Mesozoic rift basins – Onshore North Carolina and south-central Virginia, U.S.A.: Deep River and Dan River - Danville total petroleum systems (TPS) and assessment units (AU) for continuous gas accumulation

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Forward

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Mesozoic rift basins – Onshore North Carolina and south-central Virginia, U.S.A.: Deep River and Dan River - Danville total petroleum systems (TPS) and assessment units (AU) for continuous gas accumulation

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Summary

Two continuous gas assessment units (AUs) are present in the Late Triassic (Carnian) onshore rift basins of North Carolina and south-central Virginia. The source rocks are freshwater lacustrine shales that were deposited near the paleo-equator after the onset of Pangea rifting.

These two rift basins, the Deep River basin wholly contained within North Carolina's border, and the Dan River-Danville basin, present in north-central North Carolina and south-central Virginia have been assessed numerically as part of the USGS's National Petroleum Resource Assessment (Fig. 1). These two rift basins are part of a series of formerly larger continental rift basins that formed during the Permian to Early Jurassic extension in central Pangea as the supercontinent began to fragment.

These continuous gas-prone AUs are total petroleum systems (TPS). The Deep River basin continuous AU has an estimated mean gas (BCFG) content of 1,660 and an estimated mean of natural gas liquids (mmbngl) of 83. The Dan River-Danville basin continuous AU has an estimated mean gas content (BCFG) of 49 and no natural gas liquids (mmbngl) from data available in 2011 assessed by the U.S. Geological Survey (Milici and others, 2012) (Fig. 2).

Horizontal drilling and hydraulic fracturing became legal in North Carolina by Act of the N.C. General Assembly in 2012. The same Act requires rules and regulations to be established for permitting by October 2014. The North Carolina Geological Survey is the custodian of geophysical well logs, cores and samples. These are available for examination at its Raleigh, N.C. repository.

The Deep River basin continuous gas AU, North Carolina

The Deep River basin continuous gas AU is a 150-mile-long northeast-trending half-graben with a steeply-dipping eastern border fault in central North Carolina (Fig. 1). The basin is divided into three sub-basins, which are named from north to south, the Durham sub-basin, the Sanford sub-basin and the Wadesboro sub-basin (Fig. 3). The Sanford sub-basin is a total TPS containing a source rock (the Cumnock Formation), seal (the Sanford Formation), and has structural and depositional traps. This relatively untested exploration area with some drilling, and two shut-in natural gas wells, has about 9,700 acres under lease since January 2010.

The three sub-basins are filled with ~7,000 feet of Triassic strata, that are divided into the following three formations in ascending stratigraphic order: (1) Pekin Formation (gray sandstone and shale) is mostly fluvial with fluvial with basin-border conglomerates, (2) Cumnock Formation (black shale, with some beds of gray shale, sandstone and coal) is lacustrine, and the (3) Sanford Formation (red and gray siltstone and shale) is mostly fluvial, some lacustrine, and basin-border conglomerates. The Cumnock Formation includes a thick interval (up to ~800 feet) of Late Triassic (Carnian) organic-rich black shale. This shale extends across ~59,000 acres, at depths of less than 3,000 feet in the Sanford sub-basin, 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 northwesterly-trending fractures are filled with diabase dikes (that locally heated the Cumnock Formation), although mapping in underground coal mines (now abandoned) has shown that a diabase sheet fringing the northwestern Sanford sub-basin margin does not extend far into the basin. The diabase dikes are very narrow in width (up to tens of feet), vertical, limited in number, and have heated the sedimentary strata to about one-half the width of a dike on each side – a volumetrically small amount.

Four exploration wells preceded acquisition of ~75 miles of dip and strike seismic lines that provide considerable 2D control in the Sanford sub-basin and the Durham sub-basin. The deeper parts of the Sanford sub-basin are unexplored and are constrained by two drill holes that penetrated basement. Preliminary seismic interpretation suggests multiple stratigraphic and/or structural targets.

