Stratigraphy, Geochemistry, and Organic petrology from the Esso Hatteras Light #1 and the Mobil State of North Carolina #3 and their effect on hydrocarbon prospectivity in Coastal North Carolina

North Carolina Geological Survey Open-File Report 2018-06



Socony Mobil Oil. Co., Inc.

Mobil State of North Carolina #

intermittent. Sulfur species are not

wet gas - gas condensate: 8%

Sulfur species are rarely found.

Several occurences of gas prone kerog

and rare to common occurrences of o

low hydrocarbon responses: 86%

Hydrocarbon species to C9 are found in this zone. There are no proximity to gas

Proximity to liquid petroleum indications

are rare. Sulfur species are rarely found.

Rare occurences of gas prone kerogen

are observed on thin section slides from

gas condensate - oil: 0%

Hydrocarbon species to C7 are

to liquid petroleum indications are

gas prone kerogen and several

occurrences of oil prone kerogen are observed on a slide from samples from

low hydrocarbon responses: 86%

ocumented in this interval. Proximity to

as indications are intermittent. Proximit

intermittent. Sulfur species are extensivel

Several, low gravity petroleum inclusions

are recorded and several occurrences of

and rare occurrences of oil prone kerogen

dications preserved in this zone.

prone kerogen are observed on thin section

his interval. There are no proximity to ga indications in this zone. Proximity to liqu

Abstract

Carolina (NC) Geological Survey undertook a geochemical study to determine: (1) if hydrocarbons reported in a fluid inclusion e Mobil State of North Carolina #3 (NC#3) (Coleman *et al.*, 2014), and oil shows reported in post-drilling examination o Hatteras Light #1 (HL#1) well were *in situ* or migrated, and (2) to provide new data on the petroleum offshore NC. Drilling for oil/gas in coastal NC began in 1921. Oil and/or gas shows have been reported in wells, and oil occurrences were described in local, early 20th century newspapers. No reports of oil/gas have been found in wells in similar settings in VA, SC, and GA.

used on intervals where hydrocarbons had been reported. Analyses included %TOC, %Ro, programmed pyrolysis, organic petrology, and biomarkers. The NC#3 penetrated 7,222' of Tertiary and Cretaceous strata overlying Precambrian granite. The down-dip HL#1, the deepest well drilled on the NC Atlantic Coastal Plain, encountered 9,878' of Tertiary and Cretaceous strata above granite.

Geological and geochemical data indicate sampled intervals are too thin, organically lean, and immature to source commercial conventional or unconventional hydrocarbons in the onshore or state waters of NC. Anomalously high %Ro values in the HL#1 may be due to allochthonous kerogen from nearby exposed Triassic rift basins of the Piedmont. Analyses of these basins indicate ~3,300′ – ~10,000' of syn-rift strata were removed during their inversion, exhumation, and erosion.

The in situ or migrated nature of the hydrocarbons remains problematic. Biomarkers suggest an in situ origin. However, in the HL#1, interpreted mobile hydrocarbons were detected at ~815' in Tertiary strata, and solid bitumen and migrabitumen sporadically were identified in Cretaceous rocks. These, the lack of viable source rocks, and low level of thermal maturity suggest their relation to a migration pathway(s), the "Carolina Ridge Complex". Both interpretations suggest better hydrocarbon source rock potential and generation-expulsion-migration may have existed farther offshore in deep waters of the Atlantic OCS. Sea-surface hydrocarbon seepage slicks identified on satellite synthetic aperture radar images, and hydrocarbon-related diagenetic zones and "chimneys" interpreted on reflection seismic data suggest vertical hydrocarbon migration in this area (Post et al., 2018).

Geological overview of Eastern North Carolina

The geology of eastern North Carolina consists of an eastward thickening veneer of siliciclastic and carbonate sedimentary rocks and coastal plain sediments, which range in age from Cretaceous to Recent. This coastal plain section has a relatively simple structural geology, with few faults and structures. These sediments typically overlie a complex of folded and faulted meta-igneous and metasedimentary rocks of Early Paleozoic to Late Proterozoic age.

Late Triassic-Early Jurassic syn-rift strata are exposed on the surface in the Deep River basin >150 mi west-northwest and updip from the NC#3 and HL#1 wells. Approximately 80 mi northwest, beneath onlapping Cretaceous and younger coastal plain strata, a single well (Weems et al., 2007) penetrates what may be Late Triassic–Early Jurassic (L Tr–E J) syn-rift strata beneath Cretaceous and younger age sediments in easternmost North Carolina.

