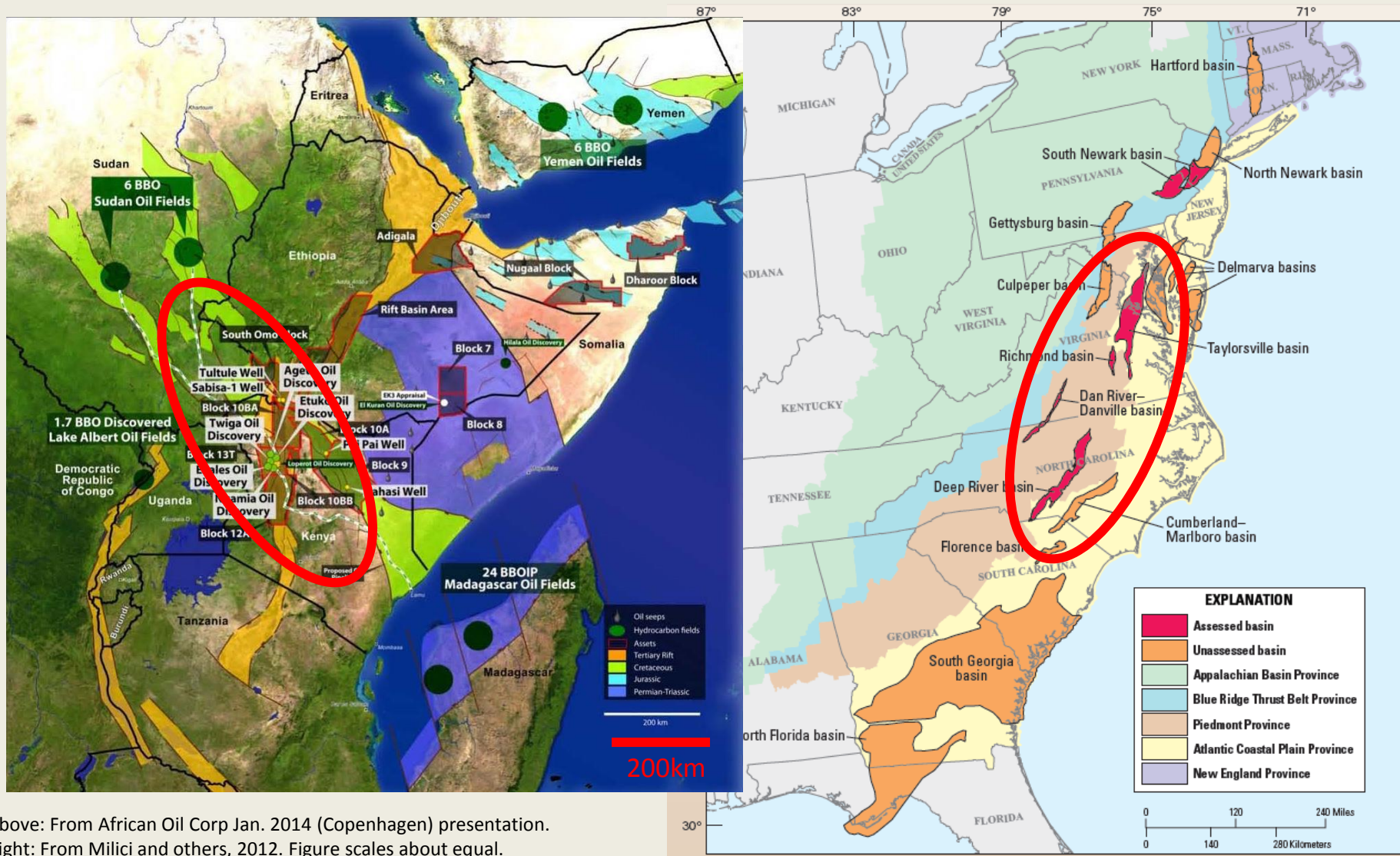


U. S. Atlantic Mesozoic Basin Types



Coleman, 2009, in Lassetter, Jr., Proceedings of the 2009 Southeastern U.S. Mesozoic Basins Energy Resources Potential Workshop.

East Africa rift size compared to Eastern U.S. Mesozoic basins



Above: From African Oil Corp Jan. 2014 (Copenhagen) presentation.
 Right: From Milici and others, 2012. Figure scales about equal.

Estimated technically recoverable resources (ETRR): N.C. and VA results (Milici and others, 2012)

Deep River basin AU:

Gas (BCFG)				NGL (MMBNGL)			
F95	F50	F5	M*	F95	F50	F5	M*
779	1,527	2,990	1,660	35	75	158	83

Dan River – Danville basin AU:

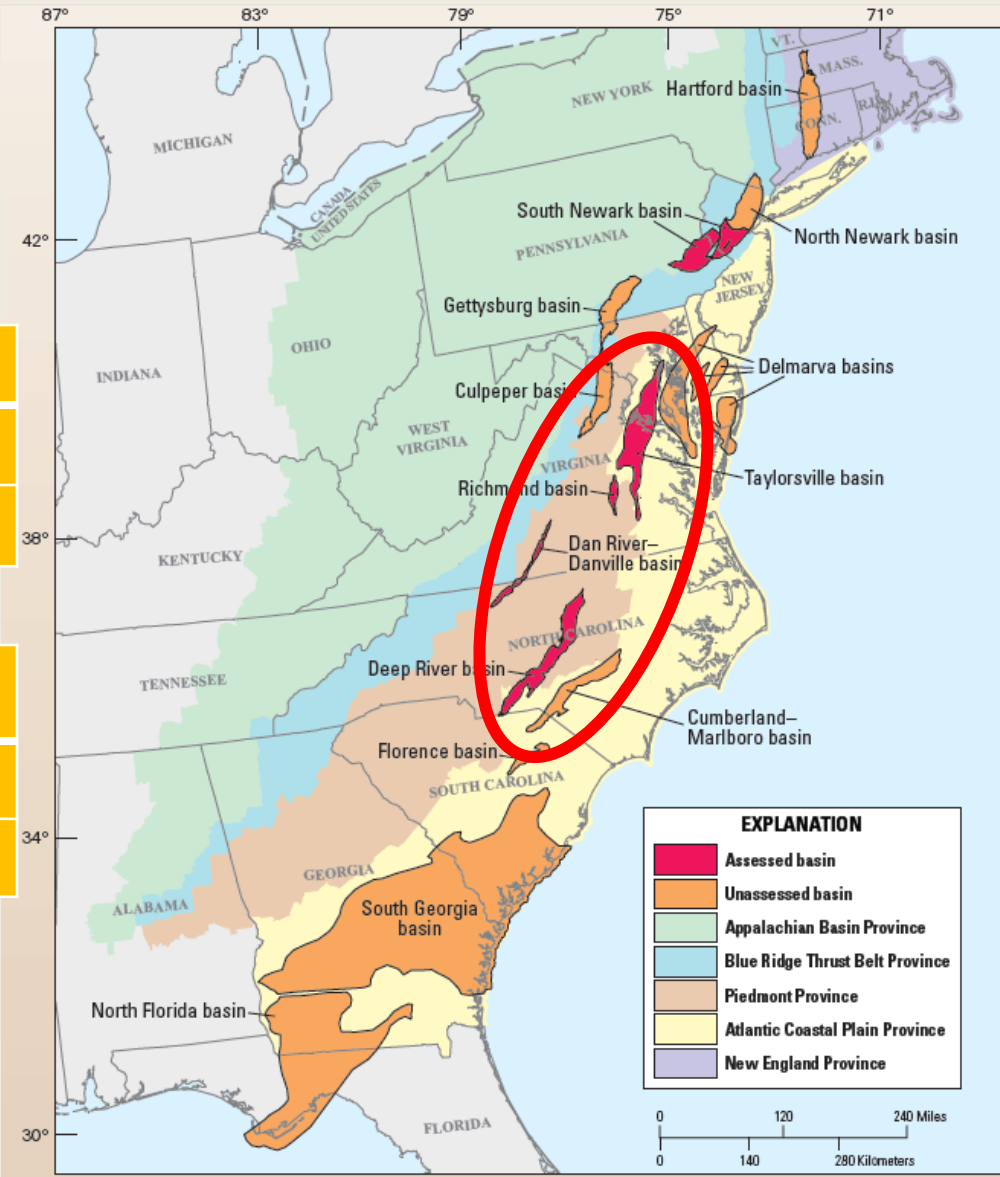
Gas (BCFG)				NGL (MMBNGL)			
F95	F50	F5	M*	F95	F50	F5	M*
17	42	106	49	0	0	1	0

Cumberland-Marlboro AU:

- Not assessed
- Aeromagnetic anomaly to be drilled by the NC Geological Survey

Note 1: M* = Mean

Note 2: Mean of 3.86 TCF for all East Coast Mesozoic basins; Deep River basin ~ 40% of the ETRR.



East Coast USA Mesozoic basins:

Common characteristics

- **Basin evolution:**

- Formed: along the continental margin from regional uplift, extension (deep rifting), and crustal thinning from the early Atlantic opening.
- Rifting: started about 227 mya – Middle Triassic – Carnian time.
- Basin fill (fluvial to lacustrine environments): boulder beds, coarse-grained fluvial to deltaic sandstones, red siltstone, mudstones, gray and black shales.
- Rifting ended: in Jurassic accompanied by regional volcanism and intrusion of diabase dikes and sills (CAMP).

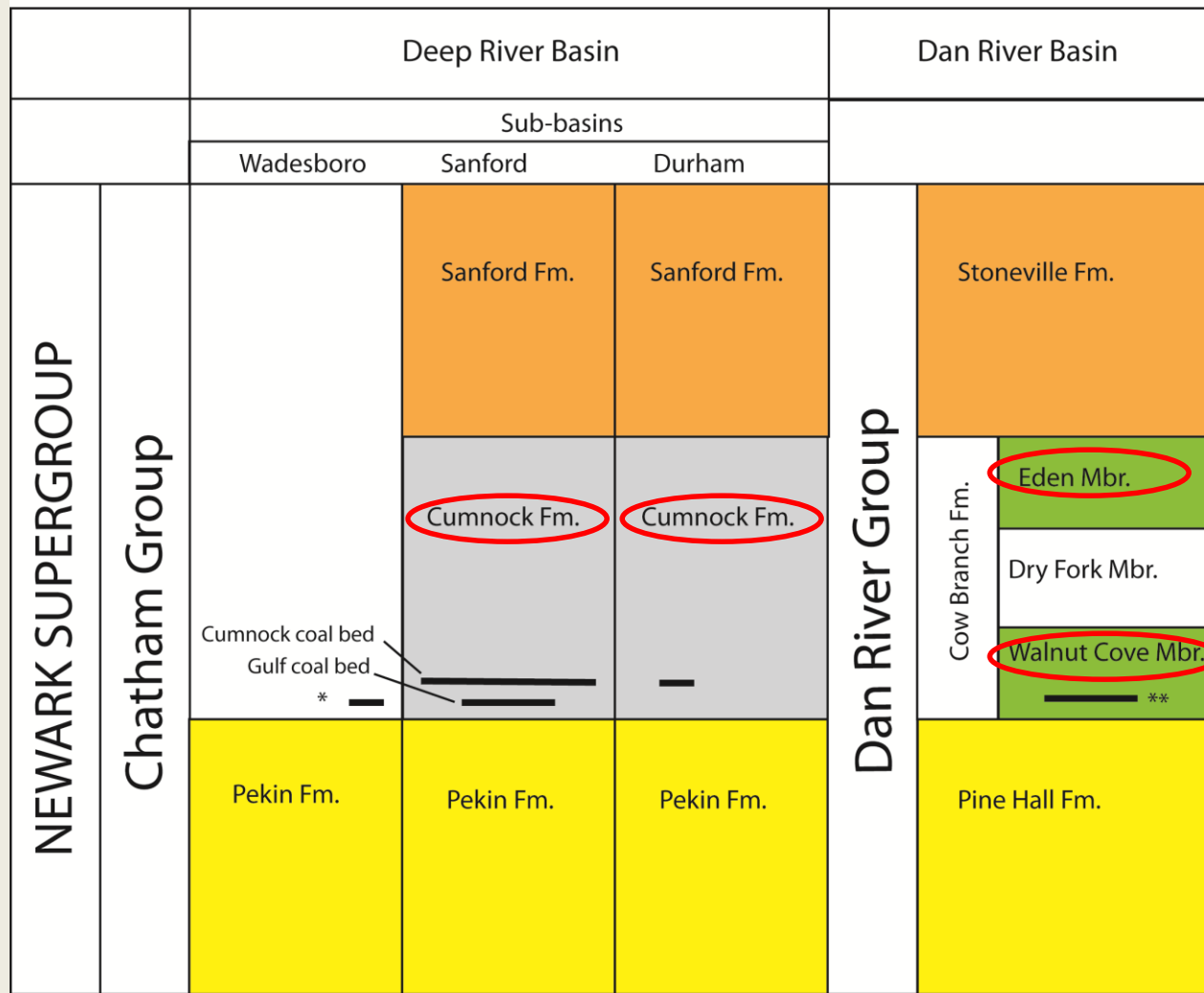
- **Hydrocarbon potential:**

- Source rocks: gray and black shales and coal beds.
- Kerogen: derived from vascular plants and algae => gas and oil.
- Thermal maturation: Wide range from immature to dry gas.
- Potential reservoirs: Continuous accumulations in wide range of lithologies (boulder conglomerates, very coarse sandstones to mudstone, shale and coal).
- Seals (potentially): shale beds interbedded with coarser strata.