The primary exploration focus has been on the Sanford sub-basin and its TPS because of the abundance of drill core, geophysical logs, two shut-in wells with substantial measured pressures, gas chemistry (molecular, BTU content, and carbon, oxygen and nitrogen stable isotopes), rock exposures including thin coal beds, and a basinal network of 2D seismic lines. Key references to the Sanford sub-basin are: Reid and others (2011), Reid and Milici (2008); Reinemund (1949, 1955); Reid and Taylor (2008, 2009a-c); Reid (2009); Reid and others (2010a, b); Hu (1991); Whiteside and others (2011), Olsen and Gore (1989) and Arbogast (1976).

The Durham sub-basin, located north of the Sanford sub-basin, has had fewer studies but has three vibroseis seismic lines, and intensive geotechnical exploration study of the shallow subsurface in the Sanford Formation for the construction of a nuclear power plant, and for the characterization of a multi-state low-level radioactive waste disposal (LLRW) facility (effort now abandoned). There is only one shallow drill hole that did not encounter the source rock. The extensive geotechnical studies investigated a depth shallower than most of the Cumnock Formation. The vibroseis data show several horsts and grabens in a basin of similar depth to the Sanford sub-basin.

The North Carolina Geological Survey is the custodian of the cores, geophysical logs, and technical reports from the LLRW study. These data are available for public inspection upon request.

The Wadesboro sub-basin, south of the Sanford sub-basin, is least well known – lacking both detailed geologic mapping, drilling or seismic data. However, the Cumnock Formation is exposed in clay pits and basin margin outcrops, and has been investigated by vertebrate paleontologists. Brazell and others (2012) began geologic mapping in the Wadesboro sub-basin. However the extent, thickness, TOC and maturity of the source rock are unknown and source rock outcrops are sparse in this sub-basin.

Dinen (1982) studied the Ellerbe Basin, a 20-square-mile Triassic basin geographically separated from the Wadesboro sub-basin. The Ellerbe basin's depth ranges from ten feet to not more than 200 feet, is filled with clastic sediments, and lacks organic source rocks.

Area: Sanford sub-basin (146,530 acres); Durham sub-basin (405,236 acres), and Wadesboro sub-basin (205,809 acres), or ~757,575 total acres.

Age: Late Triassic (Carnian).

Type: Half graben rift basin; principle normal fault zone on the southeast basin margin.

Thickness: Maximum estimated basin depth of 7,100 feet based on two-way travel time from seismic and by control of two wells penetrating basement rocks.

Exploration wells (including coal holes): Eleven of the 28 wells (including old coal exploration drill holes) that penetrated the Cumnock Formation have natural gas and oil shows. Two shut-in wells have measured pressures of 900 psi (Butler #3) and 300 psi (Simpson #1). Coal mines, now closed, had underground oil shows and multiple fatal methane gas mine explosions.

Oil and gas shows: Numerous – see 'Exploration wells (including coal)' above. The oil and gas shows in the Cumnock Formation include oil, gas, asphalt, and pyrobitumen encountered while drilling and reported from underground coal workings (now abandoned). Degraded oil and pyrobitumen occur in the Sanford Formation that overlies the Cumnock Formation. Methane was detected while drilling through thick intervals of the Sanford Formation (potential tight gas?). Complete molecular composition, BTU, and stable isotopic data (Δ Nitrogen, Δ Carbon, and Δ Deuterium), and helium in the shut-in well gases and pressures were obtained from the Butler #3 and Simpson #1 wells. "Wet ends" (ethane, ethylene, propane, iso-butane, n-butane, n-pentane, and hexanes+) are present in measurable quantities in these same wells. Helium was measured in both wells at a concentration of about 0.218 mol. % (Butler #3) and 0.223 mol. % (Simpson #1). Neither hydrogen sulfide nor carbon dioxide was detected in either of these two wells. Limited gas composition and BTU data for the Dummitt-Palmer #1 well is available.

Source rock and maturity: Cumnock Formation lacustrine shale is up to 800 feet thick and contains a bituminous coal up to 42 inches thick. This is a gas-prone continuous AU. The Deep River basin continuous AU has a mean gas (BCFG) content of 1,660 and a mean of natural gas liquids (mmbngl) of 83. The average TOC content of the Sanford sub-basin is 1.96% (n = 353). The average %Ro of the Cumnock Formation in the Sanford sub-basin is 1.25% (n = 42).

