Preliminary Carbon Dioxide (CO_2) Sequestration Characterization: Dare, Tyrrell, and Hyde counties, North Carolina

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ABSTRACT

Preliminary assessment of potential saline aquifers suitable for carbon dioxide (CO_2) sequestration in North Carolina's Coastal Plain (Dare, Tyrrell, and Hyde counties) was undertaken on Lower (Early) and Upper (Late) Cretaceous strata from -3,000 feet to -6,100 feet below sea level. National assessment criteria by the U.S. Geological Survey, U.S. Environmental Protection Agency, and the U.S. Department of Energy for CO_2 injection into geologic formations are a depth greater than -3,000 feet, and formation waters with over 10,000 ppm dissolved solids.

About 153 line miles of 1970's-era 2D seismic data along with paper geophysical logs from nineteen oil exploration wells and sub-surface structural maps (circa 1980's) were converted from paper to digital formats – .sgy, .las, and .shp formats respectively suitable for geographic information system (GIS) and modern seismic software.

Analysis indicates a potentially continuous 150 to 200-foot thick sand at a depth of -4,500 to -6,600 feet along a coast parallel strike line for ~35 miles. This sand is above the crystalline basement. An overlying stratigraphic sequence has sand units beginning at a depth of about -3,500 feet extending downward to the top of the lower sand. Some structural closure is present. These sands could be a potential natural gas storage reservoir.

The M2-6600 sand (depositional unit 1 of Almy 1987a,b) of Lower (Early) Cretaceous age underlies most of Dare County at a depth below surface of -3,000 feet or more. The M2-6600 sand has estimated salinities that are close to the 10,000 ppm total dissolved solids (TDS) criterion, and in many cases exceed that value. There are well-to-well variations in the estimated salinity content. The spontaneous potential (SP) salinity estimates of formation water resistivity used to determine TDS tend to be more saline (NaCl) than those determined by the induction log method supplemented by a few resistivity logs.

The M2-3950 sand in depositional unit #2 of Almy 1987a,b, is shallower and in the northern half of Dare County where it appears to be too shallow (e.g., above -3,000 feet) for CO_2 sequestration. Continuity of sand units is somewhat less clear. However the seismic-stratigraphy approach of Sunde and Coffey provided clarity on the distribution of sands.

Estimated salinities are generally well above the 10,000 ppm TDS criterion. There are also well-to- well variations in the estimated salinity content. The SP salinity estimates tend to be more saline than those determined by the induction log method.

Substantial additional work would be required to determine if these sands are suited for natural gas storage potential.

Porosities of these sands were determined from well log data and estimated from point data to range from 18% to >50%.

The prime target area, Dare County, is near several large industrial CO_2 emitters. The sparsely populated area has extensive federally-owned lands including the Navy-Air Force electronic bombing range and qualification range (Dare Bombing Range).

The impetus to undertake this reconnaissance-level examination for potential geological CO2 sequestration targets was a USGS grant for $50,000. The focus of that research was to utilize existing data from the N.C. Geological Survey's peer-reviewed archives and the oil and gas regulatory files. Grant deliverables included conversion of all paper documents to digital forms which were compatible with industry-standard software. In addition, the grant included funding to conduct a series of workshops explaining the project with local land owners in the study area, who were to include representatives from several federal agencies (U.S. Air Force, U.S. Navy, U.S. Army Corps of Engineers -- Department of Defense); U.S. Fish and Wildlife Service -- Department of Interior; state agencies (Division of Land Resources, Division of Water Quality, Division of Water Resources – Department of Environment and Natural Resources; Wildlife Resources Commission; Department of Transportation; Department of Commerce); local government, and private landholders.

During the summer of 2011, wildfires burned a large numbers of acres in Dare County. Some of these intense fires ignited the organic rich soil to create ground fires. Hundreds of firefighters were occupied for several months to extinguish these fires. As a result of the six-month fire suppression effort, local, state and federal agencies in that study area were not available to meet with the grant principal investigators. Funding budgeted for those workshops was not spent. Also, because of analytical instrument problems, we were unable to use of a scanning electron microscope (SEM) to characterize grain shape.

CONTENTS

OVERVIEW, LOCATION AND AVAILABLE DATA

Overview

In 2007, the Energy Independence and Security Act (Public Law 110-140) authorized the U.S. Geological Survey (USGS) to conduct a national assessment of potential geologic storage resource for carbon dioxide (CO_2) in cooperation with the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). Subsequently the assessment methodology for CO_2 is focused on the technically accessible resource, not a total in-place volume using present-day geological and engineering knowledge and technology for CO_2 injection into geologic formations (Brennan and others, 2010).

The national effort is a volumetric resource effort. Potential storage formations with salinities less than 10,000 ppm (mg/L) total dissolved solids (TDS) will not be assessed by the methodology. A "sequestration formation" means a deep saline formation, unminable coal seam, or oil or gas reservoir that is capable of accommodating a volume of industrial carbon dioxide. The methodology generally follows that used in the national oil and gas assessment which is geologically driven with numerical probabilistic assessment volumes reported. Such an assessment is beyond the scope of this report.

This report provides results of reconnaissance investigations into potentially suitable geologic formations for CO_2 sequestration in the subsurface geology of northeastern North Carolina coastal plain Lower Cretaceous strata at a depth of greater than -3,000 feet below sea level to a depth of about -7,000 feet. Dare, Tyrrell, and Hyde counties are in the study area (Figure 1).

Review of available subsurface 1970's-era seismic, geophysical logs (self potential, induction and resistivity), available sub-surface structure maps and stratigraphic correlation sections (1980's) indicate a potentially continuous sand with a thickness for 150-200 feet at a depth below sea level of -4,500 to -6,600 feet along a coastal strike parallel line of about 35 miles or more on land and below state waters. This sand unit overlies the crystalline basement. An overlying younger stratigraphic sequence appears to have potential sand units beginning at a depth of about -3,500 feet extending downward to the top of the previous unit.

Dare, Hyde and Tyrrell counties, North Carolina are the primary study focus. They are located relatively near several large industrial CO_2 emitters. Dare County is sparsely populated except along the barrier islands. It has extensive federally-owned lands including a large parcel used as a U.S. Navy / U.S. Air Force electronic bombing range and qualification range (Dare Bombing Range). Hyde County, also sparsely populated, has no permanent residents on its barrier islands and has extensive federally-owned lands, and state waters. Tyrrell County, in the northern part of the study area, is also sparsely populated and does not have barrier islands. Potential CO_2 injection well locations and facilities could be located on state or Federal lands.

Location and available data

The study area in Dare, Tyrrell, and Hyde counties, North Carolina includes portions of the Croatan, Albemarle and Pamlico Sounds (Figure 1). The area ranges roughly from Cape Hatteras north to the North Carolina-Virginia state line. Almy (1987a,b) conducted a lithostratigraphic-seismic evaluation of this area for hydrocarbons as part of the Minerals Management Service / Association of American State Geologists (MMS/AASG) continental margins program under a contract from the North Carolina Geological Survey (NCGS). Almy used NCGS data consisting of 1970's era, 153 miles of 2D seismic (mylar), geophysical logs (paper) of nineteen wells to crystalline basement and developed five depositional units cross-linked to those of Brown and others, 1972, and to Owens and Gohn, 1985). The NCGS maintains well cuttings from all these wells, in addition to the seismic lines and well logs. During Almy's study modern sequence stratigraphy was just becoming more widely adopted.

The lowest of the two units (Depositional Units 1 and 2) defined by Almy are at or below -3,000 feet below sea level (Figure 1). Zarra (1990) provided biostratigraphic information for some of the wells in the proposed study area.

McKinney (1985) provided information on lithostratigraphy and seismic stratigraphy. In particular, McKinney (p. 43) interpreted in his Facies 1, subfacies 1b, "…mature barrier or perhaps barrier islands" based on the thickness, coarsening upward base, composition and low angle accretion dips of the sandstones. Much of this appears to be the M2-6600 sand that was investigated in the lower unit by this study. Sunde and Coffey (2007) applied a modern sequence stratigraphic analysis for these Lower Cretaceous rocks using thin sections, well logs, 2D seismic data, and biostratigraphic control using NCGS core respository data.

Lawrence and Hoffman (1993) in a study of the geology of the basement rocks beneath the North Carolina Coastal Plain provided a depth to basement map controlled by wells that encountered the basement. The core and cuttings used in that study are available from the NCGS.

OBJECTIVES

Our objectives were to investigate the extent, thickness, structural feature, and potential seal(s) and of selected sands in Almy's depositional units 1 and 2 both of which located below -3,000 feet or greater. Almy interpreted his depositional unit 1 as non-marine, and his depositional unit 2 as deltaic.

Two potential CO_2 reconnaissance sequestration targets are a thick sand at the top of Almy's lower unit, depositional unit 1 (M2-6600), and recurring sands in his upper unit, depositional unit 2 (Figures 2, 3). Almy denoted the sand that occurs at the top of his depositional unit 1 as M2-6600 (Aptian Age). It occurs at a depth of -6,600 feet in well DR-OT-02-65 State of North Carolina #2 (Mobil #2) well. This sand is also distinctive and present in all nineteen wells examined in this study. The M2-6600 sand has a mean thickness (N=17) of 82.1 feet with a standard deviation of 39.7 feet. Overall the sand thickens to the southeast from its updip limit. Basic bed thickness statistics and comparative bed thickness with selected sands of Almy's depositional unit 1 are shown in Figure 4. This corresponds to McKinney's (1985) 'coastal barrier or barrier islands'.

The M2-6600 sand, shown on Sunde and Coffey's panel, is bounded by their transgression surface TS 1.1 and overlain by a moderately thin quartz sandy mollusk packstone or grainstone, which is overlain by a fairly thick siltstone that may serve as a seal. The same sequence is present in the DR-OT-3-65 Marshall Collins #1 well. In the well HY-OT-1-65 State of North Carolina #3 (Mobil #3) the sand thickens considerably occurring as two thick quartz sandstones separated by a moderately thin shale-siltstone; the quartz sandy mollusk packstone or grainstone is not present. Other potential seals (shale-siltstone, marl-lime mudstones, and quartz sandy mollusk packstone or grainstone) are present within a short stratigraphic interval above the M2-6600 sand.

A second target zone is Almy's depositional unit 2 (Cenomanian Age) (corresponding to McKinney's Facies 2, subfacies 2a). According to McKinney (1985) it consists of a "coarsening upward facies characterized by sandstones with a blocky repetitive SP pattern. They are mostly fine- to medium-grained, calcareous, micaceous and fossiliferous quartz sandstones about 25 feet thick." This interval is about 200 feet thick beginning at a depth of about -3,440 feet below sea level. The sands thickness measurements of the M2-3950 interval are for individual sands unlike for the M2-6600 sand (see above). The individual sands have a mean thickness (N = 36) of about 45.2 feet with a standard deviation of 12.9 feet. Insufficient data is available to determine trends in thickness of individual sands. Basic bed thickness statistics and comparative bed thickness with selected sands of Almy's depositional unit 2 are shown in Figure 4.

This skeletal quartz sandstone (depth about -5,957 feet) is shown on Sunde and Coffey's panel as well DR-OT-02-65 State of North Carolina #2 (Mobil #2) is bounded above by their transgression surface HS 2.12 and to be overlain by a moderately thick quartz sandy mollusk packstone/grainstone, in turn is overlain by a fairly thick siltstone that may serve as a seal. A similar sequence is present in the well DR-OT-03-65 Marshall Collins #1 except that the sand is a quartz sand and is overlain by a siltstone/shale. In the well HY-OT-01-65 State of North Carolina Mobil #3 (Mobil #3) there are three quartz sands separated by silty-shale and quartz sandy mollusk packstone/grainstone. Other potential seals (shale-siltstone, marl-lime mudstones, and quartz sandy mollusk packstone or grainstone) are present within a short stratigraphic interval above the M2-6600 sand.

CRITERIA FOR CO_2 STORAGE

The criteria under the national carbon dioxide (CO_2) assessment for the geologic storage and sequestration of CO_2 (Warwick and others, 2011; EPA, 2011; Brennen and others, 2010) assuming that a reservoir has been identified. They are:

1. Salinity of water in the storage formation must be >10,000 ppm total dissolved solids TDS) per USEPA (2008) regulations (Brennan and others, 2010), and

2. The storage assessment unit depth range is -3,000 feet to -13,000 feet (Brennan and others, 2010).

In addition, sufficient minimum buoyant trapping pore volume is available, and the formation is bounded by a sealing formation (Brennan and others, 2010).

The final U.S. Environmental Protection Agency rule for Federal requirement under the underground injection control (UIC) program for carbon dioxide (CO_2) geologic sequestration (GS) wells (class VI injection wells) is at URL http://water.epa.gov/type/groundwater/uic/class6/gsregulations.cfm. Final support document and regulatory development history are linked at the same URL (EPA, September 7, 2011).

METHODS AND TERMINOLOGY

Well naming convention

Table 3 lists the NCGS well code (e.g., DR-OT-01-65). The first two letter group is the county code – in this case, Dare County. The second two letter group, OT, denotes an oil test. The next numbers – in this case, 01-65 indicate that this was the first well drilled in Dare County in 1965. Table 3 provides the API well number, in addition to a number of other important information about each well (total depth, logs run, amount of samples (and type), geographic location (decimal degrees for latitude and longitude, etc.).

Analog to digital data conversion

Overview: One task was to convert analog data to digital data. The analog data was in three categories as listed below:

- *Structure contour lines*: Almy's report (1987b - NCGS Open-file report 87-3) contains seven plates. Almy's original report is included in this report's Appendix. Almy's plates 1-4 were scanned commercially and converted to shape files and projected to NC state plate meters, NAD83. Almy's Plates 5-7 (all PDF files) were not converted to digital files as these are cross sections.

Table 1. List of structure maps scanned and converted to georeferenced shape files from Almy, 1987b.		
Plate number	Plate title	Converted to shape file (yes / no)
1	Structure map on crystalline basement	yes
2	Structure map on M2-6600 (Aptian Age)	yes
3	Structure map on M2-3950 (Cenomanian Age)	yes
4	Structure map on top (sic – of the) Cretaceous Age	yes

Seismic lines: Six 2D seismic lines, about 153 line miles, from 1970-71 vintage were scanned commercially and converted to .sgy files that can be imported into modern software programs for display and further analysis. The location of these seismic lines is shown in Figure 1. These data can be combined with the digital well logs (see below).

