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Abstract

Fluid inclusion stratigraphy (FIS) data confirm the presence of $C_1 - C_5$ (plus $C_6 - C_7$) hydrocarbons, a total petroleum system, and helium along a ~20-mile strike of Late Triassic lacustrine / rift strata in the Dan River basin. FIS data complement organic geochemist and vitrinite reflectance data that indicate the Walnut Cove Fm., a source rock, is gas prone, and is in the oil- and wet-gas window. The basin stratigraphy consists in ascending order, the Pine Hall (PH), Walnut Cove (WC), Dry Fork (DF), Cow Branch (CB) and Stoneville (SV) formations. The basal PH is largely fluvial and consists of red, gray, buff and relatively coarse fluvial clastic rocks. The WC consists of black and gray, largely lacustrine mudstone and minor coal. The DF is comprised of gray, buff, and red lacustrine to fluvial strata. The CB, also a source rock but not part of this FIS study, is made up of mostly black and gray, predominantly lacustrine mudstone and sandstone and is gas prone. The uppermost unit is the SV consisting mostly of red clastic rock with abundant gray lacustrine, and gray and red fluvial components.

FIS samples came from shallow (<900-ft-deep) continuous cores drilled in 1981 by industry that penetrated the WC and portions of the PH. A 1,477-ft-deep continuous core hole drilled in 2015 by the NC Geological Survey also provided FIS samples and penetrate all of the WC and PH before terminating in metamorphic basement. The WC in this core degassed when extracted from the core barrel FIS data from these cores show hydrocarbons present throughout the WC and large parts of the PH.

Typical FIS response in the WC included C species ranging from C_1 to C_5 with some C_6 , C_7 and dry gas signals. The WC exhibits mostly dry gas FIS responses with some wet gas FIS spectra. Visible petroleum inclusions observed in thin sections prepared from coarser-size sedimentary fractions include gas inclusions, and high- to intermediate gravity gas-rich gas-condensate to wet gas inclusions with white-, blue-, or yellow fluorescence. Inclusions suggest that most hydrocarbons have migrated, possibly in response to basin uplift and inversion. Helium FIS responses in the WC average ~100 ppm (range 30 ppm to 250 ppm). The PH shows mostly weak dry gas FIS responses, with rare wet gas spectra; their source has not been identified. The highest FIS helium response (1,600 ppm) is in the PH.

The documentation of helium in the four core holes from this basin, in addition to a full suite of helium and noble gases from the Deep River basin, NC, suggests the potential for a new helium and noble gas province in the Triassic rift basins of the Eastern United States.



The geology of eastern North Carolina consists of a relatively thin to increasingly thick veneer of 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 (modified and adapted from **Schruben and others, 1998**).



Exposed Newark Supergroup basins in the Southeastern USA (from **Olsen and others, 2015**). The Deep River basin is labeled 2; the Dan River basin is labeled 1 (includes both 1a, and 1b).



Town of Walnut Cove parcels in area of interest (bordered in red). The "Town of Walnut Cove" (SO-C-01-15) stratigraphic core hole was drilled on the triangular-shaped parcel (center right of field of view). A railroad track and the Town Fork Creek lies immediately to the northwest of the parcel.

This report confirms that light hydrocarbons and helium were the gas emitted from a stratigraphic core hole where it intersected the Walnut Cove Formation in the Dan River basin. Three legacy cores, also from the Walnut Cove Formation, were found to have light hydrocarbons and helium also. No previous oil or natural gas shows had been documented in this basin before. The basin is untested for hydrocarbons, there has been no leasing, and no seismic lines are known in this basin. This study includes three legacy cores, and exposed quarry faces in the Cow Branch Formation in the Ararat quarry.

In 2015 the North Carolina Geological Survey (NCGS) drilled a 1,447-ft-deep continuous stratigraphic core hole (**Reid and others, 2015a**). The "Town of Walnut Cove" (SO-C-01-15) stratigraphic core hole began in the lower part of the Dry Fork Formation, and cored the entire Walnut Cove and Pine Hall formations before penetrating Paleozoic metamorphic basement rocks at a depth of 1,415.2 feet. The core hole penetrated about 325 ft of organic lacustrine sediment (interpreted as the entire Walnut Cove Formation) between a depth of 98 feet to 423.7 ft. The "Town of Walnut Cove" (SO-C-01A-15) side track stratigraphic core hole was deviated about 2° from vertical, was advanced to a depth of 277 ft to fully recover a coal and coaly section that was penetrated but only partly recovered in the main core hole. Beginning at a depth of 253.1 ft, at least 3 ft of coal was recovered and organic mudstone and siltstone that degassed. The remainder of the side track hole is coaly black organic matter to its total depth and contains multiple

gas shows that triggered the fluid inclusion stratigraphy (FIS) study. The stratigraphic core plus three archived 1981 shallow legacy industry cores from the Walnut Cove Formation were analyzed by fluid inclusion stratigraphy (FIS). Results from all four cores confirmed the presence of light hydrocarbons and helium throughout the Dan River basin, and confirmed the presence of a petroleum system.