Adapted from Milici and others, 2012, and NCGS contributions

Triassic stratigraphy and lacustrine strata (gray and green colors)



** Very thin coal in North Carolina only



Conglomerate, sandstone, and mudstone



Sandstone, mudstone, coal and carbonaceous shale



Gray mudstone and sandstone, with thin coal beds



Conglomerate, fanglomerate, sandstone, and mudstone

* Gray shale beds in Wadesboro sub-basin



Cumnock Fm. - TOC / Potential source /reservoir rock

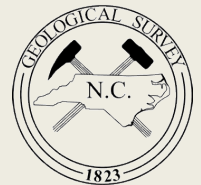


** TOC Sanford sub-basin,
Deep River basin = 1.96%, N =
353.

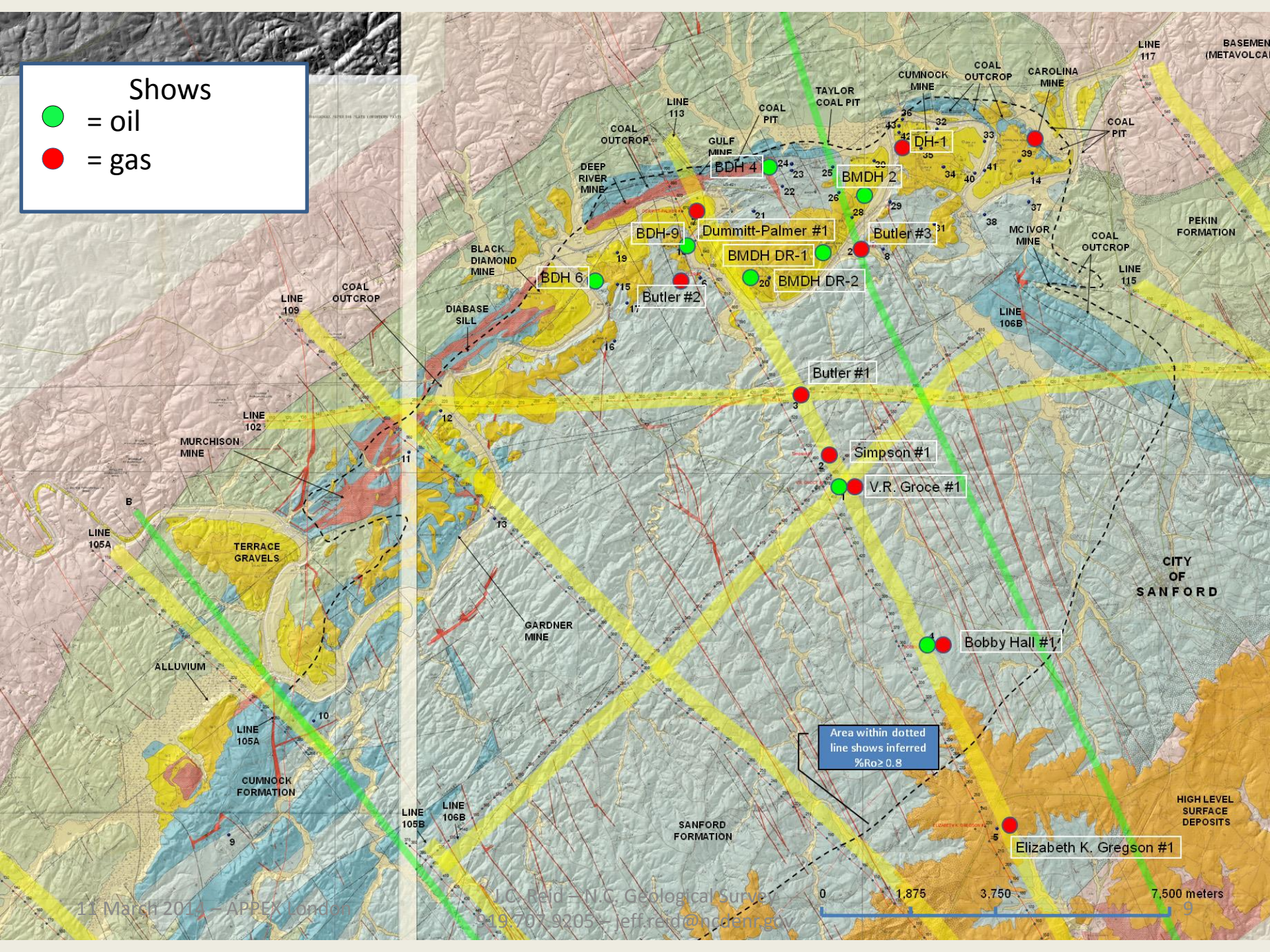
** TOC Cow Branch Mbr. =
3.55%, N = 122; Eden Mbr. =
1.38%, N=42 – Dan River-
Danville basin.

← Drill Hole : BMDH 2
NCGS No.: CH-C-1-45
Box No. : 118
From : 1423 feet
to 1440 feet