The seismic lines, contributed by Cities Service Oil Co., are 12-fold common depth-point stack (CDPS) data recorded to four seconds. The data was shot with airgun for inland waters and VibroSeis for land data. The data came to the N. C. Geological Survey processed, including deconvolution. Statics corrections in general are appropriately applied, although some lines show areas where additional corrections could be made. Refer to Almy, 1987b for additional details about the seismic and also the well data available to him at that time.

Drill logs: Drill logs were scanned into TIF file formats by the Virginia Geological Survey. Subsequently the TIF files were converted into .las file format by a commercial vendor. A list of converted logs follows (Table 2).

Table 2. List of wells and logs converted to .las format by well		
Number	Well	Logs (file names for .las logs in Appendix)
1	CK-OT-01-65	Caliper-gamma, caliper-gamma-interpretation, sp-res, sp-res2
2	CK-OT-01-69	Caliper-gamma, saturation, unknown
3	CM-OT-01-65	Gamma1, gamma 2, sp-res1, sp-res2
4	DR-OT-01-46	SP-res1, sp-res2, sp-res3, sp-res4 + tracing (only as tif)
5	DR-OT-01-47	IncompleteUnknown, sp-res2, sp-res3 + tracing (only as tif)
6	DR-OT-01-65	Continuous dipmeter, continuous dipmeter interpretation (tif only), continuous velocity, gamma2, sp-caliper1, sp-res1, sp-caliper2 and 3 (tif only)
7	DR-OT-01-69	SP-res
8	DR-OT-01-70	Calipher-gamma, cementbond, gamma-neutron, SP-res, temperaturelog
9	DR-OT-01-71	Caliper-gamma2, caliper-gamma, res-microcaliper, SP-caliper, SP-res2, SP-res,
10	DR-OT-01-73	Caliper-gamma, caliper-gamma2, SP-res (all tiff only)
11	DR-OT-01-74	Caliper-gamma, SP-res
12	DR-OT-02-65	Caliper2, continuousDipmeter, continuousVelocity, gamma2, SP-

		res
13	DR-OT-02-71	Caliper-gamma2, caliper-gamma, SP-caliper, SP-res
14	DR-OT-02-73	Caliper-gamma2, caliper-gamma, SP-res
15	DR-OT-02-74	Caliper-gamma1, caliper-gamma2, caliper-gamma3, SP-res, formationtester (tif only)
16	DR-OT-03-65	Gamma, SP-res, gamma_interpretation (tif only)
17	DR-OT-04-65	Caliper, gamma, SP-res, gamma_interpretations (tif only)
18	HY-OT-01-65	Caliper, continuousDipmeter, gamma, SP-res
19	HY-OT-02-65	Gamma-neutron

Salinity estimates

Overview: A second task was to provide estimates of salinity in the targeted horizons (Table 3). For the purpose of this study, it was assumed that salinity would be only sodium chloride (NaCl). Two primary methods, SP-method and induction log method, were used. For two wells conductivity logs were available. It should be emphasized that the salinity estimates reported here are just that - estimates. Variations in reported data may include thin beds or septa that influence curve shape and graphical solution. The methods described below used graphical nomographs. Log data was picked manually from the geophysical well logs. The salinities determined from the induction logs and resistivity logs tend to be lower than those of formation water resitivity (R_w) and thus are more conservative.

SP method: Targeted sands were identified using their SP curves. A common horizon in the lower interval, Almy's M2-6600 sand, occurs at the top of his Depositional Unit 1 at a depth of 6,600 feet in the DR-OT-02-65 State of North Carolina #2 (Mobil #2) and in other wells used in this study. Two thick sands in each well were identified in the upper units where possible.

The following procedure (from Asquith, 1982) was used to obtain the resistivity of the formation water (R_w) from the SP log:

From the log header the following were obtained (given data):

- R_{mf} (mud filtrate),
- R_m (drilling mud),
- Surface temperature (^{o}F),
- Total depth (feet), and
- Bottom hole temperature (BHT).

From the log track the following were obtained:

- SP – measured from the log at the formation depth and uncorrected for bed thickness; the deflection (measured in millivolts) was from an author drawn shale base line,
- Bed thickness,
- Resistivity short normal (R_i), and
- Formation depth.

Procedure:

- Determine formation temperature (T_f) – use BHT and nomogram,
- Correct R_m and R_{mf} to T_f – use nomogram (resistivity varies with changes in temperature so this adjustment is required) [R_m = drilling mud; R_{mf} = mud filtrate],
- Determine SP – from user defined baseline,
- Correct SP to SSP (thin bed correction) – used on only some of the beds (that approach 10-feet in thickness) because of general overall bed thickness being thicker,
- Determine R_{mf}/R_{we} ratio – use chart (Asquith, 1982),
- Determine R_{we} – divide corrected value for R_{mf} by the ratio R_{mf}/R_{we} value,
- Correct R_{we} to R_w – use nomogram [R_{we} = equivalent resistivity] (Schlumberger, 1985), and
- Determine salinity (ppm NaCl) using the method described below in the induction log method (Asquith, 1982).

Induction log method: The log track on the far right of most of the logs available contains a conductivity curve measured by the induction log. The induction log measures conductivity, not resistivity, but because conductivity is a reciprocal of resistivity, resistivity can be derived. Resistivity equals 1,000 divided by conductivity to yield resistivity, so conductivity is converted to resistivity in ohm-meters.

For this study it was assumed that the resistivity observed was only from sodium chloride (NaCl). The formation temperature (T_f) was determined for its depth using a nomogram and known bottom hole temperatures (BHT).

Resistivity was then plotted at formation temperature on a standard nomogram to yield ppm NaCl. Results are reported in Table 3.

Resistivity log method: Two of the older logs, DR-OT-01-46 Hatteras Light #1 (Esso #1) well and DR-OT-01-47 Pamlico Sound (Esso #2) well had conductivity logs. Salinity estimates were obtained from these two wells at T_f using the plotting procedure for the induction log method. Results are reported in Table 3.

<u>Porosity estimates</u>

Where porosity logs were available, porosity was taken from the logs in sand-rich intervals based on the SP curve pattern. The assumption was that the matrix is sand. Results are included in Table 3.

RESULTS AND DISCUSSION

Depth of formations of interest and salinities

Cenomanian Age [deposition unit 2] (as mapped by Almy): The -3,000-foot-depth below sea level structure contour map on the top of Almy's Cenomanian Age unit cuts through southern Dare County and the southeastern corner of Hyde County. This eliminates from consideration a number of wells with estimated salinities >10,000 ppm NaCl located updip of the -3,000-foot structural contour.

The following wells have the more conservative deep induction log salinity estimates that include 10,000 ppm. Their corresponding estimated salinities estimated from the SP log are listed also. Refer to Table 3 for all data. All of the wells mentioned have the M2-6600 at a depth of -3,000 feet or greater.

Well	***Deep induction log salinity estimate as ppm NaCl***	***SP log estimate as ppm NaCl***
HY-T-01-65 State of N.C. #3 (Mobil #3)	28,500 – 30,000	70,000
DR-OT-02-65 State of N.C. #2 (Mobil #2)	29,000 – 38,000	44,000
DR-OT-01-71 Westvaco "A" #1 Stumpy Point	17,000 – 20,000	23,500 - 27,000
DR-OT-07-47 Pamlico Sound (Esso #2)	13,000 (by resistivity log)	

The structure contours increase in depth to the southeast and toward the DR-OT-01-46 Hatteras Light #1 (Esso #1) well located on Hatteras Island.

One well, the DR-OT-02-65 State State of North Carolina #2 (Mobil #2) has sufficient salinity in selected sands and is located down-dip of the -3,000-foot structure contour. The well is located on the southeast flank of a low amplitude structural low as mapped by Almy. No specific structural feature is associated with the HY-OT-01-65 State of North Carolina #3 (Mobil #3) well that has salinity values at, or just below 10,000 ppm NaCl. Thus there may be 'islands' of suitable formation water salinity at depths greater than -3,000 feet.

Features in the M2-6600 Aptian Age sand:

All of the Aptian Age sand, as mapped by Almy, are below the -3,000-foot structure contour. As with the Cenomanian structural map the structure contours increase in depth to the southeast and toward the DR-OT-01-46 Hatteras Light #1 (Esso #1) well located on Hatteras Island.

The following wells have the more conservative deep induction log salinity estimates that include 10,000 ppm. Their corresponding estimated salinities estimated from the SP log are listed also. Refer to Table 3 for all data. All of the wells mentioned have the M2-6600 at a depth of -3,000 feet or greater.

Well	Deep induction log salinity estimate as ppm NaCl	SP log estimate as ppm NaCl
DR-OT-01-71 Westvaco "A" #1 Stumpy Point	6,500 – 21,000	27,000
DR-OT-01-70 Laverne Twiford #1	8,000 – 15,000	35,000
DR-OT-01-73 Westvaco #2 (Gentles)	6,200 – 10,500	35,000
DR-OT-04-65 West VA Pulp & Paper #1	10,000 – 16,000	48,000
DR-OT-02-71 Westvaco "A" 2 South Lake	9,500 – 15,000	55,000
DR-OT-03-65 Marshall Collins #1 (Blair #3)	6,000 – 11,000	13,500
DR-OT-02-74 First Colony Farms "A" #2	9,800 – 24,000	100,000
DR-OT-01-46 Hatteras Light #1 (Esso #1)	17,000 (by resistivity log)	
HY-OT-01-65 State of N.C. #3 (Mobil #3)	7,900 – 10,000	85,000

These nine wells are clustered on land near the Dare Bombing Range and southward to the south edge of the mainland part of Dare County.

The following three features may be viewed as potential buoyant trapping pore volume areas in the M2-6600 sand. Additional study would be required to determine if sufficient volume and an appropriate seal is present.

1 – Almy's 1987b structure contour map on the top of the M2-6600 sand shows a closure of more than 20 feet but less than 40 feet under the Pamlico Sound in the vicinity of the well DR-OT-02-65 State of North Carolina #2 (Mobil #2) well at a depth of -6,500 feet. Its longest dimension as drawn is slightly more than five miles, and with a shorter axis of slightly over four miles. Estimated salinity of this well at this depth interval ranges from ~5,000 to ~8,500 ppm NaCl based on the induction log method. The SP method yields a higher value of ~75,000 ppm NaCl.

2 – The DR-OT-01-74 First Colony Farms "A" #1 well is in a small faulted block with a structural elevation of more than -5,100 feet but less than -5,000 feet. Its dimensions are about four miles by one mile. Salinities determined from the induction method (three points) ranging from ~9,800 to ~24,000 ppm NaCl. These span the 10,000 ppm NaCl threshold. The SP value for estimated salinity is 100,000 ppm.

3 – The M2-6600 sand is faulted upward along a northeasterly-trending fault parallel to and about one mile north of the G9 seismic line (refer to Figure 1 for numbered seismic line locations). Upward displacement is as much as 100 feet according to Almy's 1987b structure contour map. The DR-OT-01-71 Westvaco "A" #1 Stumpy Point was drilled on the down-faulted

side of the fault. This well has estimated salinities range of ~6,500 ppm to ~21,000 ppm NaCl, spanning the 10,000 ppm NaCl threshold. The DR-OT-O1-47 Pamlico Sound (Esso #2) well was drilled on the down-faulted side of the fault. The salinity estimate at formation depth is about 13,000 ppm NaCl from the resistivity log (no induction log is available). Almy (1987b) mapped this fault in the subsurface for about 16 miles.

See Table 3 for additional salinities for the nineteen wells used in this study. Salinity data are presented for the SP and induction log methods.

Digital well and seismic data for oil and gas exploration

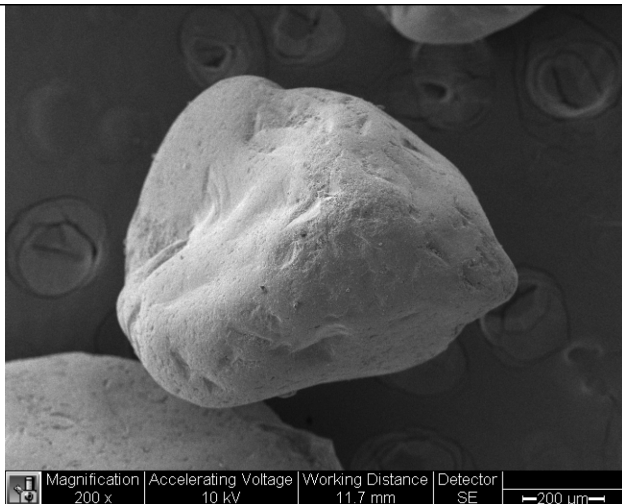
Potential offshore oil and gas exploration can make use of the digital well log and seismic data contained in this report. The well log data is in .las format; the seismic data is in .sgy format. TIF images accompany the well logs. These formats allow utilization of these data with modern industry-standard software.

Natural gas storage

The geological and physical characteristics of these sands are known only at a reconnaissance level. Investigating these sands – especially the M2-6600 sand – as a natural gas storage reservoir would require additional studies to determine if they are suitable.

Porosity estimates

Porosity determined from sonic logs is listed in Table 3. Overall porosity is high with data points ranging from 18% to >50%.



Reconnaissance SEM images of hand-picked grains from the M2-6600 sand in the well DR-OT-01-46 State of North Carolina Hatteras Light (Esso #1) indicate sub-rounded to sub-angular sand grains. Magnifications are: upper left – 200x, upper right – 200x, and lower left – 50x.

CONCLUSIONS

M2-6600 sand

The M2-6600 sand of Lower Cretaceous age underlies most of Dare County at a depth below surface of -3,000 feet or more which exceeds the minimum depth requirement.

The M2-6600 sand has estimated salinities exceed the 10,000 ppm TDS minimum criterion, with only three exceptions. There are well-to-well variations in the estimated salinity content. The

SP salinity estimates tend to be more saline than those determined by the induction log method supplemented by a few resistivity logs.

Upper unit sands

The upper unit (Almy's depositional unit 2) also has sand units but it is shallower and in the northern half of Dare County, it appears to be too shallow (e.g., less than a depth of -3,000 feet). Continuity of sand units is somewhat less clear. However the seismic-stratigraphy approach of Sunde and Coffey may provide clarity on the distribution of sands.

Estimated salinities are generally well above the 10,000 ppm TDS minimum criterion. There are well-to- well variations in the estimated salinity content. The SP salinity estimates tend to be more saline than those determined by the induction log method.

Natural gas storage potential

Substantial additional work would be required to determine if these sands are suited for natural gas storage potential.