The Walnut Cove Formation is a gas prone petroleum system (**Reid, 2015**; **Reid and others,** 2014a,b; Reid and others, 2015b). Robbins (1982) concluded that oil may have formed and had either migrated or progressed through the oil window to dry gas. **Robbins (1982, p. 94)**, reported a %Ro of 2.15 with a standard deviation of 0.08 ranking the coal as a semi-anthracite from a mine dump near Walnut Cove, North Carolina. **Robbins (1982, p. 246)** suggested that coatings on framework mineral grains are "... the residue of petroleum that was long since-expelled from these rocks" implying that maturation temperatures reached at least the oil window.

The Dan River basin contains an unconventional continuous gas-prone assessment unit (AU) and a total petroleum system with an estimated technically recoverable mean gas content 49 BCFG and no natural gas liquids from data available in 2011 as assessed by the U.S. Geological Survey (Milici and others, 2012).

The discovery of helium in all four cores from the Walnut Cove Formation analyzed by fluid inclusion stratigraphy (FIS) for this study shows that this gas is widespread. FIS is not suitable to analyze the other noble gases (Ne, Ar, Kr and Xe) as reported by **Reid and others (2015c)** from two wells in the Deep River basin – another Triassic rift / lacustrine basin in North Carolina's Piedmont. Helium stable isotope analysis by **Reid and others (2015c)** show that the helium is of crustal origin, not of a mantle origin. The discovery of helium in both the Dan River- and Deep River basins suggests that the Triassic rift basins may be a potential helium province in the Eastern United States. Further testing of core and cuttings from other wells (e.g., Virginia) and other eastern states is required to test this hypothesis. **Anderson (2017)** inidcated that "...attempts to increase production from the U.S. Federal Helium Reserve (the FHR) may not be able to compensate for the loss of one of the few major producers in the world."

Confirmation of hydrocarbon shows and helium in the Walnut Cove Formation: Triassic rift / lacustrine Dan River basin (Stokes and Rockingham counties), North Carolina -- A potential new helium province in the Eastern United States?

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Background of Study

Potential Extension to Other Areas of the Basin

The possible extension of light hydrocarbons and helium to other parts of the Dan River basin through FIS analysis provides an independent line of evidence to support the USGS's oil and gas assessment (Milici and others, 2012).

Potential Significance of Results



Stratigraphy for the Deep River- and Dan River basins; this is slightly different than that used by **Milici** and others, 2012. The lacustrine strata are colored gray in the Deep River basin part of the figure, and colored green for the Dan River basin portion of the figure. The Cumnock Formation (Deep River basin) and the Cow Branch and Walnut Cove formations (Dan River basin) are the organic source rocks and unconventional reservoirs (red ovals). The type section for the Pine Hall Formation was designated by **Reid and others**, 2017a,b,c.

The Deep River basin stratigraphy is from **Reinemund (1955)**, and the stratigraphy for the Dan River basin is from **Olsen and others (2015)**. The Cumnock Formation and Walnut Cove Formation are interpreted as early Norian Age (225-227 Ma); the Cow Branch Fm. is late-early to middle Norian Age (217-222 Ma) (Olsen and others, 2015).



Wire line core drill used for the Town of Walnut Cove (SO-C-01-15) stratigraphic core hole. The drill rig is a truck mounted Christianson CT-14 core drill. Visible in the photograph are support vehicles, some of the drill rods, cement (covered with black plastic), and logging table (under white tent).

on Panel 2 to for legibility and detail. molecular weight and two sulfur compounds.



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Fluid inclusion stratigraphy (FIS) depth profiles and data

Four core holes from the Walnut Cove Formation were sampled for FIS analysis. Three of the cores were drilled in 1981. The fourth was drilled by the North Carolina Geological Survey (NCGS) in 2015, targeted the Walnut Cove Formation, and also thin organic intervals in the stratigraphically lower Pine Hall Formation. The locations of these core holes are shown below. FIS depth profiles showing all the data are presented in this report. These data displays are enlarged for readability

Millivolt responses for selected ionic species or species ratios resulting from FIS mass spectrometric analyses are displayed below adjacent with a leader line to each core hole. The data displays are tracks (across) vs. depth. The identity of the individual track plots are in the adjacent Table 1 (right). The tracks are organized into groups of related compounds; tracks 1-6 representing inorganic gases, tracks 7-9 representing dry organic gases, tracks 8-14 representing water soluble organic species or ratios of "more soluble" to "less soluble" species, and tracks 15-20 and 21-25 representing petroleum components of higher

(COS⁺) in some cases CS₂ plus hydrocarbons Toluene (C_H_)

the hydrcarbons and helium.



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