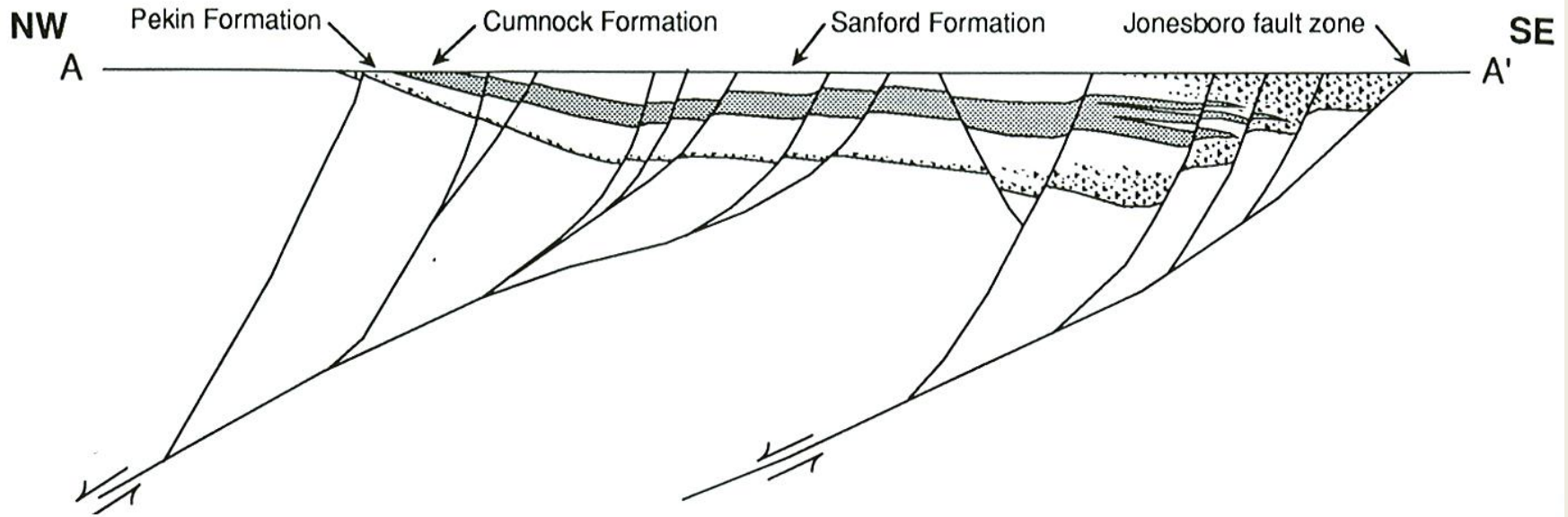
← Drill Hole : BMDH 2
NCGS No.: CH-C-1-45
Box No. : 119
From : 1440 feet
to 1449 feet



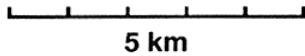
Shows
 ● = oil
 ● = gas

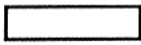





SANFORD SUB-BASIN OF THE DEEP RIVER BASIN



vertical scale = horizontal scale

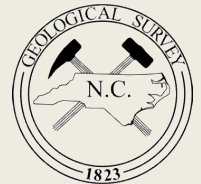


-  Mostly fluvial, red and brown clastic rocks
-  Lacustrine gray and black fine-grained clastic rocks
-  Red, brown, and gray conglomerate and sandstone
-  Major normal faults

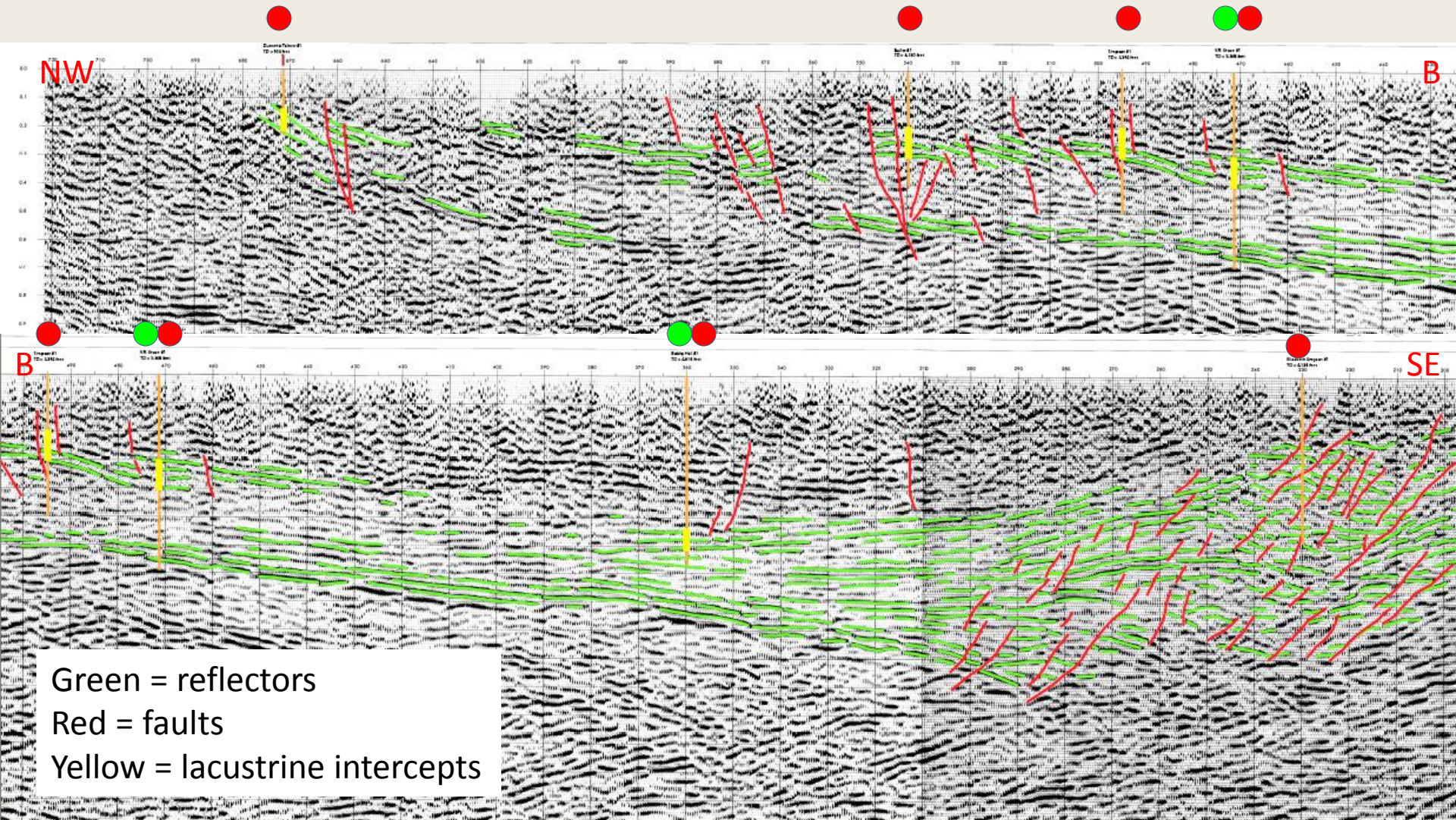


Generalized lithologies and stratigraphy.