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Special thanks to William L. Lassiter, Jr. of the Virginia Geological Survey, who arranged for our paper drill logs to be scanned to TIF format using their Neurolog scanner.

FIGURES

TABLES

APPENDIX

FIGURES

Figure 1. Location of study area (box) in Dare, Tyrrell and Hyde counties, North Carolina.

Available wells (with geophysical logs and cuttings) and 1970-era 2D seismic lines are shown (from Almy 1987a,b).

The table at the bottom of the figure is a cross-walk between the map number (above), the North Carolina Geological Survey (NCGS) well ID, US Geological Survey Professional Paper 796 (Brown and others, 1972), and the API well code. Other basic well identification data including datum, drilling operator, logging company (where known), and a summary of geological data and well logs held by the NCGS, plus well location (decimal latitude and longitude) are provided.

The North Carolina Geological Survey (NCGS) well code facilitates identification and discussion of individual wells. For example drill, well DR-OT-01-65 State of N.C. #1 [Mobil #1] is represented as follows. The first two letter group is the county code – in this case, Dare County. The second two letter group, OT, denotes an oil test. The next numbers – in this case, 01-65 indicate that this was the first well drilled in Dare County in 1965. Table 3 provides the API well number, in addition to a number of other important information about each well (total depth, logs run, amount of samples (and type), geographic location (decimal degrees for latitude and longitude, etc.).

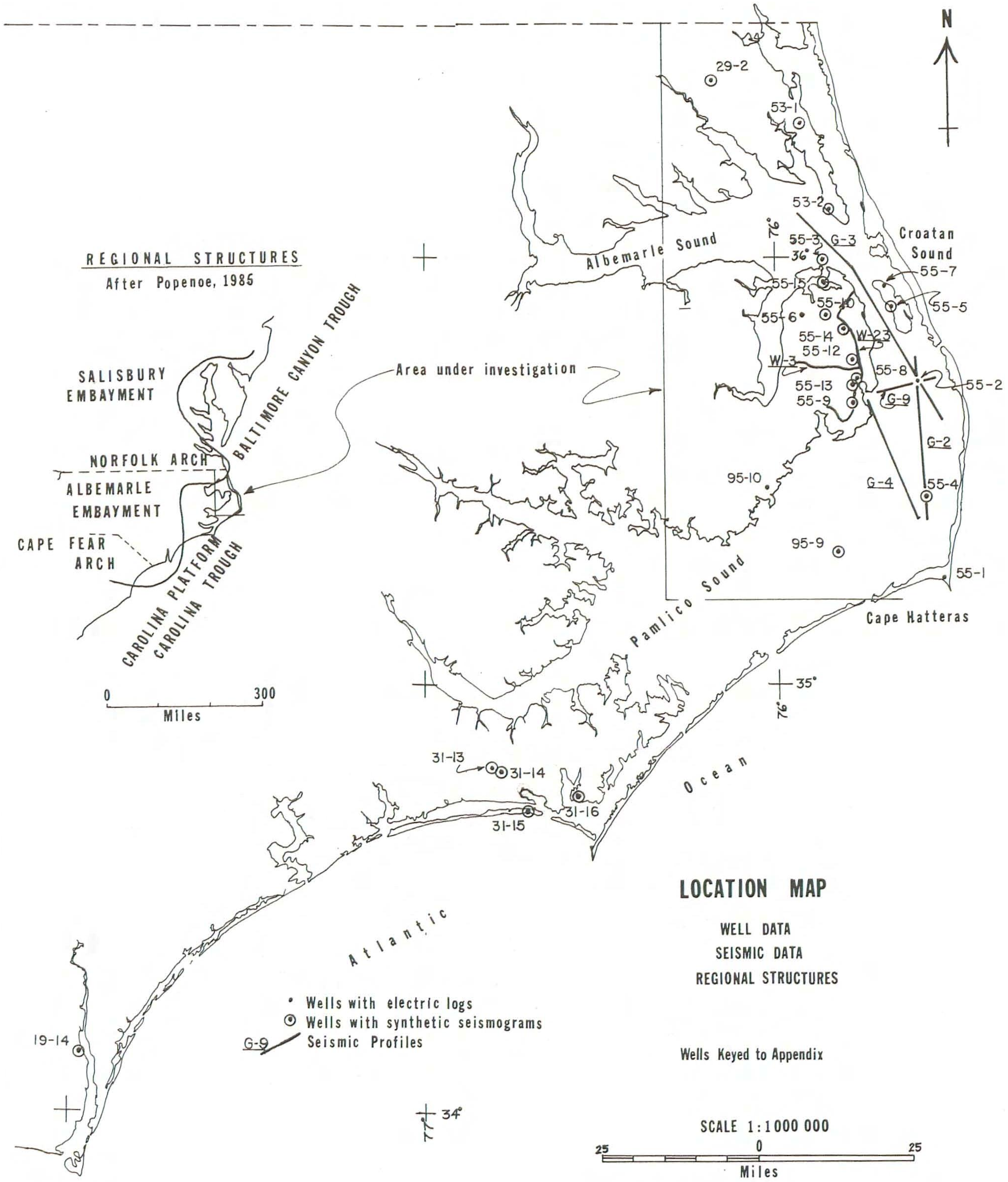
The location and name of each of the 2D seismic lines is displayed. Figures 5 and 6 show the locations of each of these 2D seismic lines in greater detail along with the location of individual shot points. Individual 2D seismic lines are numbered on Figure 1. Digital versions of all well logs as well as the 2D seismic lines are in the Appendix.

…ation of study area (box) in Dare, Tyrrell and Hyde counties, North Carolina. Available wells (with geophysical logs and cuttings) and 1970-era 2D seismic lines are shown (from Almy 1987a,b).

The table (below) is a cross-walk between the map number (above), the North Carolina Geological Survey (NCGS) well ID, US Geological Survey Professional Paper 796 (Brown and others, 1972), and the API well code. Other basic well identification data including datum, drilling operator, logging company (where known), and a summary of geological data and well logs held by the NCGS, plus well location (decimal latitude and longitude) are provided.

The North Carolina Geological Survey (NCGS) well code facilitates identification and discussion of individual wells. For example drill hole (DR-OT-01-65 – State of N.C. #1 [Mobil #1]) is represented as follows. The first two letter group is the county code – in this case, Dare County. The second two letter group, OT, denotes an oil test. The next numbers – in this case, 01-65 indicate that this was the first well drilled in Dare County in 1965. Table 3 provides the API well number, in addition to a number of other important information about each well (total depth, logs run, amount of samples (and type), geographic location (decimal degrees for latitude and longitude), etc.).

The location and name of each of the 2D seismic lines is displayed. Figures 7 and 8 show the locations of each of these 2D seismic lines in greater detail along with the location of individual shot points. Digital versions of all well logs as well as the 2D seismic lines are in the Appendix.



Map Code	NCGS_CODE	PP796	WELL_NAME	OTHER_CODE	WELL_DATUM	COUNTY	OPERATOR	DEPTH	DRILLED_BY	DATE_DRILL	LOGGED_BY	DATE_LOGGED	LOGS
53-1	CK-OT-01-65	CUR-OT-12	TWIFORD #1, (BLAIR #2)	32-053-00001	12	CURRITUCK	EDWIN F. BLAIR & ASSOCIATES	4,553.0		10/8/1965	SCHLUMBERGER	10/8/65	IES,S-G
53-2	CK-OT-01-69	CUR-OT-13	KELLOG #1	32-053-00002	17	CURRITUCK	RAPP OIL CORP.	5,140.0	DREILING DRILLING CO.	10/21/1969	SCHLUMBERGER,KNIGHT	10/21/69	IES,BHC-G-CAL,ML
29-2	CM-OT-01-65	CAM-OT-10	WEYERHAUSER #1, (BLAIR #1)	32-029-00002	16	CAMDEN	EDWIN F. BLAIR & ASSOCIATES	3,750.0		9/25/1965	SCHLUMBERGER	9/25/65	IES,S-G
55-1	DR-OT-01-46	DA-OT-10	HATTERAS LIGHT (ESSO #1)	32-055-00001	24	DARE	STANDARD OIL OF N.J.	10,054.0		7/9/1946	SCHLUMBERGER	7/9/46	E
55-2	DR-OT-01-47	DA-OT-9	PAMLICO SOUND (ESSO #2)	32-055-00002	21	DARE	STANDARD OIL OF N.J.	6,410.0		3/13/1947	SCHLUMBERGER	3/13/47	E
55-3	DR-OT-01-65	DA-OT-11	STATE OF N.C.#1, (MOBIL #1)	32-055-00003	24	DARE	SOCONY MOBIL OIL CO., INC.	5,269.0		7/30/1965	SCHLUMBERGER	7/30/65	IES,S-CAL,FD-G,ML,CD,VEL
55-7	DR-OT-01-69	DA-OT-15	ETHERIDGE #1	32-055-00007	26	DARE	RAPP OIL CORP.	6,049.0		11/16/1969	SCHLUMBERGER	11/16/69	IES
55-8	DR-OT-01-70	DA-OT-16	LAVERNE TWIFORD #1	32-055-00008	13	DARE	RAPP OIL CORP.	6,024.0		3/14/1970	SCHLUMBERGER	3/14/70	IES,BHC-G-CAL,G-NT,CB,T
55-9	DR-OT-01-71	DA-OT-17	WESTVACO "A" #1, STUMPY PT.	32-055-00009	20	DARE	CITIES SERVICE OIL CO.	6,264.0	BARNWELL DRILLING CO.	9/22/1971	SCHLUMBERGER	9/22/71	IES,DIL,BHC-CAL,SNP-G-CAL,CFD-G-CAL,FT
55-12	DR-OT-01-73	DA-OT-19	WESTVACO #2 (GENTLES)	32-055-00012	13	DARE	ALBERT GENTLES	6,178.0	GENTLES DRILLING CO.	8/23/1973	SCHLUMBERGER	8/23/73	IES,BHC-G-CAL,CFD-G-CAL
55-14	DR-OT-01-74	DA-OT-21	FIRST COLONY FARMS "A" #1	32-055-00014	13	DARE	CITIES SERVICE OIL CO.	5,582.0	MURCO DRILLING CO.	4/4/1974	SCHLUMBERGER	4/4/74	IES,BHC-G-CAL
55-4	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	32-055-00004	24	DARE	SOCONY MOBIL OIL CO., INC.	8,386.0		7/29/1965	SCLUMBERGER	7/29/65	IES,FD,ML,CD,S-G,PRX-MCL-CAL,VEL
55-10	DR-OT-02-71	DA-OT-18	WESTVACO "A" #2, SOUTH LAKE	32-055-00010	23	DARE	CITIES SERVICE OIL CO.	5,817.0	BARNWELL DRILLING CO.	10/22/1971	SCHLUMBERGER	10/22/71	IES,BHC-CAL,CFD-G,SNP-G,FT
55-13	DR-OT-02-73	DA-OT-20	WESTVACO #3 (GENTLES)	32-055-00013	7	DARE	ALBERT GENTLES	5,880.0	GENTLES DRILLING CO.	10/8/1973	SCHLUMBERGER	10/8/73	IES,S-G-CAL
55-15	DR-OT-02-74	DA-OT-22	FIRST COLONY FARMS "A" #2	32-055-00015	11	DARE	CITIES SERVICE OIL CO.	5,260.0	MURCO DRILLING CO.	4/27/1974	SCHLUMBERGER	4/27/74	IES,BHC-G-CAL,CFD-G-CAL,SNP-G,FT
55-5	DR-OT-03-65	DA-OT-13	MAR. COLLINS #1, (BLAIR #3)	32-055-00005	14	DARE	EDWIN F. BLAIR & ASSOCIATES	6,295.0		11/5/1965	SCHLUMBERGER	11/5/65	IES,S-G-CAL
55-6	DR-OT-04-65	DA-OT-14	WEST VA. PULP & PAPER #1	32-055-00006	11	DARE	EDWIN F. BLAIR & ASSOCIATES	5,150.0		12/1/1965	SCHLUMBERGER	12/1/65	IES,FD,G-NT
95-9	HY-OT-01-65	HY-OT-11	STATE OF N.C.#3 (MOBIL #3)	32-095-00009	24	HYDE	SOCONY MOBIL OIL CO., INC.	7,309.0		8/20/1965	SCHLUMBERGER	8/20/65	IES,S-G-CAL,FD-CAL,ML,CD,VEL
95-10	HY-OT-02-65	HY-OT-6	OCTAVIUS BALLANCE #1	32-095-00010	10	HYDE	EDWIN F. BLAIR & ASSOCIATES	5,570.0		12/22/1965	SCHLUMBERGER	12/22/65	G-NT

Map Code	CUTTINGS_INTERVALS	CORE_INTERVALS	BASEMENT	BASEMENT LITHOLOGY	GW_GRID	CTGSFOOTAGE	CORE_FOOTAGE	BSMT_DEPTH	BSMT_ALT	TYPE	DECILONGITUDE	DECILATITUDE
53-1	0/4540 U; 0/4540 W (INC)		T	MUSCOVITE SCHIST		4540	0	4530	-4518	Oiltest	-75.9250000	36.3027780
53-2	590/5140 U,W		T	GRANITE		4550	0	5072	-5055	Oiltest	-75.8527780	36.1172220
29-2	0/3740 U; 0/3200 W		T	CRYSTAL TUFF		3740	0	2812	-2796	Oiltest	-76.1750000	36.4111110
55-1	18/10054 U; 18/5080 W (INC)	346/10054 (5 BOXES); 480/10054 (28 BOXES)	T	GRANITE		10036	330	9878	-9854	Oiltest	-75.5291670	35.2500000
55-2	40/6410 U,W (INC)		N			6370	0			Oiltest	-75.5983330	35.7033330
55-3	0/5250 U (INT); 0/5250 W (INC)		T	ALTERED GRANITE		5250	0	5155	-5131	Oiltest	-75.8666670	35.9986110
55-7	0/6046 U (INT); 2130/5500 W (INC		N			6046	0			Oiltest	-75.6772220	35.9238890
55-8	710/5840 U (INT); 710/5960 W (IN		N		L-5,s-1	5250	0			Oiltest	-75.7713890	35.7033330
55-9	74/6260 U (INC); 80/6260 W (INC)	6236/6259 (9 BOXES)	T	GRANITE		6186	23	6120	-6100	Oiltest	-75.7780560	35.6600000
55-12	0/6190 U,W (INT)		T	ALKALI GRANITE		6190	0	6064	-6051	Oiltest	-75.7733330	35.7541670
55-14	980/5580 U; 980/5580 W (INT)		T	GRANITE		4600	0	5538	-5525	Oiltest	-75.7966670	35.8052780
55-4	0/8380 U (INC); 0/8380W		T	INTERMEDIATE METAPLUTONIC		8380	0	8360	-8336	Oiltest	-75.5763890	35.4388890
55-10	80/5808 U (INT); 860/5540 W (INC	5803/5806 (2 BOXES)	T	GRANITE		5728	3	5430	-5407	Oiltest	-75.8511110	35.8633330
55-13	0/5860 U (INC); 2790/5860 W (INC		T	SHEARED 2-MICA GRANITE		5860	0	5808	-5801	Oiltest	-75.7802780	35.6900000
55-15	1000/5260 U; 1000/5260 W (INT)		T	STRAINED LEUCOGRANITE		4260	0	5216	-5205	Oiltest	-75.8722220	35.9438890
55-5	0/6281 U; 0/6281 W (INC)		T	AMPHIBOLITE		6281	0	6270	-6256	Oiltest	-75.6708330	35.8833330
55-6	0/5144 U; 0/5150 W		T	ALTERED DIORITE		5150	0	5126	-5115	Oiltest	-75.9250000	35.8638890
95-9	0/7309 U (INT); 0/7310 W		T	LEUCOGRANODIORITE		7310	0	7222	-7198	Oiltest	-75.8291670	35.3069440
95-10	0/5570 U (INC); 0/4500 W		N			5570	0			Oiltest	-76.0305560	35.4569440

Figure 2. Notable industrial sources of CO_2 emission and suggested targets for sequestration characterization (from Marshall Miller & Associates) prepared from source data at www.natcarb.org database.