Reservoirs: Potential petroleum reservoirs are a continuous accumulation that could reside in the basin-border conglomerates, and very coarse-grained sandstones to mudstones, gray and black shale, and the coaly interval. The potential seals are shale beds interbedded with the coarser-grained strata. Systematic fractures trend northwesterly, whereas the conjugate fractures trend northeastward. Longitudinal basin faults and basinal cross faults, and a cross-basin trending anticline may provide structural plays in conjuction with the continuous accumulation.

Estimated technically recoverable resources: The Deep River basin continuous AU has an estimated mean gas (BCFG) content of 1,660 and a mean of natural gas liquids (mmbngl) of 83 (Milici and others, 2012).

References cited – Deep River basin:

Arbogast, J.S., 1976, Fluvial deposition of Triassic red beds, Durham Basin, North Carolina: unpublished master's degree, Department of Geology, Duke University, 117p.

Brazell, S.J., Diemer, J.A., Felts, M.S., Rachide, S.P., and Bobyarchick, A., 2012, Department of Geography & Earth Sciences, University of North Carolina at Charlotte, viewed on line 5 May 2012 at URL http://gsa.confex.com/gsa/2012SE/finalprogram/abstract_202255.htm

Dinen, M.J., 1982, Geology of the Triassic "Ellerbe Basin", Richmond County, North Carolina: unpublished master's degree thesis, North Carolina State University, Department of Marine, Earth and Atmospheric Sciences, Raleigh, N.C., 68p. plus two plates.

Hu, L., 1991, Petrology and depositional cycles of subsurface Triassic Cumnock formation of the Sanford sub-basin, North Carolina: unpublished master's thesis, Department of Geology, University of North Carolina, Chapel Hill, 81p.

Milici, R.C., Coleman, J.L., Rowan, E.L., Cook, T.A., Charpentier, R.R., Kirschbaum, M.A., Klett, T.R., Pollastro, R.M., and Schenk, C.J., 2012, Assessment of undiscovered oil and gas resources of the East Coast Mesozoic basins of the Piedmont, Blue Ridge Thrust Belt, Atlantic Coastal Plain, and New England Provinces, 2011: U.S. Geological Survey Fact Sheet 2012–3075, 2 p. available at URL http://pubs.usgs.gov/fs/2012/3075/).

Olsen, P.E., and Gore, P.J.W., 1989, Tectonic, depositional, and paleoecological history of Early Mesozoic rift basins, Eastern North America, 28th International Geological Congress, Field trip guidebook T351, Gulf, North Carolina, USA to Parrsboro, Nova Scotia, Canada: American Geophysical Union, 174p.

Reid, J.C., 2009, "Natural gas and oil in North Carolina," North Carolina Geological Survey, Information Circular 36, 8p (see URL http://www.geology.enr.state.nc.us/pubs/PDF/NCGS_IC_36_Oil_and_Gas.pdf) – includes drilling regulations and permitting details.

Reid, J.C., and Milici, R.C., 2008, "Hydrocarbon source rocks in the Deep River and Dan River Triassic Basins, North Carolina, U.S. Geological Survey, Open-File report 2008-1108, 35 p. plus tables (see URL http://pubs.usgs.gov/of/2008/1108/).

Reid, J.C., and Taylor, K.B., 2008, Tools to Evaluate the Hydrocarbon Potential of the Mesozoic Basins, North Carolina, USA. This PDF can be viewed as article #90084 at URL http://www.searchanddiscovery.net/abstracts/html/2008/eastern-pittsburgh/abstracts/reid.htm?q=%2Btext%3Areid (AAPG Search and Discovery contribution).