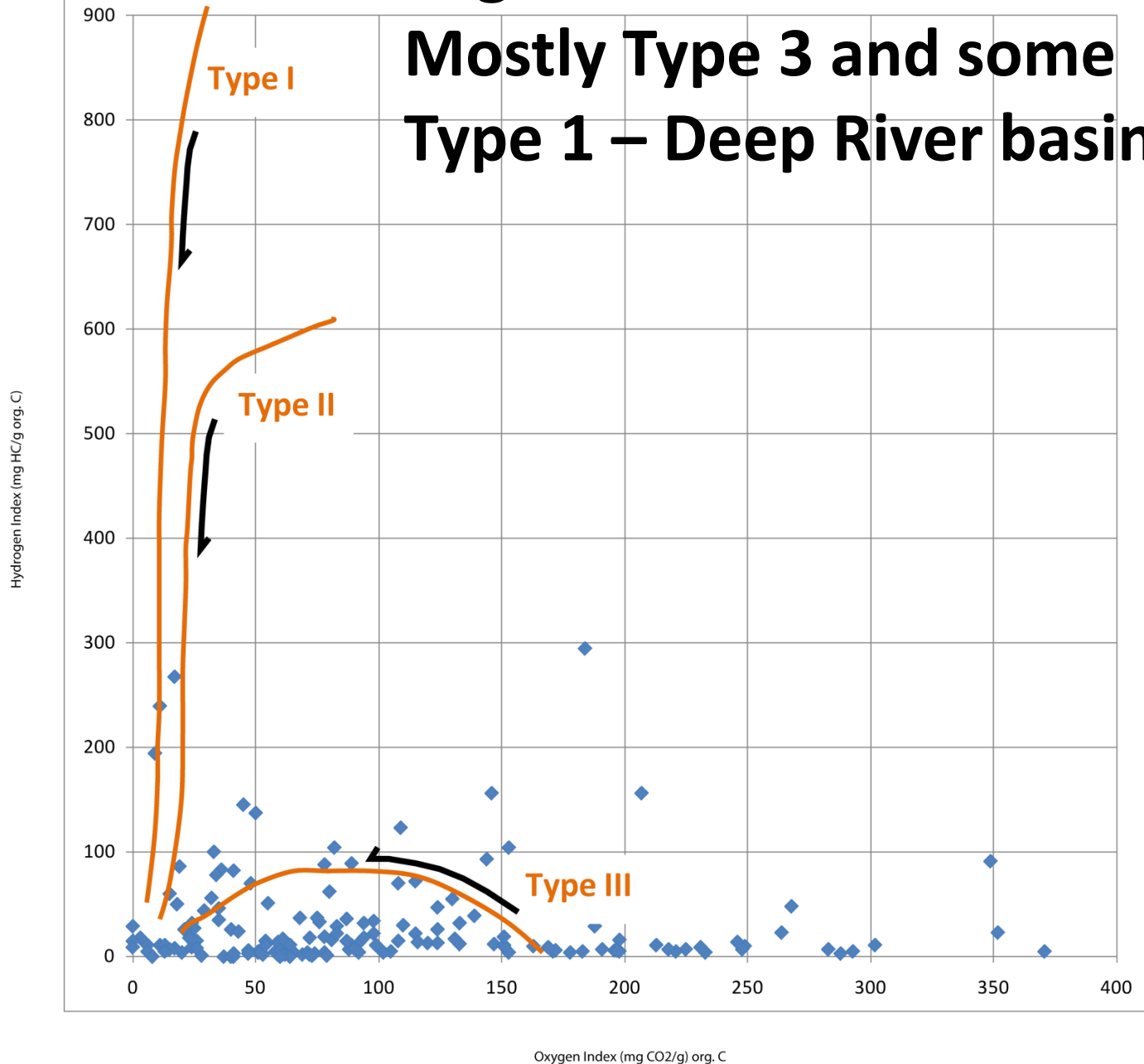
From Olsen and others, 1991



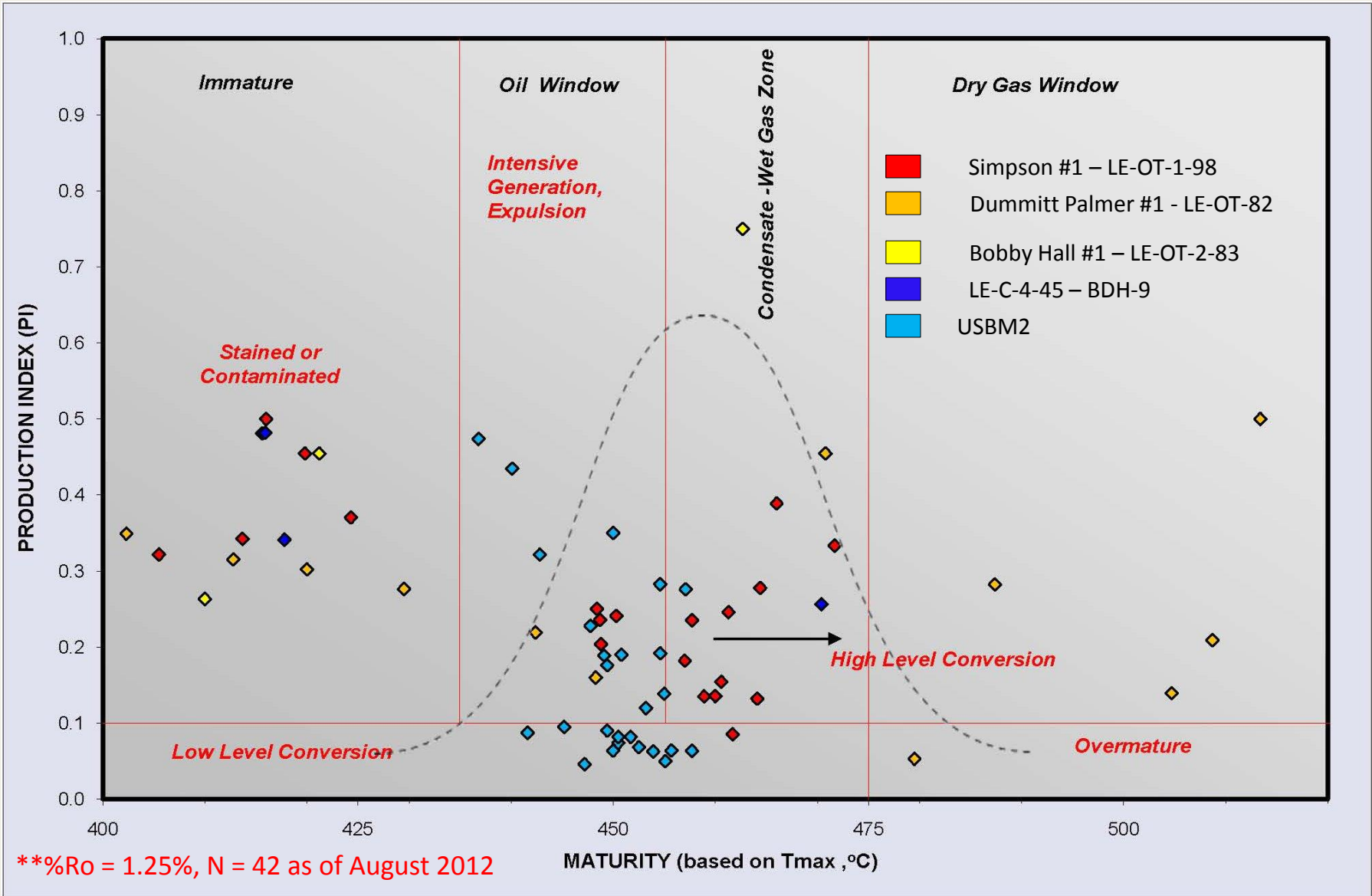
Deep River basin seismic line 113 – half graben