This study focused on a deep saline aquifer ranked as high potential and located onshore. Carbon dioxide emitters are ranked by tons. Proposed power plants are shown as green squares. This study did not include the Mesozoic basins of North Carolina.

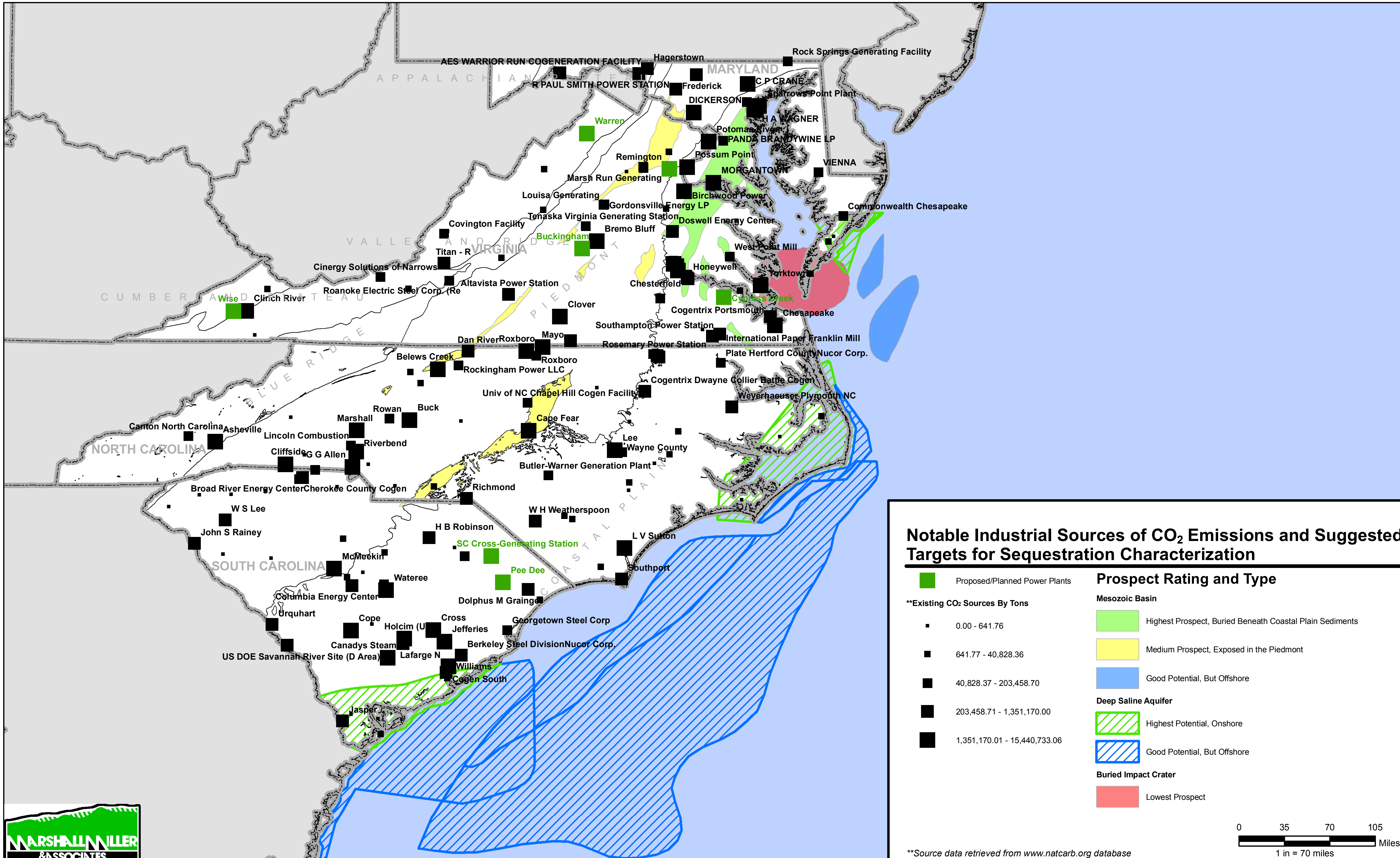

Notable Industrial Sources of CO_2 Emissions and Suggested Targets for Sequestration Characterization
Proposed/Planned Power Plants
**Existing CO_2 Sources By Tons
0.00 - 641.76
641.77 - 40,828.36
40,828.37 - 203,458.70
203,458.71 - 1,351,170.00
1,351,170.01 - 15,440,733.06
Prospect Rating and Type
Mesozoic Basin
Highest Prospect, Buried Beneath Coastal Plain Sediments
Medium Prospect, Exposed in the Piedmont
Good Potential, But Offshore
Deep Saline Aquifer
Highest Potential, Onshore
Good Potential, But Offshore
Buried Impact Crater
Lowest Prospect
0
35
70
105
Miles
1 in = 70 miles
**Source data retrieved from www.natcarb.org database
MARYLAND
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
A P P A L A C H I A N P L A T E A U
V A L L E Y A N D R I D G E
C U M B E R L A N D P L A T E A U
B L U E R I D G E
P I E D M O N T
C O A S T A L P L A I N
AES WARRIOR RUN COGENERATION FACILITY
Hagerstown
Rock Springs Generating Facility
R PAUL SMITH POWER STATION
Frederick
C P CRANE
Sparrows Point Plant
DICKERSON
H A WAGNER
Warren
Potomac River
PANDA BRANDYWINE LP
Possum Point
Remington
VIENNA
MORGANTOWN
Marsh Run Generating
Louisa Generating
Birchwood Power
Gordonsville Energy LP
Commonwealth Chesapeake
Tenaska Virginia Generating Station
Doswell Energy Center
Covington Facility
Bremo Bluff
Buckingham
West Point Mill
Titan - R
Cinergy Solutions of Narrows
Honeywell
Yorktown
Altavista Power Station
Roanoke Electric Steel Corp. (Re
Chesterfield
Wise
Clinch River
Cypress Creek
Clover
Cogentrix Portsmouth
Chesapeake
Southampton Power Station
Mayo
Dan River
Roxboro
Rosemary Power Station
International Paper Franklin Mill
Belews Creek
Roxboro
Plate Hertford County
Nucor Corp.
Rockingham Power LLC
Cogentrix Dwayne Collier Battle Cogen
Univ of NC Chapel Hill Cogen Facility
Weyerhaeuser Plymouth NC
Rowan
Buck
Marshall
Cape Fear
Canton North Carolina
Asheville
Lincoln Combustion
Lee
Wayne County
Riverbend
Cliffside
G G Allen
Butler-Warner Generation Plant
Broad River Energy Center
Cherokee County Cogen
Richmond
W S Lee
W H Weatherspoon
John S Rainey
H B Robinson
L V Sutton
SC Cross-Generating Station
McMeekin
Southport
Pee Dee
Wateree
Columbia Energy Center
Dolphus M Grainger
Urquhart
Cope
Cross
Georgetown Steel Corp
Holcim (U
Jefferies
Canadys Steam
Berkeley Steel Division
Nucor Corp.
US DOE Savannah River Site (D Area)
Lafarge N
Williams
Cogen South
Jasper

Figure 3. Almy's 1987a,b cross sections.

These cross sections are from Almy (1987a,b). They show the Lower and Upper Cretaceous section in the subsurface of the study area. The longitudinal cross section with well control showing target units and depths is on the left. Each well shown has a SP log on the left and a resistivity log on the right. The upper and lower units of Almy are indicated. The inset section is an enlargement of part of the longitudinal section that shows the sand at top of Almy's Unit 1 (lower yellow intervals) and Unit 2 with multiple sands denoted by the blocky SP curve for the sand units (upper yellow intervals).

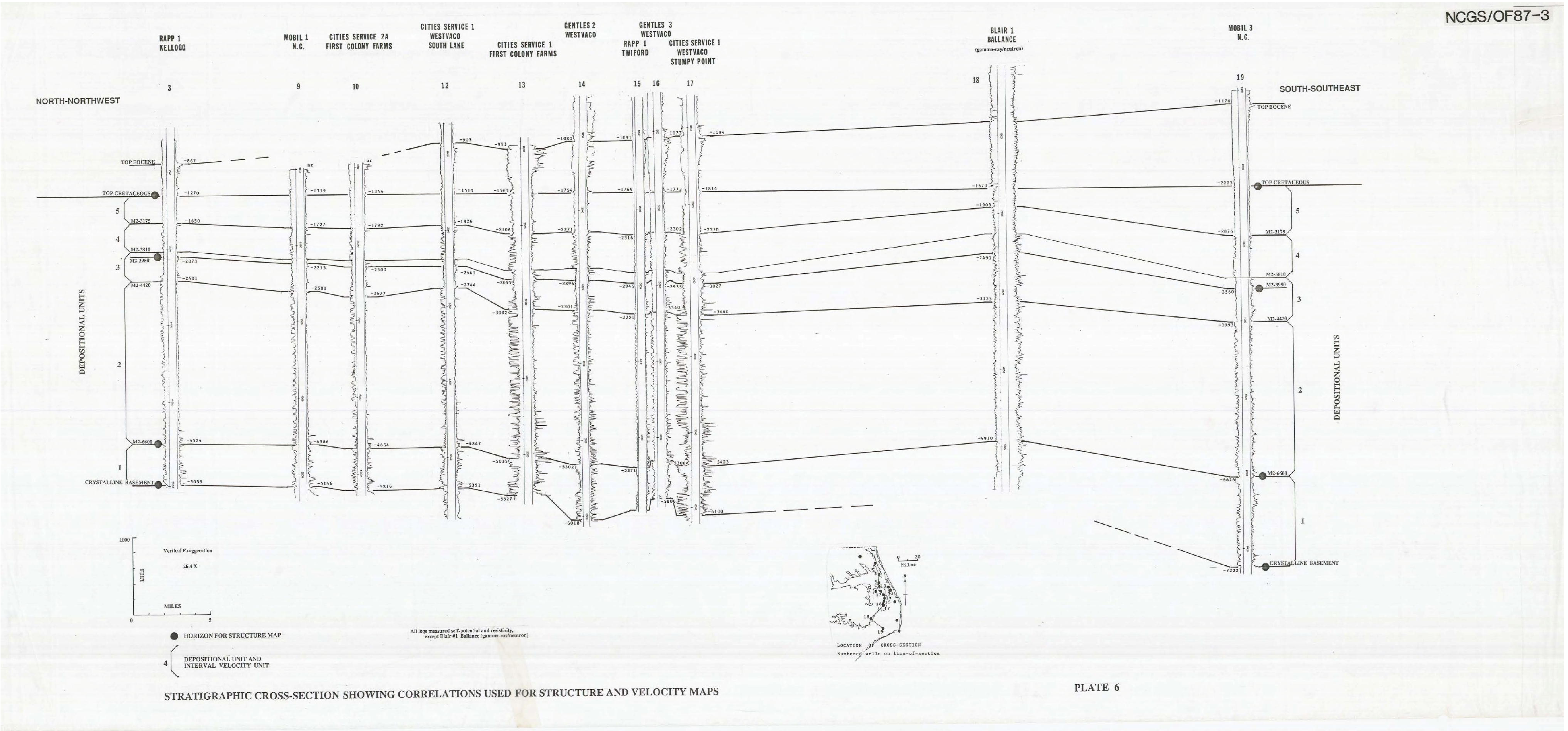


Figure 2 ï Longitudinal cross section with well control showing target units and depths. Each well shown has a SP log on the left and a resistivity log on the right. Inset map shows seismic line location.