A large, linear, negative aeromagnetic anomaly strike-parallel and seaward of the Deep River basin (~150 mi southwest of the NC#3 and the HL#1) was interpreted to indicate a large L Tr–E J rift basin, the "Cumberland-Marlboro" rift basin (Reid et al., 2016). The North Carolina Geological Survey (NCGS) drilled three rotasonic drill holes to basement (Reid et al., 2016) to evaluate this anomaly. At depths ranging from 185 to 334 ft below the present surface, all the drill holes recovered metavolcanic and metasedimentary basement rock along the tested strike extent of the anomaly. Consequently, the interpreted "Cumberland-Marlboro" basin does not exist (Reid et al., 2016), and the use of aeromagnetics to define Late Triassic–Early Jurassic rift basins is questionable.

Most of the wells drilled within and around Pamlico Sound reached total depth in a high grade metamorphic basement composed of metavolcanic and volcanogenic metasedimentary rocks of the Roanoke Rapids terrane and metamorphic plutonic rocks of the Hatteras terrane (Horton et al., 1991). With the possible exception of a hypothesized and undrilled Triassic-Jurassic rift basin in Jones, Craven, and Pitt Counties, NC, there is no likely local source rock kitchen to provide petroleum to available reservoirs.

Background and Study Objectives

Coleman et al. (2014) confirmed the presence of hydrocarbons in the Mobil State of North Carolina #3 (NC#3) well located in Dare County, NC, using Fluid Inclusion Stratigraphy (FIS). FIS is a patented technique that was used for the NC#3 study. FIS allows rapid analysis for formation fluids trapped as inclusions in cuttings, core, or outcrop samples. Coleman et al. (2014) hypothesized an offshore source for these hydrocarbons, implying that these represent migrated hydrocarbons. However, they could not preclude locally generated and expelled hydrocarbons. At least nineteen wells (right) have reported shows, oil and/or gas shows including the Esso Hatteras Light #1 (HL#1), drilled in 1946 as a stratigraphic test on the easternmost promentory of Cape Hatteras to a total measured depth of 10,054 ft, is the deepest well drilled on the Atlantic Coastal Plain.

Malinconico and Weems (2010) examined the thermal maturity of the U.S. East Coast Atlantic legacy wells including the HL#1 well and concluded that all onshore and state water wells in eastern North Carolina are either thermally immature or just marginally mature for hydrocarbon generation. However, no "standard" geochemical analysis including determination of Total Organic Carbon (TOC) and Rock-Eval pyrolysis of samples, organic petrographic analysis and interpretations of biomarkers were ever performed on

Exhaustive literature research as part of this study increased the number of wells with shows in Coastal NC compared to Coleman et al. (2014). The majority of these shows occur in Cretaceous sediments.

Questions to be addressed in this study

migrate from another area (presumably further basinward - likely offshore and eastward)?

Did the hydrocarbons in the Esso Hatteras Light #1 (HL#1) and the Mobil State of North Carolina #3 (NC#3) wells form in situ or did they

Possible Extension to Other Wells with Shows

This two-well study sheds light on reported hydrocarbon shows (primarily in Creaceous-age strata) in nineteen wells from coastal NC. In his initial examination, Richards (1954) questioned the formation at total depth for the Foreman #1 (DuGrandlee) as possibly being Triassic. However, Richards (1967) upon correlation and subsequent 1965 drilling at the Blair-Weyerhaeuser well 300 ft from the Foreman #1 penetrated unquestionable diabase. Its well records are unclear and there are no modern studies confirming the stratigraphy / lithology at total depth.

Now nearly five years after Coleman et al. (2014), our additional work has uncovered additional wells with shows. However, several of these were drilled by the Carolina Petroleum Company to basement in Carteret County, NC, with "Slight odor of gas and oil and ether cuts of oil and fluorescence cuts..., but these reported showings have not been proved beyond question to be petroleum" (Richards, 1947). Not all the wells in coastal NC had hydrocarbon shows reported until recently examined, e.g., HL#1. This raises a significant question: Why were no shows ever reported in exploration wells in adjacent states (VA, SC, and GA), like many of those in coastal NC. What

The nearest, best quality, and documented potential source rock intervals are in the DSDP Well 603B, ~200 miles offshore and are of Cretaceous age. There might be a link between these shows and potential mature source rocks elsewhere in the basin. Gas detections in the shallow portions of the nineteen onshore coastal wells might be biogenic gas similar to that detected in the NC#3 FIS analysis (Coleman et al., 2014; Reid, 2018a).