Reid, J.C., and Taylor, K.B., 2009a, Shale Gas Potential in Triassic Strata of the Deep River Basin, Lee and Chatham Counties, North Carolina, USA. The PDF can be viewed as article #90095 at URL http://www.searchanddiscovery.net/abstracts/html/2009/eastern/abstracts/reid02.htm?q=%2Btext%3Areid – see also extended presentation (PDF) on AAPG's Search and Discovery site at URL http://www.searchanddiscovery.net/documents/2009/80072reid/ndx_reid.pdf (posted 11 December 2009 - (AAPG Search and Discovery contribution).

Reid, J.C. and Taylor, K.B., 2009b, Geology and Infrastructure Data for the Development of Shale Gas Wells in Triassic Strata of the Deep River Basin, Lee and Chatham Counties, North Carolina, USA. The PDF can be viewed as article #90095 at URL http://www.searchanddiscovery.net/abstracts/html/2009/eastern/abstracts/reid.htm?q=%2Btext%3Areid (AAPG Search and Discovery contribution).

Reid, J.C., and Taylor, K.B., 2009c, "Shale gas potential in Triassic strata of the Deep River Basin, Lee and Chatham counties, North Carolina with pipeline and infrastructure data," North Carolina Geological Survey, Open-File Report 2009-01 (see URL http://www.geology.enr.state.nc.us/news.htm for PDF file).

Reid, J.C. and Taylor, K.B., 2011, with contributions by Olsen, Paul E., and Patterson, III, O.F., "Natural Gas Potential of the Sanford sub-basin, Deep River Basin, North Carolina," 57p., *in* Taylor, Kenneth B. and Jeffrey C. Reid, editors, "Field Trip Guidebook – 60th Annual Meeting," Southeastern Section, Geological Society of America, Wilmington, North Carolina, March 2011. Note: updated and revised version of this field trip guidebook was prepared for the 2011 annual meeting of the Eastern Section, AAPG and is available at URL http://www.searchanddiscovery.com/documents/2011/10366reid/ndx_reid.pdf (AAPG Search and Discovery contribution).

Reid, J.C., Taylor, K.B., and Cumberbatch, N.S., 2010a, Digital compilation map Sanford sub-basin, Deep River Basin, parts of Lee, Chatham and Moore Counties, North Carolina [Seismic lines, drill hole locations, geologic units (from Reinemund, 1955), hydrocarbon shows (gas, oil asphaltic – or combination), and %Ro in wells – Area within dotted line inferred extent of %Ro ≥ 0.8]: North Carolina Geological Survey, Open-file report 2010-07.

Reid, J.C., Taylor, K.B., and Simons, J.D., 2010b, North Carolina Shale Gas – A Progress Report – Lee, Chatham and Moore Counties: American Association of Petroleum Geologists' Eastern Section Meeting, Kalamazoo, Michigan, September 25-29, 2010, program with abstracts, p. 52. The PDF can be viewed as article #40704 at URL http://www.searchanddiscovery.com/documents/2011/40704reid/ndx_reid.pdf (AAPG Search and Discovery contribution).

Reinemund, J.A., 1949, Geology of the Deep River Coal Field. Chatham, Lee and Moore counties, North Carolina: U.S. Geological Survey, Preliminary Map (in two sheets).

Reinemund, J.A., 1955, Geology of the Deep River Coal Field North Carolina: U.S. Geological Survey Professional Paper 246, 159p.

Whiteside, J.H., Grogan, D.S., Olsen, P.E., Kent, D.V., 2011, Climatically driven biogeographic provinces of Late Triassic tropical Pangea. Published online before print, May 13, 2011. Doi: 10.1073/pnas. 1102473108, and in print at Proceedings of the National Academy of Sciences of the United States of America (PNAS), May 31, 2011, vol. 108, no. 22, pp. 8972-8977 with supporting information.

The Dan River-Danville basin continuous gas AU, North Carolina and Virginia

The Dan River-Danville basin is both a topographic basin and a structural basin (Fig. 1). The basin drains older igneous and metamorphic rocks that surround the basin, and the Dan River discharges water into Kerr Lake northeast of Dan River, Virginia.