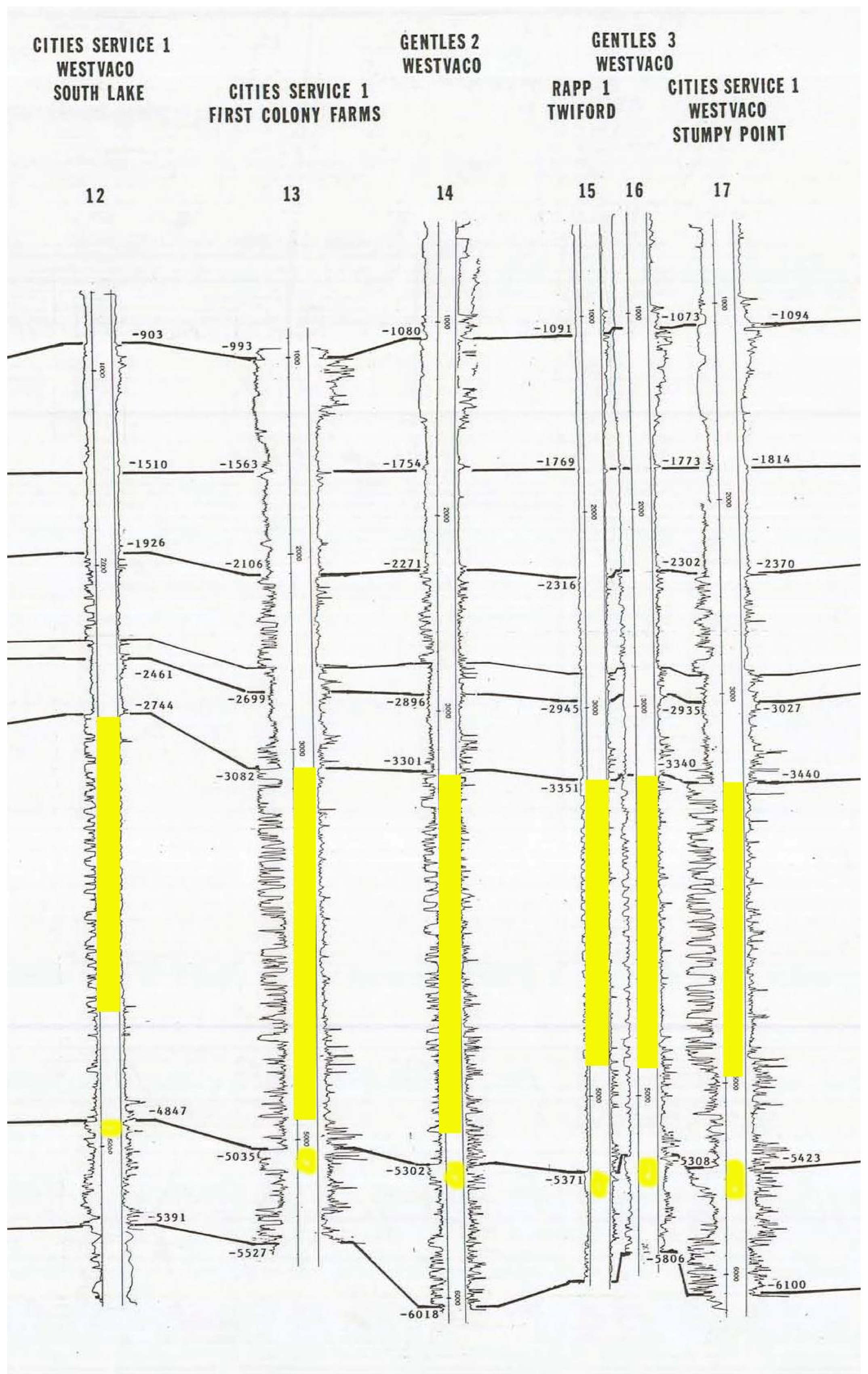


Figure 3 (above) ï shows the M2-6600 sand at top of Almyõs Unit 1 and multiple sands in his Unit 2 denoted by the blocky SP curve. The inset (left) provides greater detail by highlighting these sands in yellow.

Figure 4. Bed thickness statistics.

Figures 4A-K provide basic salinity and sand unit thicknesses. They are:

Figure 4A: Descriptive statistics by SP – overall and split by lower and upper units.
Figure 4B: Descriptive statistics by deep induction log – overall and split by lower and upper units.
Figure 4C: Histogram of estimated salinity, lower unit, by SP.
Figure 4D: Histogram of estimated salinity, upper unit, by SP.
Figure 4E: Histogram of estimated salinity, lower unit, by deep induction log.
Figure 4F: Histogram of estimated salinity, upper unit, by deep induction log.
Figure 4G: Box plot of SP estimated salinity compared to deep induction log estimated salinity, split by lower and upper units.
Figure 4H: Bed thickness (feet), – overall and split by lower and upper units.
Figure 4I: Bed thickness (feet), lower unit, or the M2-6600 unit.
Figure 4J: Bed thickness (feet), upper unit, or sands in the M2-3950 unit.
Figure 4K: Box plot showing bed thickness, split by lower and upper units.

Descriptive tatistics
plit y nterval - Figure 4A

	SP salinity estimate (NaCl ppm), Total	SP salinity estimate (NaCl ppm), Lower	SP salinity estimate (NaCl ppm), Upper
Mean	44906.977	50566.667	41875.000
Std. Dev.	21365.653	24107.547	19529.951
Std. Error	3258.232	6224.542	3690.814
Count	43	15	28
Minimum	13500.000	13500.000	15000.000
Maximum	100000.000	100000.000	79000.000
# Missing	68	38	19
Variance	456491140.642	581173809.524	381418981.481
Coef. Var.	.476	.477	.466
Range	86500.000	86500.000	64000.000
Sum	1931000.000	758500.000	1172500.000
Sum Squares	105888000000.000	46491250000.000	59396750000.000
Geom. Mean	39893.641	45138.365	37339.354
Harm. Mean	35057.103	39490.235	33068.411
Skewness	.557	.618	.314
Kurtosis	-.467	-.534	-1.224
Median	44000.000	48000.000	42500.000
IQR	33500.000	35000.000	36500.000
Mode	•	•	•
10% Tr. Mean	43528.571	49615.385	41354.167
MAD	17000.000	13000.000	18750.000

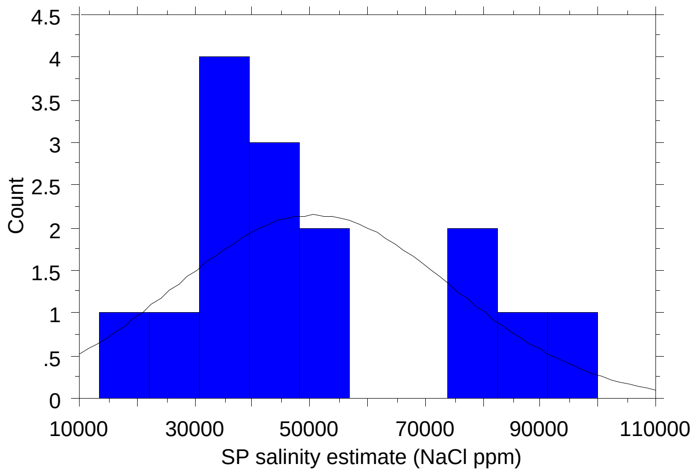
Results for totals may not agree with results for individual cells because of missing values for split variables.

Descriptive   tatistics - Figure 4B
plit   y   nterval

	Induction log salinity estimate (NaCl ppm), Total	Induction log salinity estimate (NaCl ppm), Lower	Induction log salinity estimate (NaCl ppm), Upper
Mean	13420.430	9682.000	19648.649
Std. Dev.	8089.561	4790.624	8232.612
Std. Error	838.848	677.497	1353.433
Count	93	50	37
Minimum	1800.000	1800.000	7000.000
Maximum	38000.000	24000.000	38000.000
# Missing	18	3	10
Variance	65440991.117	22950077.551	67775900.901
Coef. Var.	.603	.495	.419
Range	36200.000	22200.000	31000.000
Sum	1248100.000	484100.000	727000.000
Sum Squares	22770610000.000	5811610000.000	16724500000.000
Geom. Mean	11295.443	8635.628	17951.520
Harm. Mean	9364.134	7510.415	16276.444
Skewness	1.126	1.423	.508
Kurtosis	.646	2.211	-.478
Median	10000.000	8350.000	18000.000
IQR	10025.000	2700.000	11250.000
Mode	8000.000	8000.000	17000.000
10% Tr. Mean	12401.333	9070.000	19209.677
MAD	3000.000	1550.000	5500.000

Results for totals may not agree with results for individual cells because of missing values for split variables.

Histogram - Figure 4C
plit   y   nterval
Cell Lower

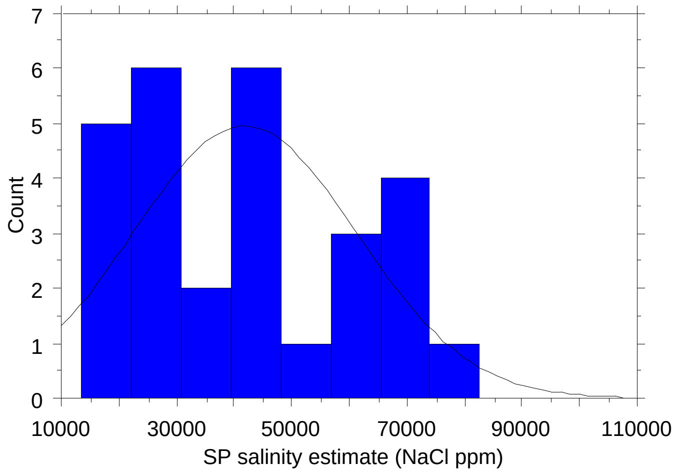


Results for totals may not agree with results for individual cells because of missing values for split variables.

Histogram - Figure 4D

plit y nterval

Cell pper

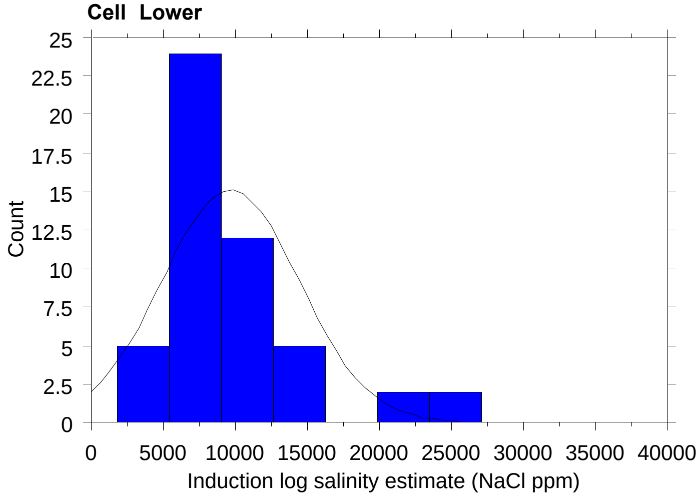


Results for totals may not agree with results for individual cells because of missing values for split variables.

Histogram - Figure 4E

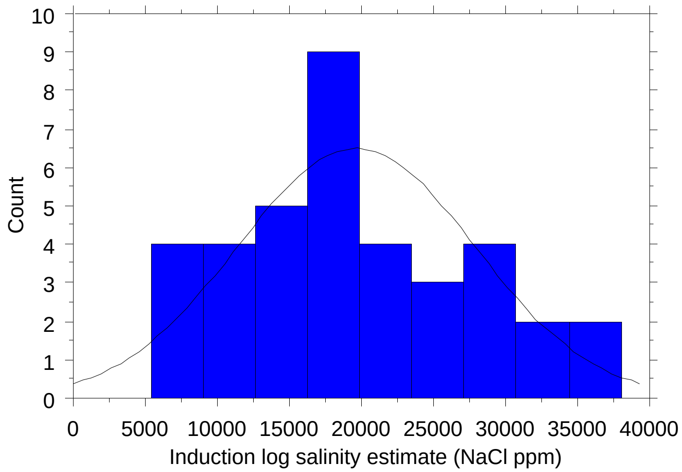
plit y nterval

Cell Lower



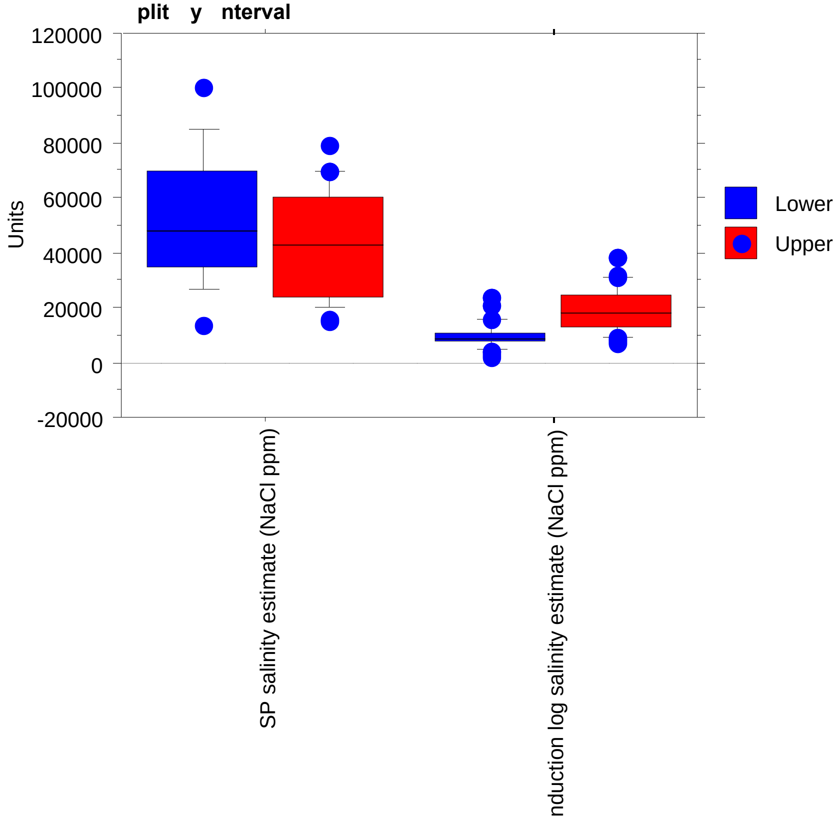
Results for totals may not agree with results for individual cells because of missing values for split variables.