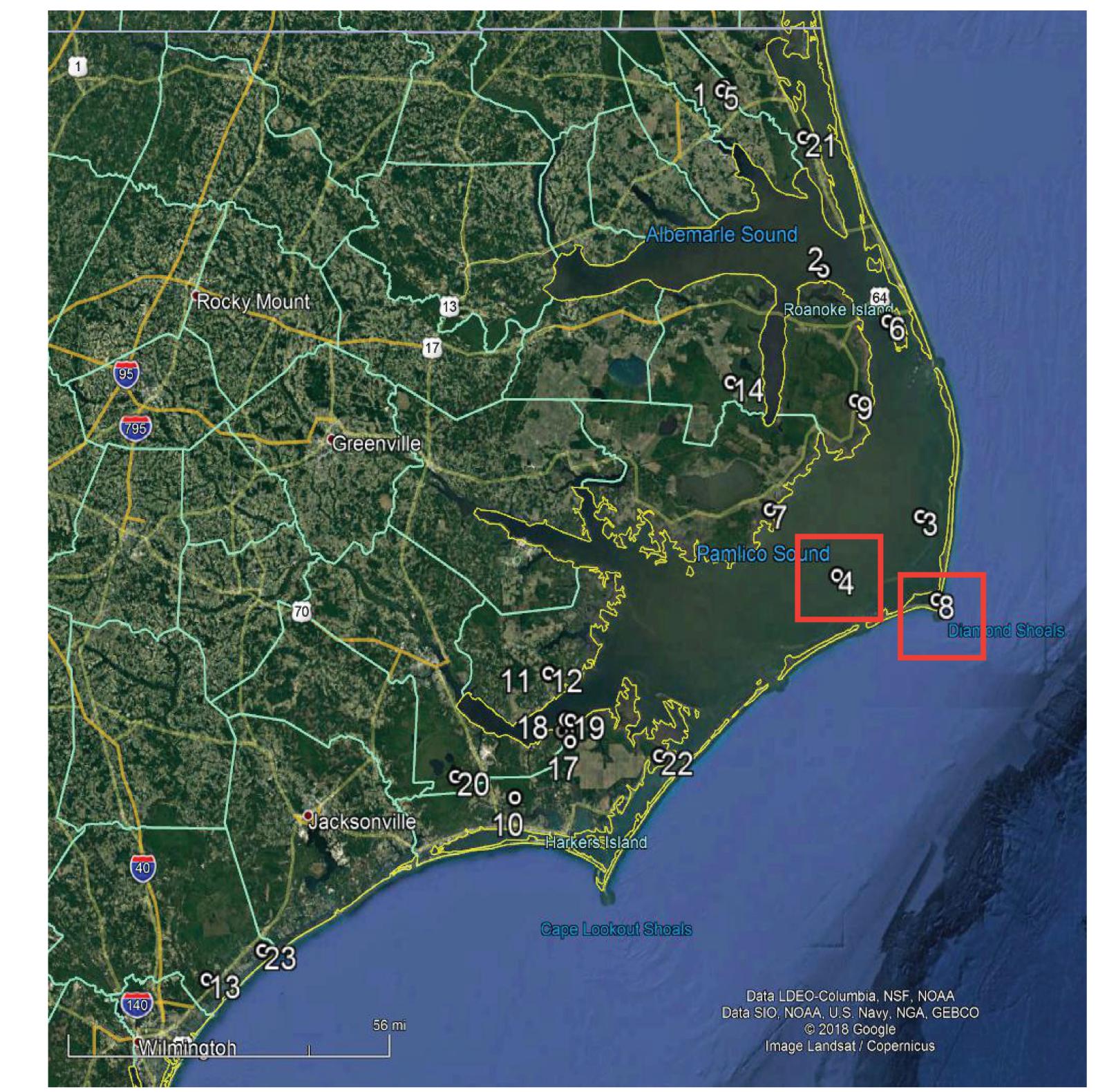
Potential Significance of Results

The in situ or migrated nature of the hydrocarbons remains problematic. Lines of evidence discussed in this contribution suggest that better hydrocarbon source rock potential and generation-expulsion-migration may have existed farther offshore in deep waters of the Atlantic OCS where the sedimentary interval is also thicker.

Sea-surface hydrocarbon seepage slicks identified on satellite synthetic aperture radar images, and hydrocarbon-related diagenetic zones and "chimneys" interpreted on reflection seismic data suggest vertical hydrocarbon migration in parts of this area (Post et al.,

by Jeffrey C. Reid*, James L. Coleman, Jr.**, and Paul J. Post***

* North Carolina Geological Survey, Raleigh, NC 27699; **Coleman Geological Services, 130 Wesley Forest Drive, Fayetteville, GA, 30214, and ***U.S. Department of the Interior, BOEM, Office of Resource Evaluation, 1201 Elmwood Park Blvd., New Orleans, LA 70123-2394.