The basin is a continuous gas-prone AU located in north-central North Carolina and south-central Virginia. This Triassic rift basin is one of a series of formerly larger continental rift basins that formed during the Permian to Early Jurassic extension in central Pangea as the supercontinent began to fragment. The 93-mile-long basin is a northeast-trending half graben with a steeply-dipping western border fault zone. The southeast contact is a major unconformity of Triassic strata on metamorphic rocks of the Piedmont.

The basin is filled with ~5,000 feet of Triassic strata that dip at about 30^{o} to the west toward the border fault zone. The Triassic is divided into the following three formations that in ascending stratigraphic order are: 1) the basal Pine Hall Formation is mostly fluvial and consists of gray- to tan, coarse-grained clastic rocks, 2) Cow Branch Formation consisting of two lacustrine members, the main source rocks composed of black- to gray shales, is separated by a gray- to tan red lacustrine to fluvial member, and 3) the Stoneville Formation consisting of red clastics with substantial lacustrine and fluvial components.

The Davie basin, located in Davie and Yadkin counties, North Carolina, is southwestward along strike. It was once connected to the Dan River-Danville basin. Post depositional faulting and erosion account for the configuration of the two basins. The Davie basin has no known organic lacustrine strata, and the clastic-filled basin is probably very shallow.

Key references to the Dan River-Danville basin are: Reid and Milici (2008); Reid and Taylor (2008); Reid (2009); Reid and others (2011), Reid and Taylor (2012), and Olsen and Gore (1989), Thayer and Robbins (1992), Olsen and others (2012).

Area: ~64,800 acres (North Carolina), ~61,500 acres (Virginia), or ~126,300 total acres.

Age: Late Triassic (Carnian).

Type: Half graben rift basin; principle normal fault zone on the northwest basin margin.

Thickness: Maximum estimated basin depth of ~5,000 feet (current estimated depth).

Exploration wells: There are only three shallow diamond drill core holes in the Walnut Cove Member of the Cow Branch Formation and the basin is untested. No seismic lines are known in this basin. The Eden Member is mined for aggregate.

Oil and gas shows: No gas or oil shows have been reported. Turn-of-the-century coal investigations investigated a carbonaceous shale interval in the Walnut Cove member that is up to 225 feet thick and contains a coal about a foot thick.

Source rock and maturity: The lacustrine source rocks of the Cow Branch Formation consists of two members. The stratigraphically lower member, the Walnut Cove member, is over 400-feet-thick, has a strike length of about twenty-two miles, and a probable width of ~1.1 miles – all in North Carolina. Its average total organic carbon (TOC) is 3.55% (n=122) from outcrop and three diamond drill hole cores. Its average %Ro is 1.85 (n=23).

The stratigraphically higher unit, the Eden member, is over 1,500 feet thick, has a strike length of at least 6.5 miles in North Carolina and an additional 2-3 miles in Virginia, and a probable width of about 1.5 miles – straddling the border between North Carolina and Virginia. Additional exposures occur to the southwest along strike up to ten miles; and an isolated patch occurs near Greta, Virginia. In North Carolina, has an average total organic carbon (TOC) of 1.38% (n=42) from a continuous aggregate quarry section. Its average %Ro is 2.08 (n=25).

Reservoirs: Potential petroleum reservoirs are a continuous accumulation that could reside in the basin-border conglomerates, and very coarse-grained sandstones to mudstones, gray and black shale, and the coaly interval. The potential seals are shale beds interbedded with the coarser-grained strata. Systematic fractures trend northwest, whereas the conjugate fractures trend northeastward. A cross-basin anticline (Spray anticline) possibly coupled with a parallel syncline may be potential structural reservoirs.

Estimated technically recoverable resources: The Dan River-Danville basin continuous AU has an estimated mean gas content (BCFG) of 49 and no NGL (mmbngl) from data available in 2011 assessed by the U.S. Geological Survey (Milici and others, 2012).

References cited – Dan River-Danville basin:

Milici, R.C., Coleman, J.L., Rowan, E.L., Cook, T.A., Charpentier, R.R., Kirschbaum, M.A., Klett, T.R., Pollastro, R.M., and Schenk, C.J., 2012, Assessment of undiscovered oil and gas resources of the East Coast Mesozoic basins of the Piedmont, Blue Ridge Thrust Belt, Atlantic Coastal Plain, and New England Provinces, 2011: U.S. Geological Survey Fact Sheet 2012–3075, 2 p. available at URL http://pubs.usgs.gov/fs/2012/3075/).