Histogram - Figure 4F
plit y nterval
Cell pper



Results for totals may not agree with results for individual cells because of missing values for split variables.

ox lot - Figure 4G
plit y nterval

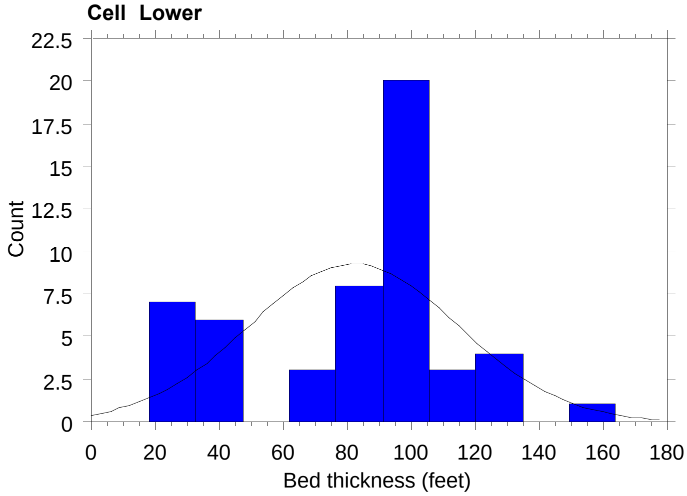


Descriptive tatistics
plit y nterval - Figure 4H

	Bed thickness (feet), Total	Bed thickness (feet), Lower	Bed thickness (feet), Upper
Mean	65.968	82.115	45.976
Std. Dev.	31.281	32.729	12.126
Std. Error	3.226	4.539	1.871
Count	94	52	42
Minimum	18.000	18.000	22.000
Maximum	164.000	164.000	100.000
# Missing	17	1	5
Variance	978.526	1071.163	147.048
Coef. Var.	.474	.399	.264
Range	146.000	146.000	78.000
Sum	6201.000	4270.000	1931.000
Sum Squares	500071.000	405262.000	94809.000
Geom. Mean	58.848	73.617	44.599
Harm. Mean	52.247	62.790	43.255
Skewness	.623	-.305	1.884
Kurtosis	-.494	-.439	7.865
Median	51.500	94.000	46.000
IQR	56.000	50.500	10.000
Mode	•	98.000	48.000
10% Tr. Mean	64.211	82.810	45.382
MAD	20.500	12.000	5.000

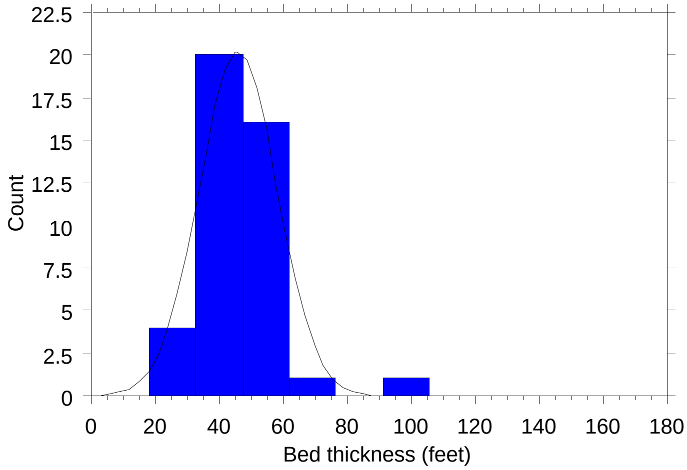
Results for totals may not agree with results for individual cells because of missing values for split variables.

Histogram - Figure 4I
plit y nterval
Cell Lower



Results for totals may not agree with results for individual cells because of missing values for split variables.

Histogram - 4J
plit y nterval
Cell pper



Results for totals may not agree with results for individual cells because of missing values for split variables.

ox lot - Figure 4K
plit y nterval

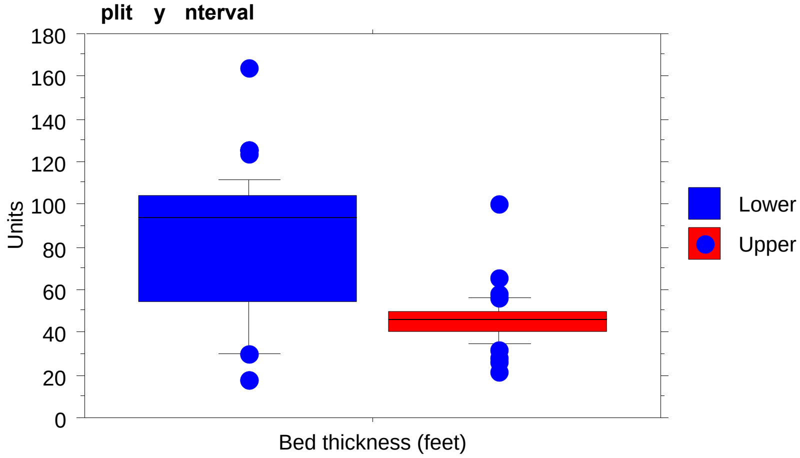
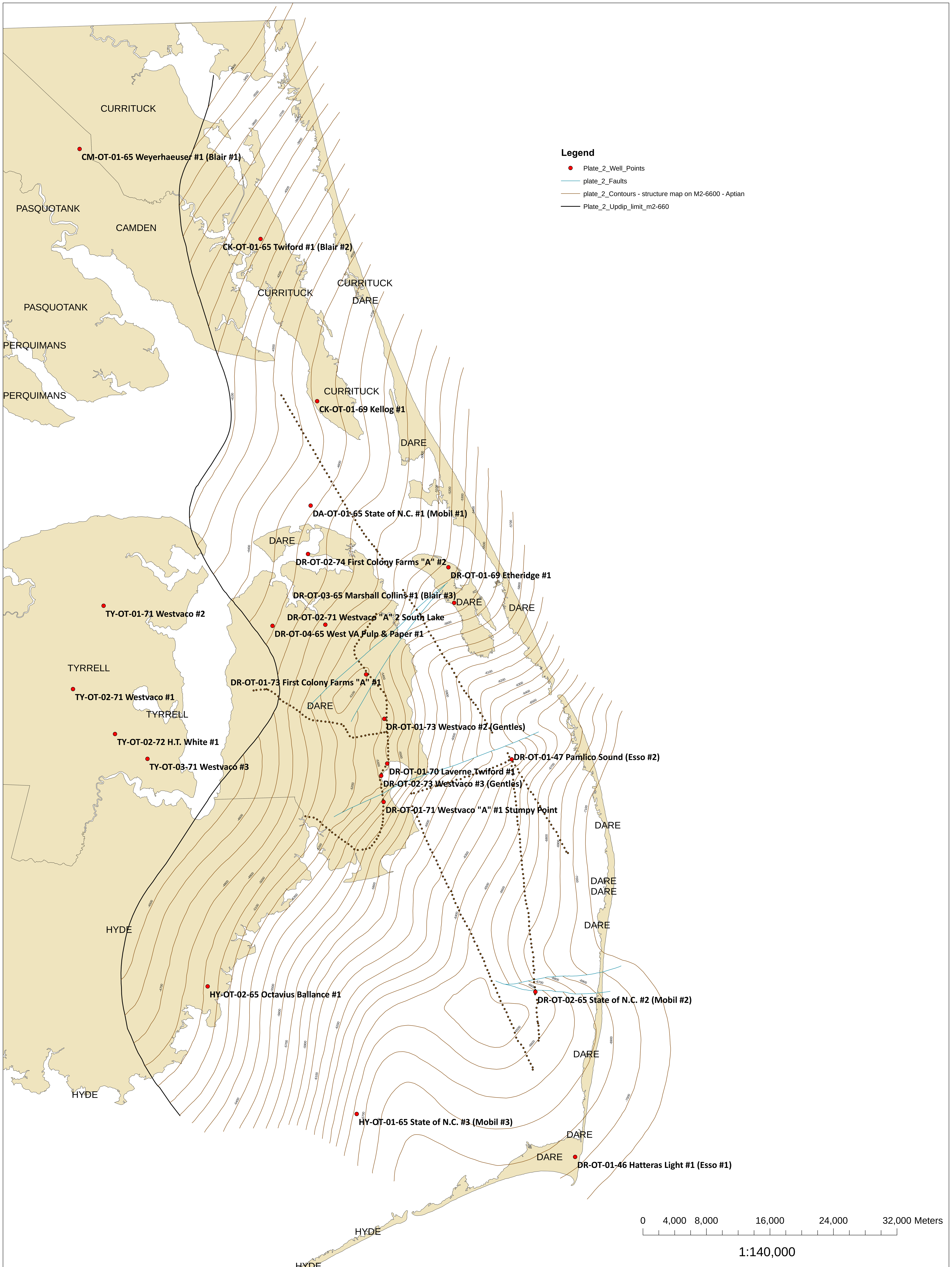


Figure 5. Structure contour map on the top of the Aptian (after Almy, 1985a,b).

Top of the M2-6600' Sand, Plate 2 of Almy 1987a,b. This is the top of Depositional Unit 1 of this Almy, and the basal sand of Unit G of Brown, et al. (1972). This sand was called the "M2-6600 sand" by Almy because of its occurrence at 6,600 feet in the well DR-OT-02-65 State of North Carolina #2 (Mobil #2) well. Seismic lines are indicated by the shot points (open black circles).

CO2 - Structure map on M2-6600 - Aptian Age (after Almy, 1987a,b)

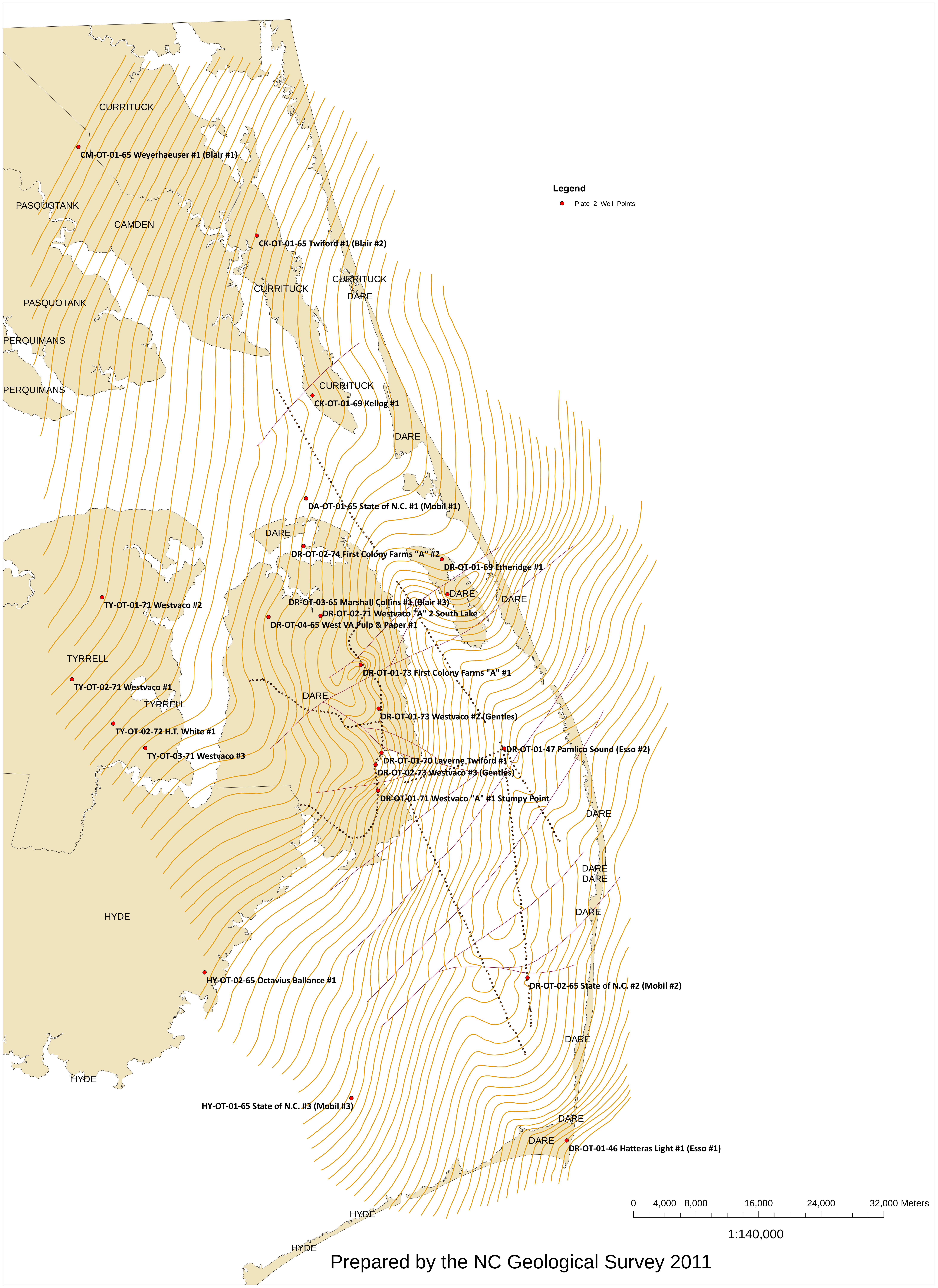


Prepared by the NC Geological Survey 2011

Figure 6. Structure contour map on the top of the Cenomanian (after Almy, 1985a,b).

Almy (1987a,b) named the M2-3950 Horizon for the thin Cenomanian Limestone at the top sequence 1 of Owens and Gohn, 1985; and the top Unit E of Brown, et al. 1972; to correspond to the middle part of Depositonal Unit 3 of Almy's report). This unit was called the M2-3950 horizon for purposes of this study because of its development at 3,950 feet in the DR-OT-02-65 State of North Carolina #2 (Mobil #2).

CO2 - Structure map on M2-3950 - Cenomanian Age (after Almy, 1987a,b)



Prepared by the NC Geological Survey 2011

Table 3 Compilation of unit thicknesses and estimated well salinities.

This table provides well identification and location information as well as a compilation of the bed thickness at formation depth (in feet at mid-point), and porosity and resistivity determinations, and estimates of salinity (SP and induction log methods, along with limited resistivity log determinations).