List of wells with recorded hydrocarbon shows (map number in table keyed to map above). Other hydrocarbon wells along the coast not shown for clarity.

(pers. comm.);

comm.); FIT

report to NCGS

(poss. scout w/GCM-Eutaw &

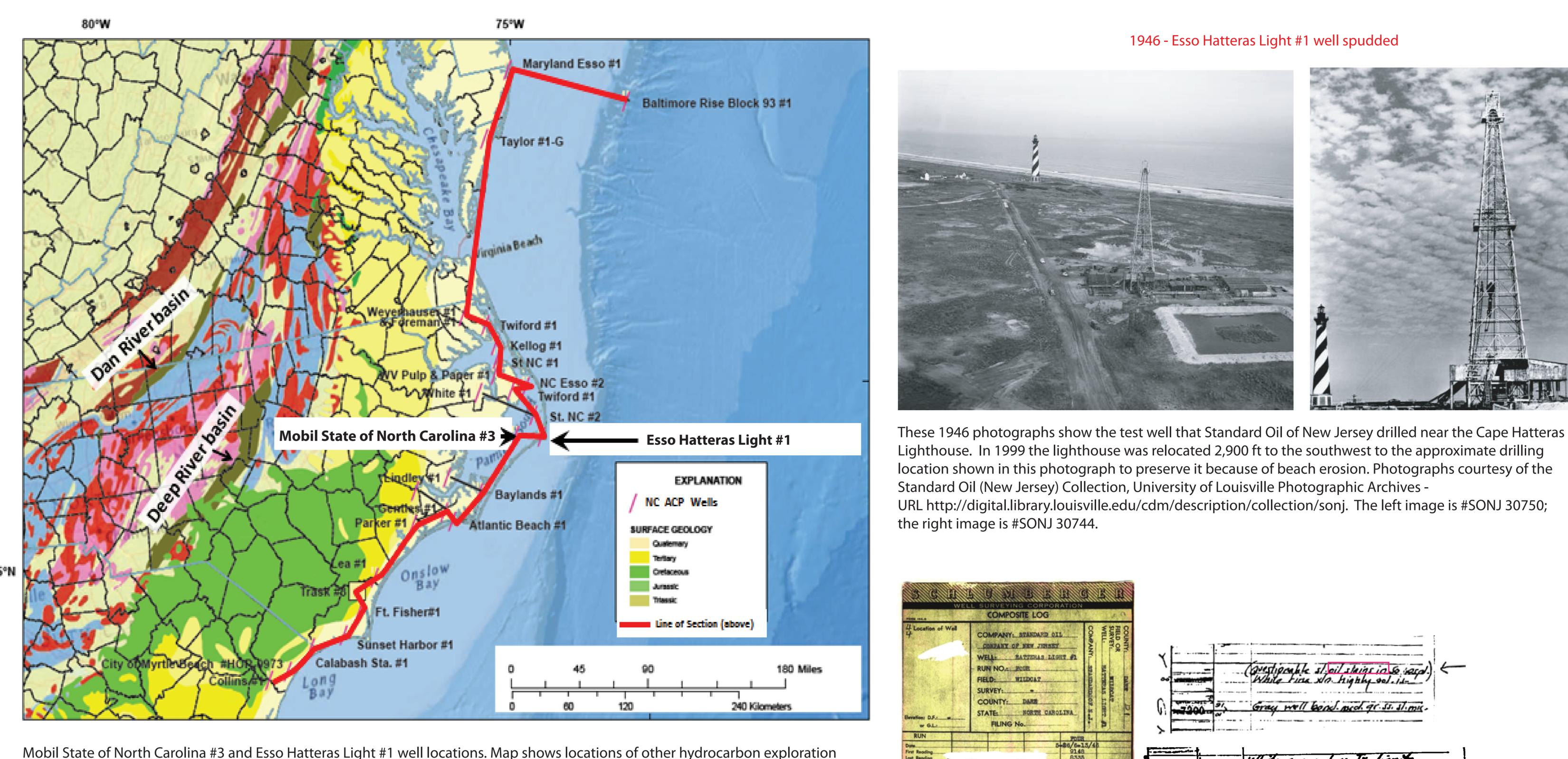
13 Coleman et al oil and gas show

(poss. scout unspecified

(poss. scout unknown depth)

Geomark (pers.