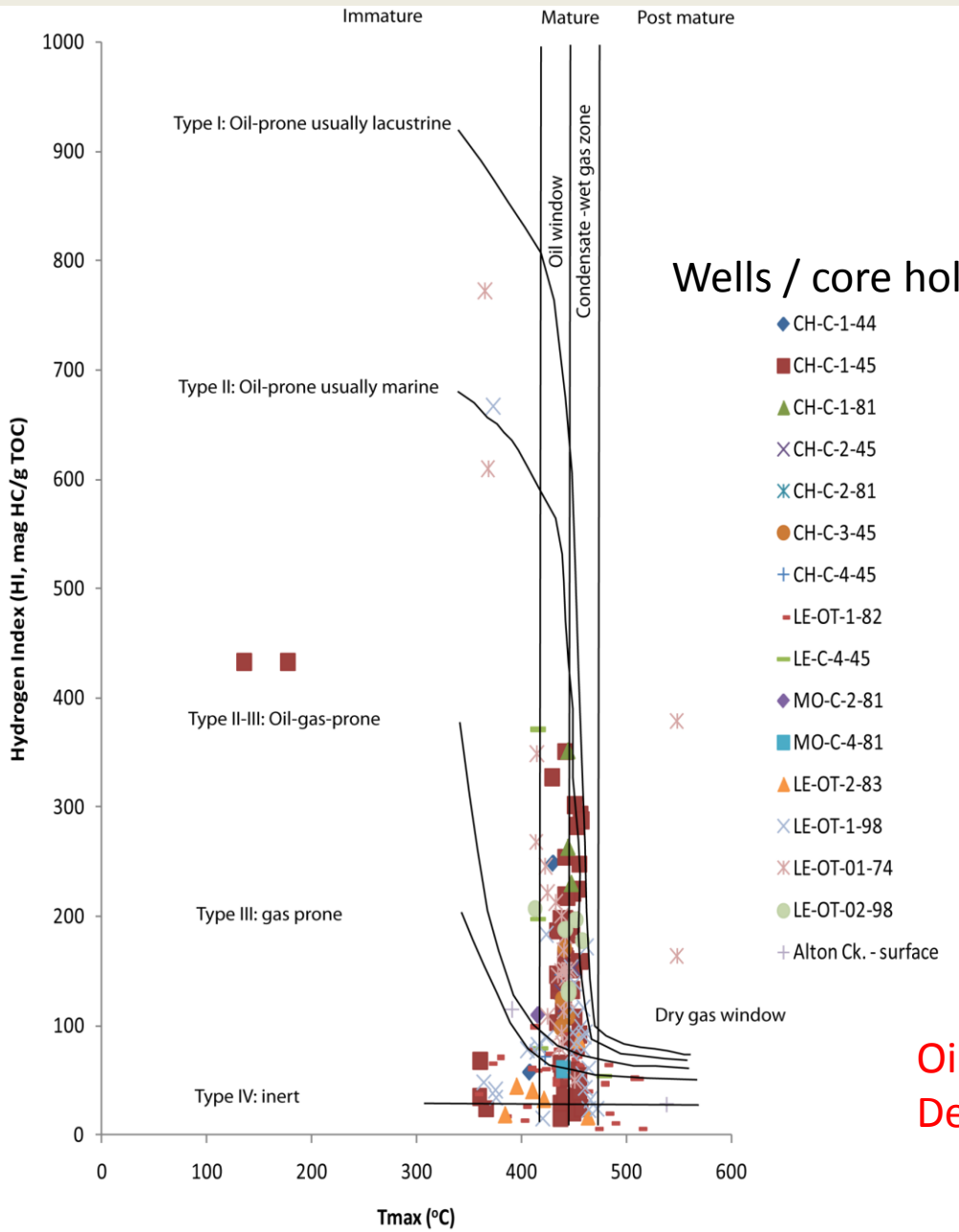


Organic source material – Mostly Type 3 and some Type 1 – Deep River basin



Kerogen type and maturity (Tmax) – multiple wells: Sanford sub-basin





Maturation: Most data plots in the oil and condensate windows + dry gas