Olsen, P.E., and Gore, P.J.W., 1989, Tectonic, depositional, and paleoecological history of Early Mesozoic rift basins, Eastern North America, 28th International Geological Congress, Field trip guidebook T351, Gulf, North Carolina, USA to Parrsboro, Nova Scotia, Canada: American Geophysical Union, 174p.

Olsen, Paul E., Reid, J.C., Kent, D.V., and Whiteside, J.H., 2012, Revised stratigraphy of Triassic age strata of the Danville and Dan River Basins (Virginia and North Carolina, USA) based on drill core and outcrop data: manuscript in preparation.

Reid, J.C., 2009, "Natural gas and oil in North Carolina," North Carolina Geological Survey, Information Circular 36, 8p (see URL http://www.geology.enr.state.nc.us/pubs/PDF/NCGS_IC_36_Oil_and_Gas.pdf) – includes drilling regulations and permitting details.

Reid, J.C., and Milici, R.C., 2008, "Hydrocarbon source rocks in the Deep River and Dan River Triassic Basins, North Carolina," U.S. Geological Survey, Open-File report 2008-1108, 35 p. plus tables (see URL http://pubs.usgs.gov/of/2008/1108/).

Reid, J.C., and Taylor, K.B., 2008, Tools to Evaluate the Hydrocarbon Potential of the Mesozoic Basins, North Carolina, USA. This PDF can be viewed as article #90084 at URL http://www.searchanddiscovery.net/abstracts/html/2008/eastern-pittsburgh/abstracts/reid.htm?q=%2Btext%3Areid (AAPG Search and Discovery contribution).

Reid, J.C., and Taylor, K.B., 2012, "North Carolina (USA) Mesozoic rift basin shale gas: A fifth year perspective," presented at the 7th International Symposium on Oil & Gas Resources in Western Newfoundland, September 12-14, 2012, Corner Brook, Newfoundland-Labrador (see URL http://www.wnloilandgas.com/media/uploads/Jeff_Reid.pdf).

Reid, J.C., Taylor, K.B., and Simons, J.D., 2011, "North Carolina Shale Gas: Dan River Basin – Stokes and Rockingham Counties," Program with abstracts, 49th Eastern Section Meeting, September 24-29, 2011, Arlington, Virginia, p. 44. The PDF can be viewed as article #80188 at URL http://www.searchanddiscovery.com/documents/2011/80199reid/ndx_reid.pdf (AAPG Search and Discovery contribution).

Thayer, P.A., and Robbins, E.I., 1992, Sedimentology of Triassic Dan River Group, North Carolina and Virginia: *in* Dennison, J.M. and Steward, K.G., editors, Geologic field guides to North Carolina and vicinity: Southeastern Section, Geological Society of America, Winston-Salem, North Carolina, p. 189-200.