Table listing shows and well attributes. Numbers and/or well names correspond to location maps (above); study wells highlighted.



wells drilled on the North Carolina coastal plain.

METAPLUTONIC

The following is a chronology of indications and shows of oil and gas in the NC coastal plain. This sequence with the pamphlet excerpt (circa 1919), and newspaper articles (1924, 1931, 1960), post card (1953), and photographs of the Esso Hatteras Light #1 well being drilled provides a historical perspective for interest in hydrocarbon exploration along the North Carolina coastline. Recent studies (Coleman et al., 2014), and the present study employed modern methods to gain an improved understanding of the presence of oil and gas shows. Hairr's (2011) account of nineteenth century oil exploration in

Indications of Petroleum - ? circa 1919 Indications of Petroleum Mr. Remick found that the natives, and especially the negroes, regarded this section with fear and superstition.

Investigation proved that most of this apprehension arose from oil seepages in various localities. The natives also complained of the difficulty in sinking wells in which the water would not be impregnated with substances strange to them. It was ascertained that many of such wells had quantities, and in many cases the walls of these wells showed

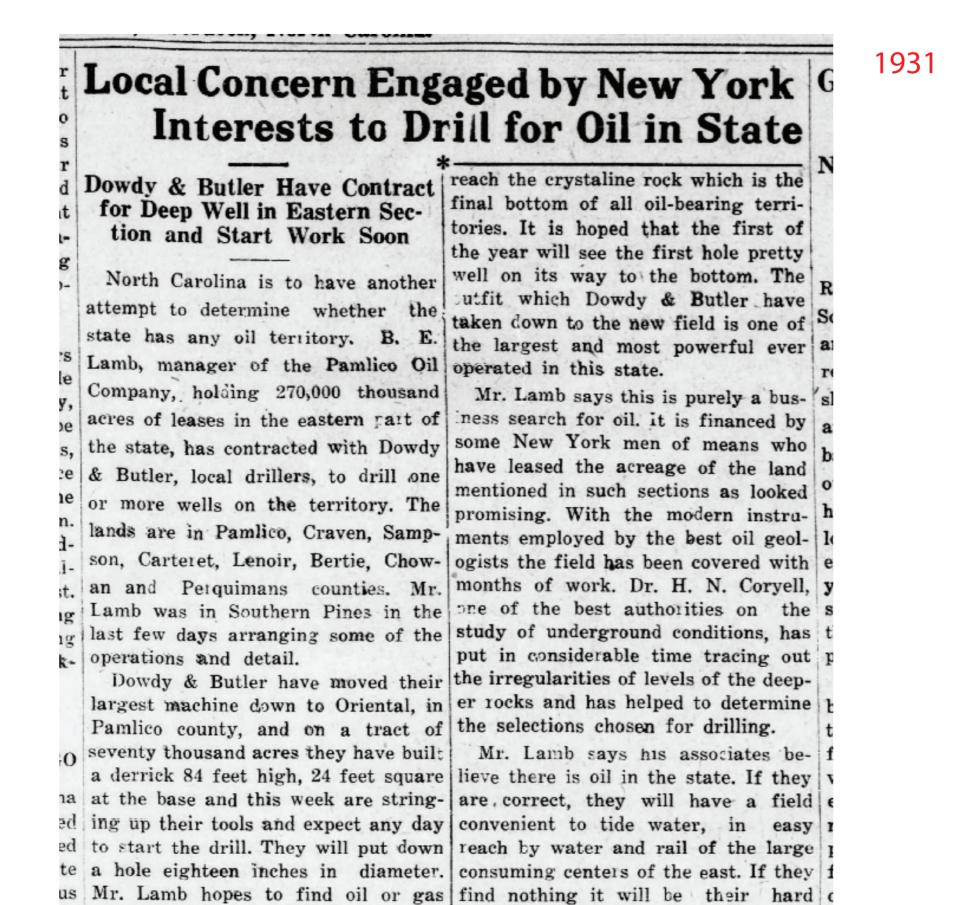
These indications of petroleum are not confined to the land. The steamers which skirt these coasts south of Cape Hatteras often pass through extensive areas in which water is covered with an oily scum. Not long ago a steamer headed for New York passed through an area so heavily covered and swept this coast. On his arrival in New York he thus ships had been lost. He was informed to the contrary.

Carolina Petroleum Co., 1919-? (see URL in references).