Oil-saturated sands above the source rock

Sanford sub-basin, Deep River Basin

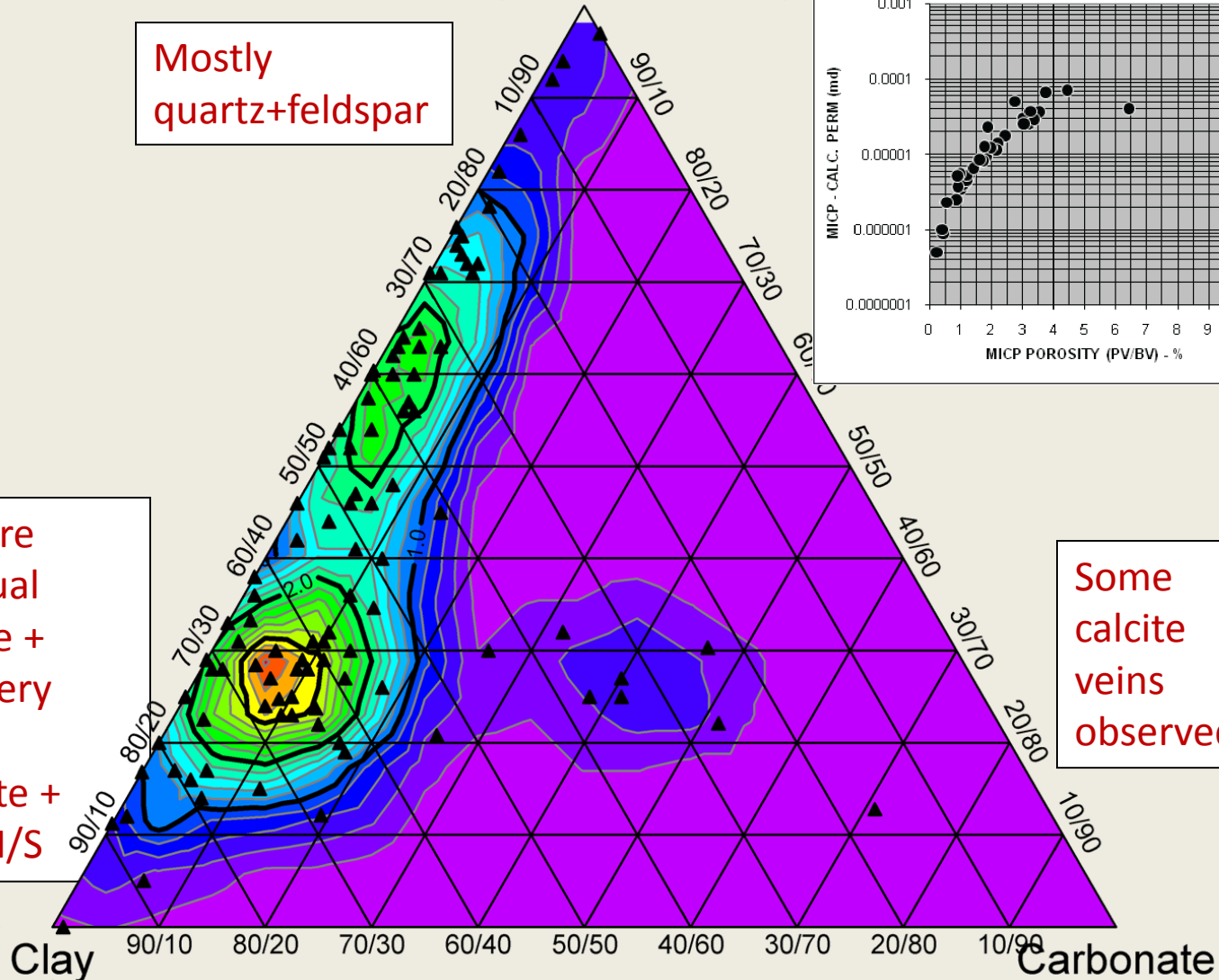
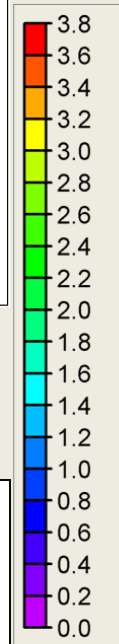
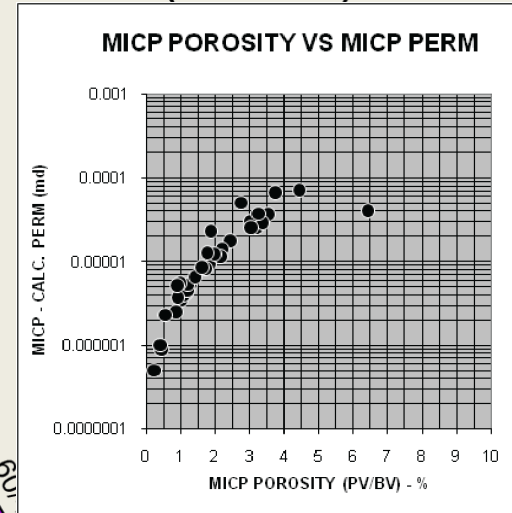
Other (brittle minerals) - clays - carbonate (N=101)

Other (brittle minerals)