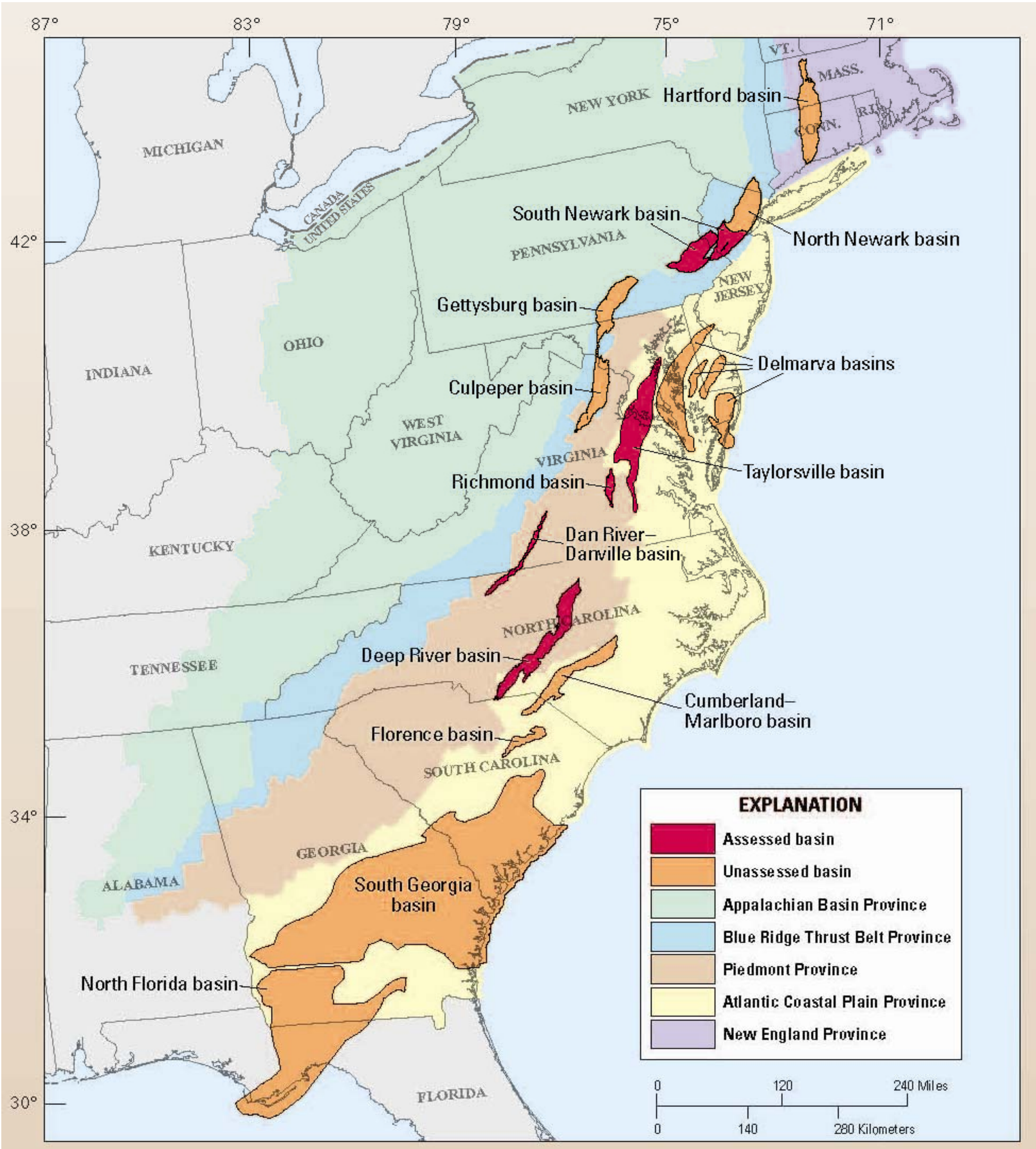

Figure 1: Map of the Eastern United States showing the location of the five quantitatively (volumetrically) assessed East Coast Mesozoic basins, the nine basins that were not volumetrically assessed, and the U.S. Geological Survey province boundaries. Each basin includes on continuous gas assessment unit (Milici and others, 2012).

Total Petroleum System (TPS) and Assessment Unit (AU)	Field type	Total undiscovered resources											
		Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Taylorsville Basin Composite TPS													
Taylorsville Basin Continuous Gas AU	Gas					516	985	1,880	1,064	16	34	71	37
Richmond Basin Composite TPS													
Richmond Basin Continuous Gas AU	Gas					99	194	382	211	4	10	20	11
Newark Basin Composite TPS													
South Newark Basin Continuous Gas AU	Gas					363	785	1,698	876	1	4	10	4
Deep River Basin Composite TPS													
Deep River Basin Continuous Gas AU	Gas					779	1,527	2,990	1,660	35	75	158	83
Dan River-Danville Basin Composite TPS													
Dan River-Danville Basin Continuous Gas AU	Gas					17	42	106	49	0	0	1	0
Total continuous resources						1,774	3,533	7,056	3,860	56	123	260	135

Figure 2: East Coast Mesozoic basin assessment results (Milici and others, 2012). The Deep River basin composite TPS and the Dan River-Danville basin composite TPS assessment results are highlighted (red).