"VERY RICH OIL SAND"

REACHED AT HAVELOCK brought to New Bern today by Dr. Armstrong from Havelock Pennsylvania Drillin Company is sinking the first well on the Great Lake place said that a stratum what was described as "very rich oil sand" was struck late Saturday and at Havelock..." through it today at a depth of

The Enterprise, September 30, 1924, p. 1, Volume XXV – Number 66



within a thousand to fifteen hundred luck, but the prospects look so good

The Pilot, a Paper With Character, Aberdeen, North Carolina, Friday, November 5, 1931, p. 3

or feet, but says the company plans to to the company that they are willing

go five thousand feet if necessary to to venture their money.

http://newspapers.digitalnc.org/lccn/sn92073968/1931-11-06/ed-1/seq-3/

Oil / gas show chronology "Esso Standard Oil Company spudded its Hatteras Light well No. 1. On July 19, 1946, the well was officially abandoned as a dry hole at the total depth of 10,054 feet. No ccurrences of oil or gas were found." (Spangler, 1950, p. 105). [Spangler was a geologist with Esso Standard Oil Company in 1949 when he submitted the original North Carolina focused mostly on the on-land Triassic rift basins and is noted here for manuscript to the North Carolina State Geologist with permission of Esso Standard

They told stories of happenings which were unexplainable to them; of strong odors, noxious vapors and of other mysteri-

1953 post card showing North Carolina coastal plain drilling rig;

source: https://www.flickr.com/photos/unclibraries_commons/23072234206

LE HATTERAS LIGHT

Hope Springs Eternal for Discovery Of Oil, Natural Gas in Coastal Area

Since that time a

but no oil or natural

gas has yet been

discovered.

Carteret County News-Times (March 25, 1960)

A service of the serv

White proceed w. Ir. liquity.

Gray well bond med gr. Ss. sl.mic.