Table 3 - Compilation of unit thicknesses and estimated well salinities

Num	NCGS code	PP796 name	Well name	Formation depth (feet) - midpoint	Bed thickness (feet)	Δt	Porosity (%) - sonic log	Bulk density	Porosity (%) formation density	Resistivity log	Resistivity log salinity estimate (NaCl ppm)	SP salinity estimate (NaCl ppm)	Induction log conductivity	Resistivity from conductivity	Induction log salinity estimate (NaCl ppm)	Interval	API code	Well datum	County	Operator	Depth (feet)	Drilled by	Date drilled	Logged by	Date logged	Log suite run	Samples	Slides	Lith log	Cuttings interval	Core intervals (feet)	Side wall cores	Tops	Basement	Basement lithology	Cuttings footage	Core footage	Basement depth	Basement altitude	Type	Deci longitude	Deci latitude
1	CK-OT-01-65	CUR-OT-12	TWIFORD #1, (BLAIR #2)	3,123	66	~125	>50					~16,000	1,200	0.830	~9,000	Upper	32-053-00001	12	CURRITUCK	EDWIN F. BLAIR & ASSOCIATES	4,553		10/8/1965	SCHLUMBERGER	10/8/65	IES,S-G	T	F	F	0/4540 U; 0/4540 W (INC)	none	none	F	T	MUSCOVITE SCHIST	4540	0	4530	-4518	Oiltest	-75.9250000	36.3027780
1	CK-OT-01-65	CUR-OT-12	TWIFORD #1, (BLAIR #2)	3,436	48	~134	>50					~15,000	1,400	0.720	~11,000	Upper	32-053-00001	12	CURRITUCK	EDWIN F. BLAIR & ASSOCIATES	4,553		10/8/1965	SCHLUMBERGER	10/8/65	IES,S-G	T	F	F	0/4540 U; 0/4540 W (INC)	none	none	F	T	MUSCOVITE SCHIST	4540	0	4530	-4518	Oiltest	-75.9250000	36.3027780
1	CK-OT-01-65	CUR-OT-12	TWIFORD #1, (BLAIR #2)	3,995	30	~117	~47					~48,000	2,000	0.500	~8,000	Lower	32-053-00001	12	CURRITUCK	EDWIN F. BLAIR & ASSOCIATES	4,553		10/8/1965	SCHLUMBERGER	10/8/65	IES,S-G	T	F	F	0/4540 U; 0/4540 W (INC)	none	none	F	T	MUSCOVITE SCHIST	4540	0	4530	-4518	Oiltest	-75.9250000	36.3027780
1	CK-OT-01-65	CUR-OT-12	TWIFORD #1, (BLAIR #2)	3,995	30								1,875	0.530	~7,800	Lower	32-053-00001																									
1	CK-OT-01-65	CUR-OT-12	TWIFORD #1, (BLAIR #2)	3,995	30								2,100	0.480	~8,100	Lower	32-053-00001																									
2	CK-OT-01-69	CUR-OT-13	KELLOG #1	3,117		<40	n.d.					~23,500	1,850	0.540	~8,500	Upper	32-053-00002	17	CURRITUCK	RAPP OIL CORP.	5,140	DREILING DRILLING CO.	10/21/1969	SCHLUMBERGER,KNIGHT	10/21/69	IES,BHC-G-CAL,ML	T	T	F	590/5140 U,W	none	none	F	T	GRANITE	4550	0	5072	-5055	Oiltest	-75.8527780	36.1172220
2	CK-OT-01-69	CUR-OT-13	KELLOG #1	4,126		<40	n.d.					~21,500	2,010	0.490	~7,000	Upper	32-053-00002	17	CURRITUCK	RAPP OIL CORP.	5,140	DREILING DRILLING CO.	10/21/1969	SCHLUMBERGER,KNIGHT	10/21/69	IES,BHC-G-CAL,ML	T	T	F	590/5140 U,W	none	none	F	T	GRANITE	4550	0	5072	-5055	Oiltest	-75.8527780	36.1172220
2	CK-OT-01-69	CUR-OT-13	KELLOG #1	4,555	30							~38,000	2,170	0.460	~7,500	Lower	32-053-00002																									
2	CK-OT-01-69	CUR-OT-13	KELLOG #1	4,555	30								2,210	0.450	~7,600	Lower	32-053-00002																									
3	CM-OT-01-65	CAM-OT-10	WEYERHAUSER #1, (BLAIR #1)	2,739	18	~125	>50					~49,000	850	1.180	~4,000	Lower	32-029-00002	16	CAMDEN	EDWIN F. BLAIR & ASSOCIATES	3,750		9/25/1965	SCHLUMBERGER	9/25/65	IES,S-G	T	F	F	0/3740 U; 0/3200 W	none	none	F	T	CRYSTAL TUFF	3740	0	2812	-2796	Oiltest	-76.1750000	36.4111110
3	CM-OT-01-65	CAM-OT-10	WEYERHAUSER #1, (BLAIR #1)	2,739	18								650	1.540	~2,500	Lower	32-029-00002																									
4	DR-OT-01-46	DA-OT-10	HATTERAS LIGHT (ESSO #1)	7,077	124					0.50	17,000	no RMF				Lower	32-055-00001	24	DARE	STANDARD OIL OF N.J.	10,054		7/9/1946	SCHLUMBERGER	7/9/46	E	T	F	F	18/10054 U; 18/5080 W (INC)	346/10054 (5 BOXES); 480/10054 (28 BOXES)	none	F	T	GRANITE	10036	330	9878	-9854	Oiltest	-75.5291670	35.2500000
4	DR-OT-01-46	DA-OT-10	HATTERAS LIGHT (ESSO #1)	6,525	100					0.50	6,500					Upper	32-055-00001																									
5	DR-OT-01-47	DA-OT-9	PAMLICO SOUND (ESSO #2)	6,227	85							no RMF				Lower	32-055-00002	21	DARE	STANDARD OIL OF N.J.	6,410		3/13/1947	SCHLUMBERGER	3/13/47	E	T	T	F	40/6410 U,W (INC)	none	none	F	N		6370	0			Oiltest	-75.5983330	35.7033330
5	DR-OT-01-47	DA-OT-9	PAMLICO SOUND (ESSO #2)	5,063	47					0.30	13,000					Upper	32-055-00002																									
5	DR-OT-01-47	DA-OT-9	PAMLICO SOUND (ESSO #2)	5,485	58					0.30	13,000					Upper	32-055-00002																									
6	DR-OT-01-65	DA-OT-11	STATE OF N.C.#1, (MOBIL #1)	3,585	50	~125	>50					27,000	2,200	0.454	8,000	Upper	32-055-00003	24	DARE	SOCONY MOBIL OIL CO., INC.	5,269		7/30/1965	SCHLUMBERGER	7/30/65	IES,S-CAL,FD-G,ML,CD,VEL	T	T	F	0/5250 U (INT); 0/5250 W (INC)	none	none	F	T	ALTERED GRANITE	5250	0	5155	-5131	Oiltest	-75.8666670	35.9986110
6	DR-OT-01-65	DA-OT-11	STATE OF N.C.#1, (MOBIL #1)	4,110	41							34,000	~2,650	0.377	10,000	Upper	32-055-00003																									
6	DR-OT-01-65	DA-OT-11	STATE OF N.C.#1, (MOBIL #1)	4,131		~107	~37									Upper	32-055-00003	24	DARE	SOCONY MOBIL OIL CO., INC.	5,269		7/30/1965	SCHLUMBERGER	7/30/65	IES,S-CAL,FD-G,ML,CD,VEL	T	T	F	0/5250 U (INT); 0/5250 W (INC)	none	none	F	T	ALTERED GRANITE	5250	0	5155	-5131	Oiltest	-75.8666670	35.9986110
6	DR-OT-01-65	DA-OT-11	STATE OF N.C.#1, (MOBIL #1)	4,649	62	~101	~34					~40,000	2,900	0.340	~9,000	Lower	32-055-00003	24	DARE	SOCONY MOBIL OIL CO., INC.	5,269		7/30/1965	SCHLUMBERGER	7/30/65	IES,S-CAL,FD-G,ML,CD,VEL	T	T	F	0/5250 U (INT); 0/5250 W (INC)	none	none	F	T	ALTERED GRANITE	5250	0	5155	-5131	Oiltest	-75.8666670	35.9986110
6	DR-OT-01-65	DA-OT-11	STATE OF N.C.#1, (MOBIL #1)	4,649	62								2,200	0.450	~7,300	Lower	32-055-00003																									
6	DR-OT-01-65	DA-OT-11	STATE OF N.C.#1, (MOBIL #1)	4,649	62								2,400	0.420	~7,800	Lower	32-055-00003																									
7	DR-OT-01-69	DA-OT-15	ETHERIDGE #1	4,058	52							No BHT				Upper	32-055-00007																									
7	DR-OT-01-69	DA-OT-15	ETHERIDGE #1	4,058	52							No BHT				Upper	32-055-00007																									
7	DR-OT-01-69	DA-OT-15	ETHERIDGE #1	4,616	48							No BHT				Upper	32-055-00007	26	DARE	RAPP OIL CORP.	6,049		11/16/1969	SCHLUMBERGER	11/16/69	IES	T	F	F	0/6046 U (INT); 2130/5500 W (INC	none	none	F	N		6046	0			Oiltest	-75.6772220	35.9238890
7	DR-OT-01-69	DA-OT-15	ETHERIDGE #1	4,616	48							No BHT				Upper	32-055-00007	26	DARE	RAPP OIL CORP.	6,049		11/16/1969	SCHLUMBERGER	11/16/69	IES	T	F	F	0/6046 U (INT); 2130/5500 W (INC	none	none	F	N		6046	0			Oiltest	-75.6772220	35.9238890
8	DR-OT-01-70	DA-OT-16	LAVERNE TWIFORD #1	4,275	50	~120	~48					~41,000	2,900	0.344	~23,000	Upper	32-055-00008	13	DARE	RAPP OIL CORP.	6,024		3/14/1970	SCHLUMBERGER	3/14/70	IES,BHC-G-CAL,G-NT,CB,T	T	F	F	710/5840 U (INT); 710/5960 W (IN	none	none	F	N		5250	0			Oiltest	-75.7713890	35.7033330
8	DR-OT-01-70	DA-OT-16	LAVERNE TWIFORD #1	4,275	50	~120	~48						3,300	0.303	~24,000	Upper	32-055-00008																									
8	DR-OT-01-70	DA-OT-16	LAVERNE TWIFORD #1	4,781	42	~110	~41					~59,000	3,200	0.310	~31,000	Upper	32-055-00008	13	DARE	RAPP OIL CORP.	6,024		3/14/1970	SCHLUMBERGER	3/14/70	IES,BHC-G-CAL,G-NT,CB,T	T	F	F	710/5840 U (INT); 710/5960 W (IN	none	none	F	N		5250	0			Oiltest	-75.7713890	35.7033330
8	DR-OT-01-70	DA-OT-16	LAVERNE TWIFORD #1	4,781	42	~110	~41						3,300	0.303	~30,000	Upper	32-055-00008																									
8	DR-OT-01-70	DA-OT-16	LAVERNE TWIFORD #1	5,438	104	~117	~46					~35,000	4,250	0.240	~15,000	Lower	32-055-00008	13	DARE	RAPP OIL CORP.	6,024		3/14/1970	SCHLUMBERGER	3/14/70	IES,BHC-G-CAL,G-NT,CB,T	T	F	F	710/5840 U (INT); 710/5960 W (IN	none	none	F	N		5250	0			Oiltest	-75.7713890	35.7033330
8	DR-OT-01-70	DA-OT-16	LAVERNE TWIFORD #1	5,438	104								2,600	0.380	~8,500	Lower																										
8	DR-OT-01-70	DA-OT-16	LAVERNE TWIFORD #1	5,438	104								2,300	0.430	~9,500	Lower																										
8	DR-OT-01-70	DA-OT-16	LAVERNE TWIFORD #1	5,438	104								2,000	0.500	~8,000	Lower																										
9	DR-OT-01-71	DA-OT-17	WESTVACO "A" #1, STUMPY PT.	4,281	26	~110	~41					~27,000	2,500	0.400	~20,000	Upper	32-055-00009	20	DARE	CITIES SERVICE OIL CO.	6,264	BARNWELL DRILLING CO.	9/22/1971	SCHLUMBERGER	9/22/71	IES,DIL,BHC-CAL,SNP-G-CAL,CFD-G-CAL,FT	T	F	F	74/6260 U (INC); 80/6260 W (INC)	6236/6259 (9 BOXES)	none	F	T	GRANITE	6186	23	6120	-6100	Oiltest	-75.7780560	35.6600000
9	DR-OT-01-71	DA-OT-17	WESTVACO "A" #1, STUMPY PT.	4,848	44	~109	~40					~23,500	2,000	0.500	~17,000	Upper	32-055-00009	20	DARE	CITIES SERVICE OIL CO.	6,264	BARNWELL DRILLING CO.	9/22/1971	SCHLUMBERGER	9/22/71	IES,DIL,BHC-CAL,SNP-G-CAL,CFD-G-CAL,FT	T	F	F	74/6260 U (INC); 80/6260 W (INC)	6236/6259 (9 BOXES)	none	F	T	GRANITE	6186	23	6120	-6100	Oiltest	-75.7780560	35.6600000
9	DR-OT-01-71	DA-OT-17	WESTVACO "A" #1, STUMPY PT.	5,491	98	~102	~34					~27,000	5,600	0.180	~21,000	Lower	32-055-00009	20	DARE	CITIES SERVICE OIL CO.	6,264	BARNWELL DRILLING CO.	9/22/1971	SCHLUMBERGER	9/22/71	IES,DIL,BHC-CAL,SNP-G-CAL,CFD-G-CAL,FT	T	F	F	74/6260 U (INC); 80/6260 W (INC)	6236/6259 (9 BOXES)	none	F	T	GRANITE	6186	23	6120	-6100	Oiltest	-75.7780560	35.6600000
9	DR-OT-01-71	DA-OT-17	WESTVACO "A" #1, STUMPY PT.	5,491	98								5,450	0.180	~21,000	Lower																										
9	DR-OT-01-71	DA-OT-17	WESTVACO "A" #1, STUMPY PT.	5,491	98								1,900	0.530	~6,500	Lower																										
9	DR-OT-01-71	DA-OT-17	WESTVACO "A" #1, STUMPY PT.	5,491	98								2,200	0.450	~7,900	Lower																										
9	DR-OT-01-71	DA-OT-17	WESTVACO "A" #1, STUMPY PT.	5,491	98								2,400	0.420	~8,000	Lower																										
9	DR-OT-01-71	DA-OT-17	WESTVACO "A" #1, STUMPY PT.	5,491	98								2,300	0.430	~8,000	Lower																										
9	DR-OT-01-71	DA-OT-17	WESTVACO "A" #1, STUMPY PT.	5,491	98								2,400	0.420	~8,000	Lower																										
10	DR-OT-01-73	DA-OT-19	WESTVACO #2 (GENTLES)	3,954	36	~115	~45					~47,000	2,400	0.417	~19,500	Upper	32-055-00012	13	DARE	ALBERT GENTLES	6,178	GENTLES DRILLING CO.	8/23/1973	SCHLUMBERGER	8/23/73	IES,BHC-G-CAL,CFD-G-CAL	T	F	F	0/6190 U,W (INT)	none	none	F	T	ALKALI GRANITE	6190	0	6064	-6051	Oiltest	-75.7733330	35.7541670
10	DR-OT-01-73	DA-OT-19	WESTVACO #2 (GENTLES)	3,954	36								2,600	0.385	~22,000	Upper	32-055-00012																									