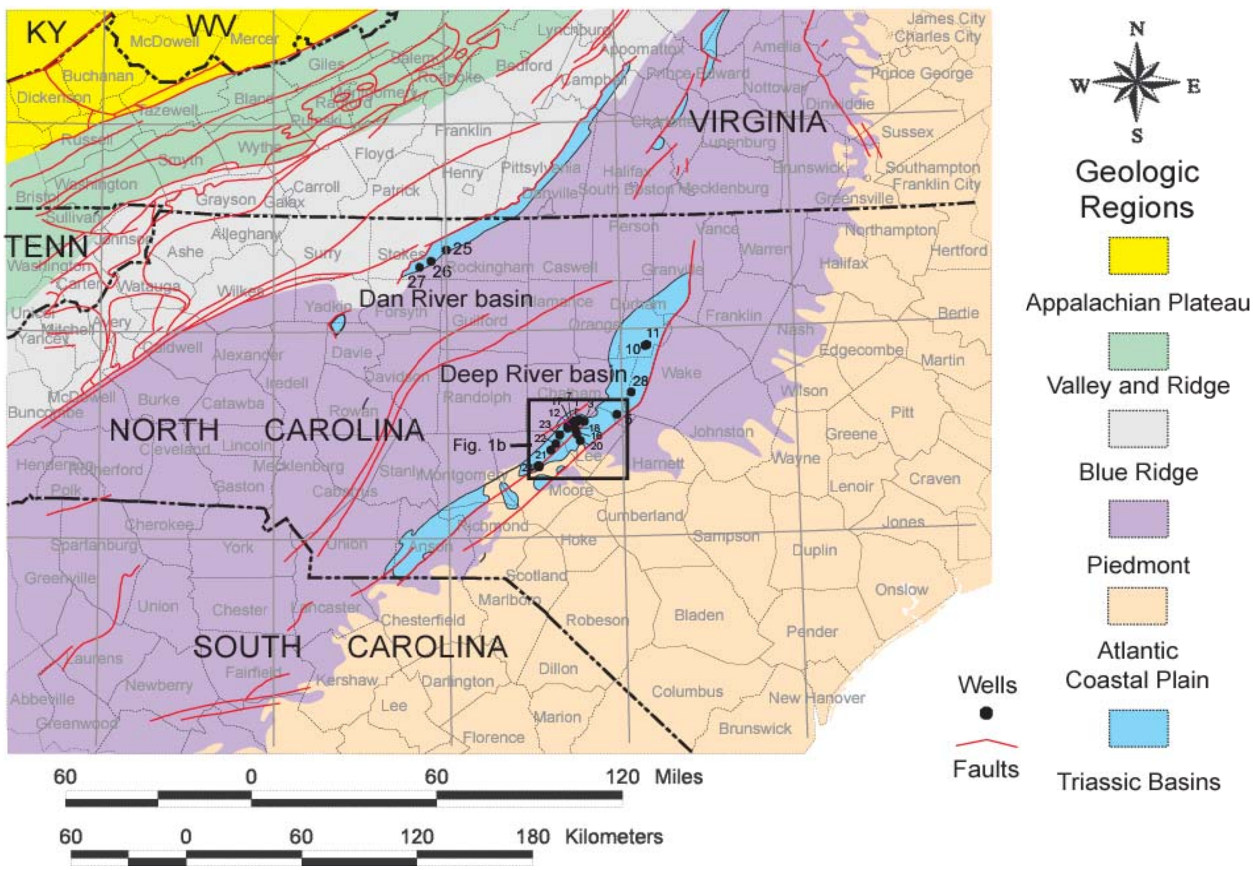

Figure 3: Location of the Deep River basin composite TPS (central North Carolina) and the Dan River-Danville basin composite TPS (north central North Carolina and south central Virginia). From Reid and Milici, 2008. The box in the central part of the Deep River basin is the location of the Sanford sub-basin; 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.