Right - Composite Esso Hatteras

Light #1 (HL#1) well log showing

available cores, %R₂ and hydro-

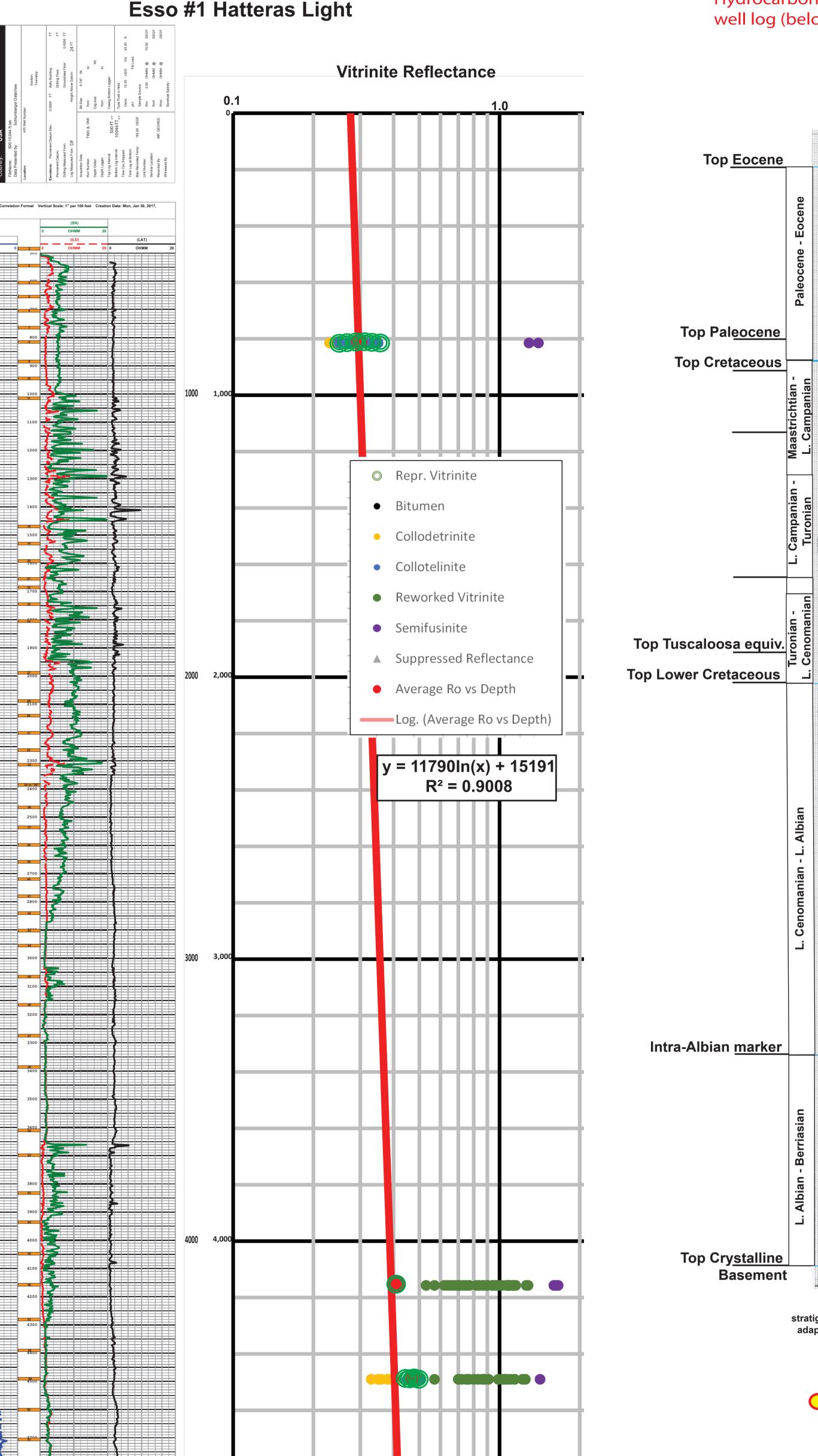
The chronology of oil/gas

section beginning ~1919.

in coastal North Carolina

is documented in this

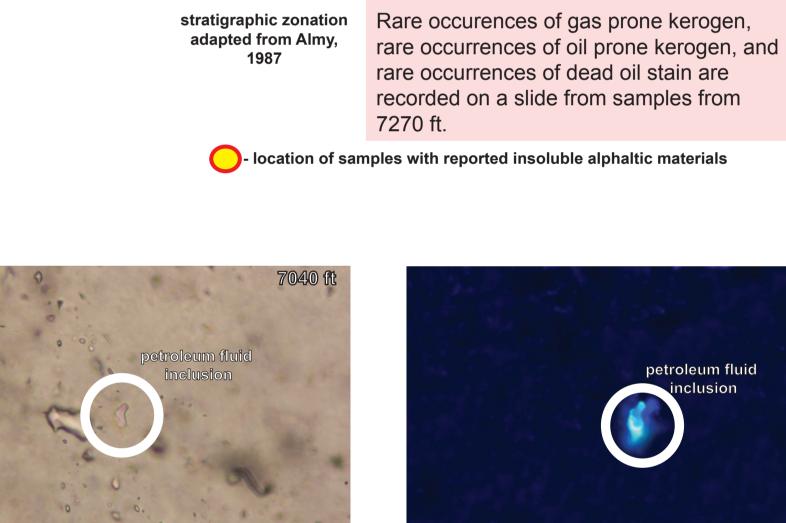
Morehead City and Beaufort N.C., p. 6, Section 2. URL http://newspapers.digitalnc.org/lccn/sn94058246/1960-03-25/ed-1/seq-12/ coastal North Carolina: North Carolina Geological Survey, Open-File Report 2018-06. Three panels

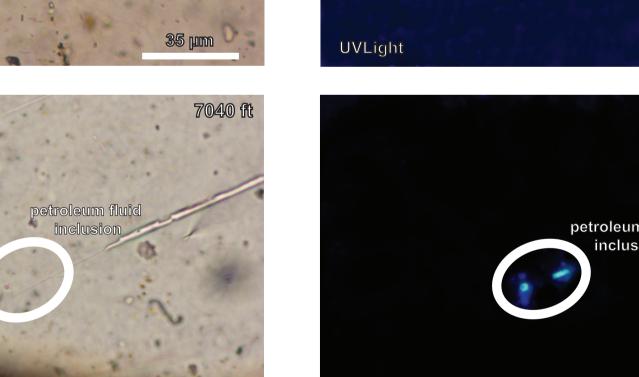


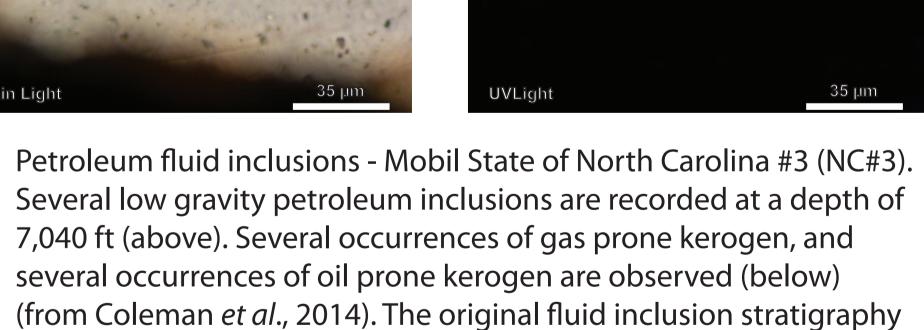
ross plot vs. depth of optical reflectance from various organic