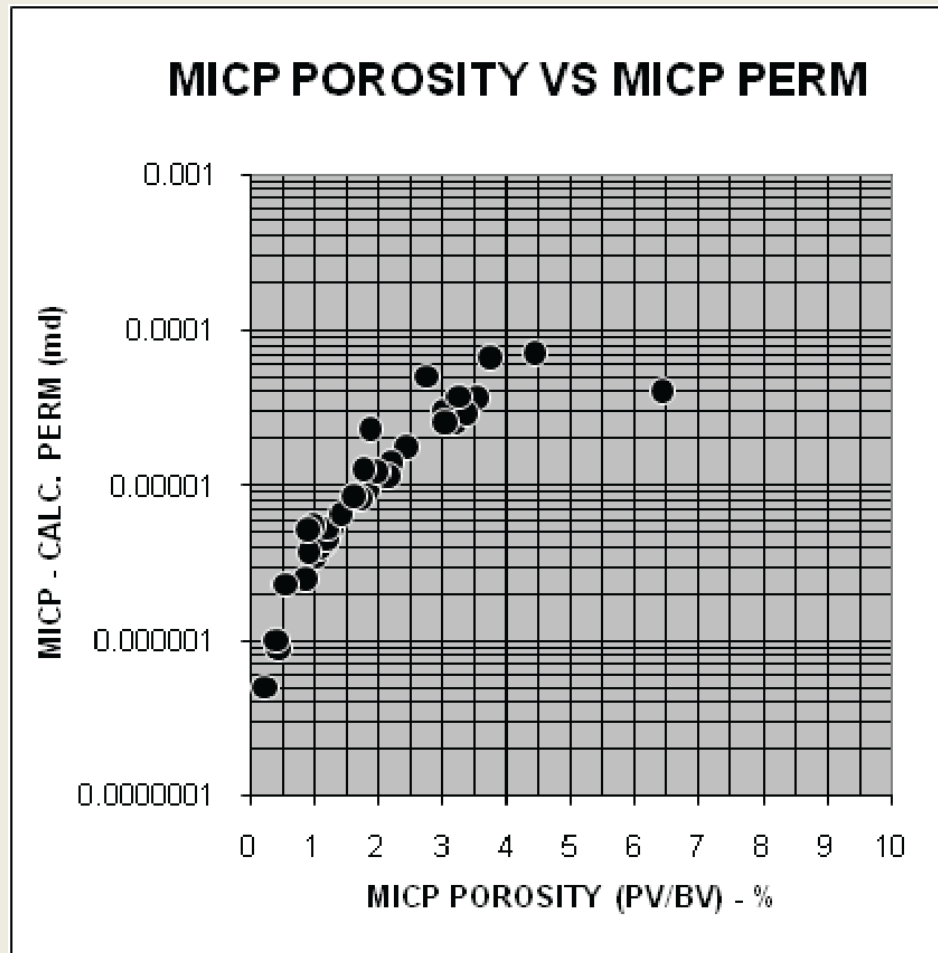
Mostly
quartz+feldspar

Clays are
subequal
chlorite +
illite; very
minor
kaolinite +
mixed I/S

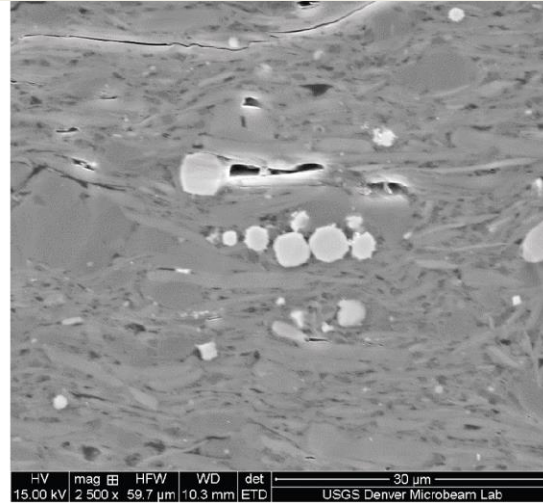
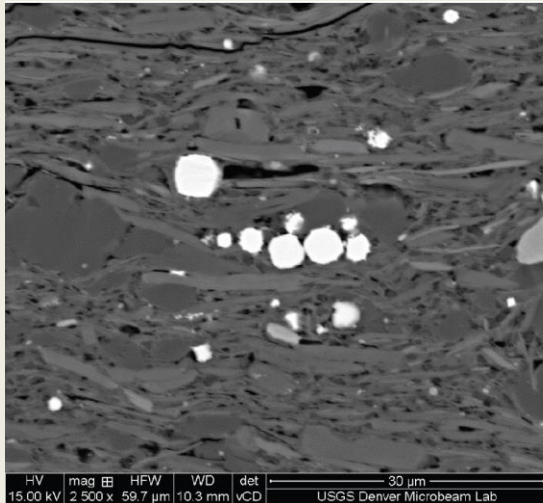
Some
calcite
veins
observed



High pressure mercury porosity and permeability (MICP) results

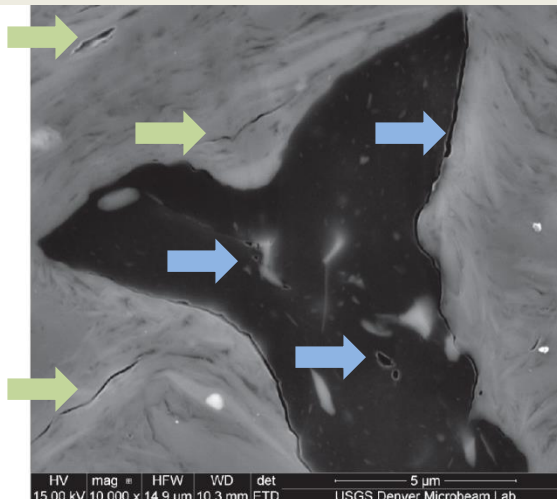
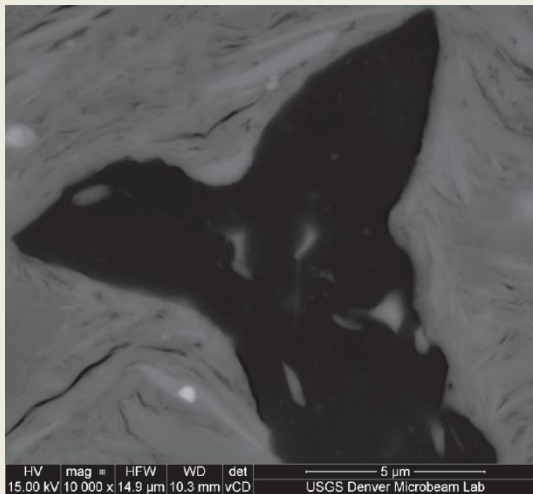


Porosity examples – reservoir characterization



Top - V.R. Groce #1, depth 2,407 feet. Field of view shows intergranular pores associated with clay minerals and contacts with rigid grains.

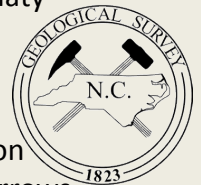
Geomechanical studies in progress



Bottom - BMDH 2, depth 1,163 feet. Evidence of “organic porosity”. The sample has 2.3% TOC and 6.4% Hg porosity. Intergranular porosity (green arrows) associated with Mg chlorite. Sample is chlorite/illite mud rock with prominent phosphate “complexes”. Organic porosity occurs both within and along the margins of organic matter (OM; blue arrows).

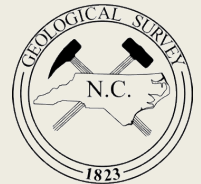
(Left) - Backscatter electron image; OM is black. Clays have typical platy appearance; chlorite is the lighter shade of gray.

(Right) - Secondary electron image; pores marked by arrows - these are of variable size (nanometer range is typical). Gray fleck in OM are occluded clay.



North Carolina - Summary

- Two continuous gas assessment units (AUs).
- Age: Late Triassic (Carnian).
- Source rocks: Freshwater lacustrine shales deposited near/at the paleo-equator.
- Continental rift basins formed from Permian to Early Jurassic extension and breakup of Pangea.
- Both North Carolina basins were assessed by U.S. Geological Survey (Fact sheet 2012-3075) – URL <http://pubs.usgs.gov/fs/2012/3075/>.
- Industry interest; some leasing – available open ground.
- Horizontal drilling and fracking legalized in 2012; new state permitting rules required by October 2014.
- First permits anticipated to be issued in March 2015.
- With new completion technology, these deposits may become economically viable.



For further information

Geological research (list of all oil and gas publications) about the Triassic strata and reservoir characterization in North Carolina are on the Internet at URL:

<http://portal.ncdenr.org/web/lr/oilandgasresearch> ,

Draft rules are available on the Internet at URL :

<http://portal.ncdenr.org/web/mining-and-energy-commission/home>



V.R. Groce #1 well pad - 1974

Drill site in Deep River basin: flat, relatively featureless, and lots of secondary roads. Typical terrain in these prospective basins – perfect for exploration!

Contact:

Jeffrey C. Reid PhD, PG CPG

Email: jeff.reid@ncdenr.gov

Voice: 919.707.9205 (USA)