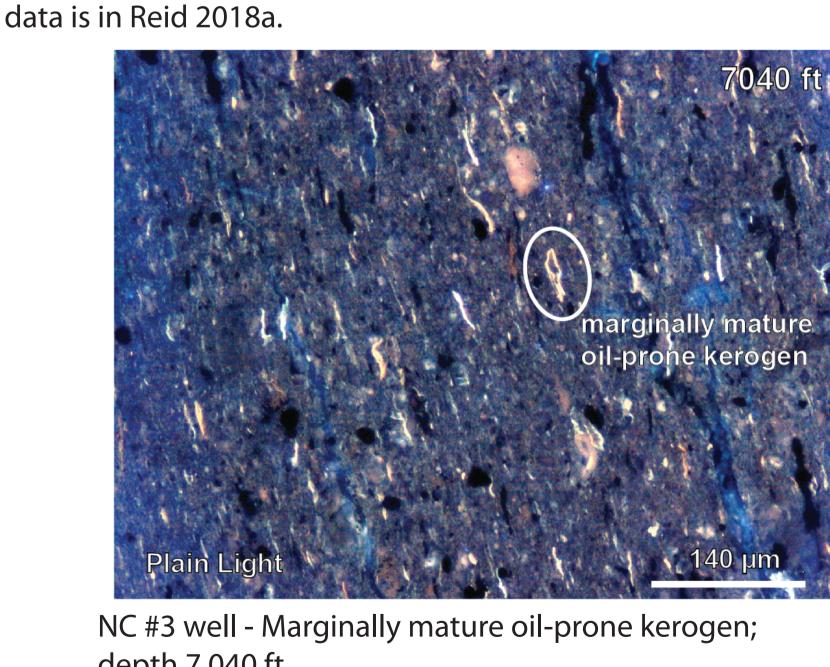
("Repr. Vitrinite") values only.

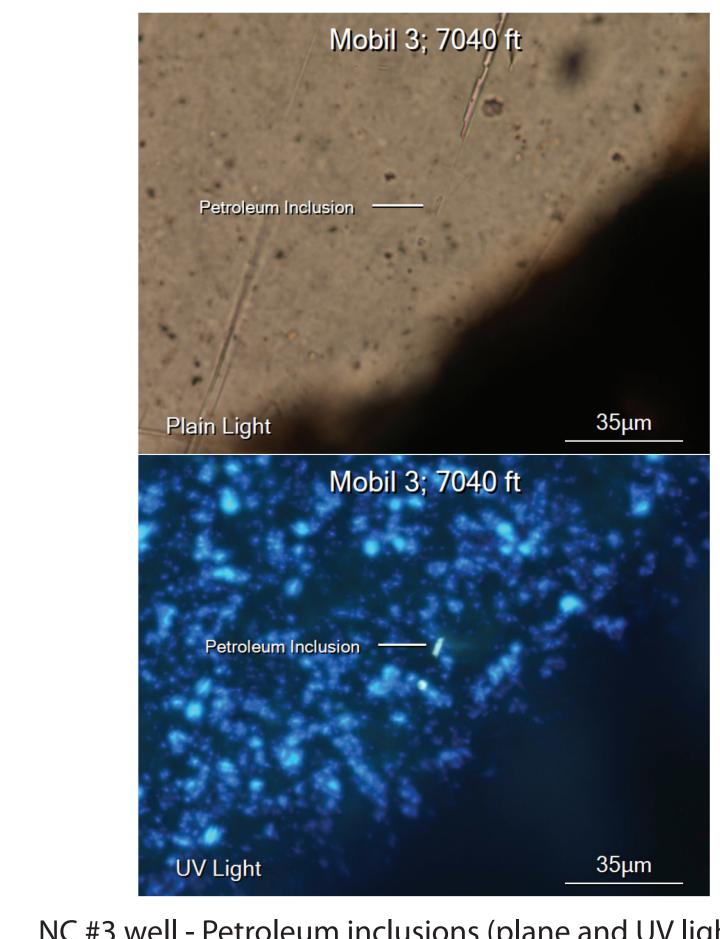
materials sampled from the Esso Hatteras Light #1 well. Regression











line is derived from average of representative vitrinite reflectance NC #3 well - Petroleum inclusions (plane and UV light);