10	DR-OT-01-73	DA-OT-19	WESTVACO #2 (GENTLES)	4,114	56	~115	~45					~47,000	2,600	0.384	~22,000	Upper	32-055-00012	13	DARE	ALBERT GENTLES	6,178	GENTLES DRILLING CO.	8/23/1973	SCHLUMBERGER	8/23/73	IES,BHC-G-CAL,CFD-G-CAL	T	F	F	0/6190 U,W (INT)	none	none	F	T	ALKALI GRANITE	6190	0	6064	-6051	Oiltest	-75.7733330	35.7541670
10	DR-OT-01-73	DA-OT-19	WESTVACO #2 (GENTLES)	4,114	56								2,800	0.357	~25,000	Upper	32-055-00012																									
10	DR-OT-01-73	DA-OT-19	WESTVACO #2 (GENTLES)	5,361	94	~85	~22					~35,000	3,300	0.300	~10,000	Lower	32-055-00012	13	DARE	ALBERT GENTLES	6,178	GENTLES DRILLING CO.	8/23/1973	SCHLUMBERGER	8/23/73	IES,BHC-G-CAL,CFD-G-CAL	T	F	F	0/6190 U,W (INT)	none	none	F	T	ALKALI GRANITE	6190	0	6064	-6051	Oiltest	-75.7733330	35.7541670
10	DR-OT-01-73	DA-OT-19	WESTVACO #2 (GENTLES)	5,361	94								2,150	0.470	~6,200	Lower	32-055-00012																									
10	DR-OT-01-73	DA-OT-19	WESTVACO #2 (GENTLES)	5,361	94								3,100	0.320	~9,500	Lower	32-055-00012																									
10	DR-OT-01-73	DA-OT-19	WESTVACO #2 (GENTLES)	5,361	94								3,400	0.290	~10,500	Lower	32-055-00012																									
11	DR-OT-01-74	DA-OT-21	FIRST COLONY FARMS "A" #1	4,034	40	~112	~33					~70,000	2,400	0.410	~19,500	Upper	32-055-00014	13	DARE	CITIES SERVICE OIL CO.	5,582	MURCO DRILLING CO.	4/4/1974	SCHLUMBERGER	4/4/74	IES,BHC-G-CAL	T	F	F	980/5580 U; 980/5580 W (INT)	none	none	F	T	GRANITE	4600	0	5538	-5525	Oiltest	-75.7966670	35.8052780
11	DR-OT-01-74	DA-OT-21	FIRST COLONY FARMS "A" #1	4,471	22	~107	~38					~61,000				Upper	32-055-00014	13	DARE	CITIES SERVICE OIL CO.	5,582	MURCO DRILLING CO.	4/4/1974	SCHLUMBERGER	4/4/74	IES,BHC-G-CAL	T	F	F	980/5580 U; 980/5580 W (INT)	none	none	F	T	GRANITE	4600	0	5538	-5525	Oiltest	-75.7966670	35.8052780
11	DR-OT-01-74	DA-OT-21	FIRST COLONY FARMS "A" #1	5,103	106	~100	~32					~31,000	1,900	0.530	~5,700	Lower	32-055-00014	13	DARE	CITIES SERVICE OIL CO.	5,582	MURCO DRILLING CO.	4/4/1974	SCHLUMBERGER	4/4/74	IES,BHC-G-CAL	T	F	F	980/5580 U; 980/5580 W (INT)	none	none	F	T	GRANITE	4600	0	5538	-5525	Oiltest	-75.7966670	35.8052780
11	DR-OT-01-74	DA-OT-21	FIRST COLONY FARMS "A" #1	5,103	106								2,600	0.380	~8,200	Lower	32-055-00014																									
11	DR-OT-01-74	DA-OT-21	FIRST COLONY FARMS "A" #1	5,103	106								3,150	0.320	~9,500	Lower	32-055-00014																									
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	4,867	38	~112	~41					~44,000	3,600	0.270	~38,000	Upper	32-055-00004	24	DARE	SOCONY MOBIL OIL CO., INC.	8,386		7/29/1965	SCLUMBERGER	7/29/65	IES,FD,ML,CD,S-G,PRX-MCL-CAL,VEL	T	T	F	0/8380 U (INC); 0/8380W	none	none	F	T	INTERMEDIATE METAPLUTONIC	8380	0	8360	-8336	Oiltest	-75.5763890	35.4388890
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	4,867	38								3,800	0.260	~38,000	Upper	32-055-00004																									
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	5,957								63,000	3,200	0.310	~29,000	Upper	32-055-00004																									
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	6,697	164	~80	~18					75,000	3,400	0.290	~8,500	Lower	32-055-00004	24	DARE	SOCONY MOBIL OIL CO., INC.	8,386		7/29/1965	SCLUMBERGER	7/29/65	IES,FD,ML,CD,S-G,PRX-MCL-CAL,VEL	T	T	F	0/8380 U (INC); 0/8380W	none	none	F	T	INTERMEDIATE METAPLUTONIC	8380	0	8360	-8336	Oiltest	-75.5763890	35.4388890
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	6,697									2,000	0.500	~5,000																											
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	6,697									2,000	0.500	~5,000																											
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	6,697									2,200	0.450	~5,500																											
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	6,697									3,050	0.320	~7,500																											
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	6,697									2,800	0.350	~7,000																											
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	6,697									2,800	0.350	~7,000																											
12	DR-OT-02-65	DA-OT-12	STATE OF N.C.#2,(MOBIL #2)	6,697																																						
13	DR-OT-02-71	DA-OT-18	WESTVACO "A" #2, SOUTH LAKE	3,272	28	~127	>50					~28,000	2,400	0.416	~19,500	Upper	32-055-00010	23	DARE	CITIES SERVICE OIL CO.	5,817	BARNWELL DRILLING CO.	10/22/1971	SCHLUMBERGER	10/22/71	IES,BHC-CAL,CFD-G,SNP-G,FT	T	F	F	80/5808 U (INT); 860/5540 W (INC	5803/5806 (2 BOXES)	none	F	T	GRANITE	5728	3	5430	-5407	Oiltest	-75.8511110	35.8633330
13	DR-OT-02-71	DA-OT-18	WESTVACO "A" #2, SOUTH LAKE	3,933	46	~113	~42					~20,000	2,750	0.363	~24,000	Upper	32-055-00010	23	DARE	CITIES SERVICE OIL CO.	5,817	BARNWELL DRILLING CO.	10/22/1971	SCHLUMBERGER	10/22/71	IES,BHC-CAL,CFD-G,SNP-G,FT	T	F	F	80/5808 U (INT); 860/5540 W (INC	5803/5806 (2 BOXES)	none	F	T	GRANITE	5728	3	5430	-5407	Oiltest	-75.8511110	35.8633330
13	DR-OT-02-71	DA-OT-18	WESTVACO "A" #2, SOUTH LAKE	4,932	78	~90	~26					55,000	3,400	0.290	~15,000	Lower	32-055-00010	23	DARE	CITIES SERVICE OIL CO.	5,817	BARNWELL DRILLING CO.	10/22/1971	SCHLUMBERGER	10/22/71	IES,BHC-CAL,CFD-G,SNP-G,FT	T	F	F	80/5808 U (INT); 860/5540 W (INC	5803/5806 (2 BOXES)	none	F	T	GRANITE	5728	3	5430	-5407	Oiltest	-75.8511110	35.8633330
13	DR-OT-02-71	DA-OT-18	WESTVACO "A" #2, SOUTH LAKE	4,932	78								2,650	0.380	~11,500	Lower	32-055-00010																									
13	DR-OT-02-71	DA-OT-18	WESTVACO "A" #2, SOUTH LAKE	4,932	78								2,180	0.460	~9,500	Lower	32-055-00010																									
14	DR-OT-02-73	DA-OT-20	WESTVACO #3 (GENTLES)	4,720	48	~115	~44					~67,000	3,400	0.294	~32,000	Upper	32-055-00013	7	DARE	ALBERT GENTLES	5,880	GENTLES DRILLING CO.	10/8/1973	SCHLUMBERGER	10/8/73	IES,S-G-CAL	T	F	F	0/5860 U (INC); 2790/5860 W (INC	none	none	F	T	SHEARED 2-MICA GRANITE	5860	0	5808	-5801	Oiltest	-75.7802780	35.6900000
14	DR-OT-02-73	DA-OT-20	WESTVACO #3 (GENTLES)	4,720	48								1,500	0.666	~13,000	Upper	32-055-00013																									
14	DR-OT-02-73	DA-OT-20	WESTVACO #3 (GENTLES)	4,822	46	~97	~31					~79,000	1,900	0.526	~16,000	Upper	32-055-00013	7	DARE	ALBERT GENTLES	5,880	GENTLES DRILLING CO.	10/8/1973	SCHLUMBERGER	10/8/73	IES,S-G-CAL	T	F	F	0/5860 U (INC); 2790/5860 W (INC	none	none	F	T	SHEARED 2-MICA GRANITE	5860	0	5808	-5801	Oiltest	-75.7802780	35.6900000
14	DR-OT-02-73	DA-OT-20	WESTVACO #3 (GENTLES)	4,822	46								2,000	0.500	~17,000	Upper	32-055-00013																									
14	DR-OT-02-73	DA-OT-20	WESTVACO #3 (GENTLES)	4,822	46								2,300	0.434	~18,000	Upper	32-055-00013																									
14	DR-OT-02-73	DA-OT-20	WESTVACO #3 (GENTLES)	5,383	126	~94	~28					~79,000	1,150	0.870	~3,000	Lower	32-055-00013	7	DARE	ALBERT GENTLES	5,880	GENTLES DRILLING CO.	10/8/1973	SCHLUMBERGER	10/8/73	IES,S-G-CAL	T	F	F	0/5860 U (INC); 2790/5860 W (INC	none	none	F	T	SHEARED 2-MICA GRANITE	5860	0	5808	-5801	Oiltest	-75.7802780	35.6900000
14	DR-OT-02-73	DA-OT-20	WESTVACO #3 (GENTLES)	5,383	126								700	1.430	~1,800	Lower	32-055-00013																									
14	DR-OT-02-73	DA-OT-20	WESTVACO #3 (GENTLES)	5,383	126								1,300	0.770	~4,000	Lower	32-055-00013																									
15	DR-OT-02-74	DA-OT-22	FIRST COLONY FARMS "A" #2	3,308	44	~145	>50					~44,000	2,000	0.500	~17,000	Upper	32-055-00015	11	DARE	CITIES SERVICE OIL CO.	5,260	MURCO DRILLING CO.	4/27/1974	SCHLUMBERGER	4/27/74	IES,BHC-G-CAL,CFD-G-CAL,SNP-G,FT	T	F	F	1000/5260 U; 1000/5260 W (INT)	none	none	F	T	STRAINED LEUCOGRANITE	4260	0	5216	-5205	Oiltest	-75.8722220	35.9438890
15	DR-OT-02-74	DA-OT-22	FIRST COLONY FARMS "A" #2	3,412	32	~147	>50					~44,000	2,000	0.500	~17,000	Upper	32-055-00015	11	DARE	CITIES SERVICE OIL CO.	5,260	MURCO DRILLING CO.	4/27/1974	SCHLUMBERGER	4/27/74	IES,BHC-G-CAL,CFD-G-CAL,SNP-G,FT	T	F	F	1000/5260 U; 1000/5260 W (INT)	none	none	F	T	STRAINED LEUCOGRANITE	4260	0	5216	-5205	Oiltest	-75.8722220	35.9438890
15	DR-OT-02-74	DA-OT-22	FIRST COLONY FARMS "A" #2	4,869	46	~100	~33					~100,000	2,700	0.370	~24,000	Lower	32-055-00015	11	DARE	CITIES SERVICE OIL CO.	5,260	MURCO DRILLING CO.	4/27/1974	SCHLUMBERGER	4/27/74	IES,BHC-G-CAL,CFD-G-CAL,SNP-G,FT	T	F	F	1000/5260 U; 1000/5260 W (INT)	none	none	F	T	STRAINED LEUCOGRANITE	4260	0	5216	-5205	Oiltest	-75.8722220	35.9438890
15	DR-OT-02-74	DA-OT-22	FIRST COLONY FARMS "A" #2	4,869	46								2,700	0.370	~24,000	Lower	32-055-00015																									
15	DR-OT-02-74	DA-OT-22	FIRST COLONY FARMS "A" #2	4,869	46								1,200	0.830	~9,800	Lower	32-055-00015																									
16	DR-OT-03-65	DA-OT-13	MAR. COLLINS #1, (BLAIR #3)	4,009	38	120	~50					~55,000	3,010	0.330	~11,000	Upper	32-055-00005	14	DARE	EDWIN F. BLAIR & ASSOCIATES	6,295		11/5/1965	SCHLUMBERGER	11/5/65	IES,S-G-CAL	T	T	F	0/6281 U; 0/6281 W (INC)	none	none	F	T	AMPHIBOLITE	6281	0	6270	-6256	Oiltest	-75.6708330	35.8833330
16	DR-OT-03-65	DA-OT-13	MAR. COLLINS #1, (BLAIR #3)	4,009	38								3,350	0.298	~13,000	Upper	32-055-00005																									
16	DR-OT-03-65	DA-OT-13	MAR. COLLINS #1, (BLAIR #3)	4,280	51	~115	~45					~23,000	3,200	0.313	~12,500	Upper	32-055-00005	14	DARE	EDWIN F. BLAIR & ASSOCIATES	6,295		11/5/1965	SCHLUMBERGER	11/5/65	IES,S-G-CAL	T	T	F	0/6281 U; 0/6281 W (INC)	none	none	F	T	AMPHIBOLITE	6281	0	6270	-6256	Oiltest	-75.6708330	35.8833330
16	DR-OT-03-65	DA-OT-13	MAR. COLLINS #1, (BLAIR #3)	4,280	51								3,500	0.286	~14,000	Upper	32-055-00005																									
16	DR-OT-03-65	DA-OT-13	MAR. COLLINS #1, (BLAIR #3)	5,457	42							~13,500	2,000	0.500	~6,000	Lower	32-055-00005																									
16	DR-OT-03-65	DA-OT-13	MAR. COLLINS #1, (BLAIR #3)	5,457	42								2,700	0.370	~8,000	Lower	32-055-00005																									
16	DR-OT-03-65	DA-OT-13	MAR. COLLINS #1, (BLAIR #3)	5,457	42								3,900	0.260	~11,000	Lower	32-055-00005																									
16	DR-OT-03-65	DA-OT-13	MAR. COLLINS #1, (BLAIR #3)	5,480		~102	~34									Lower	32-055-00005	14	DARE	EDWIN F. BLAIR & ASSOCIATES	6,295		11/5/1965	SCHLUMBERGER	11/5/65	IES,S-G-CAL	T	T	F	0/6281 U; 0/6281 W (INC)	none	none	F	T	AMPHIBOLITE	6281	0	6270	-6256	Oiltest	-75.6708330	35.8833330
17	DR-OT-04-65	DA-OT-14	WEST VA. PULP & PAPER #1	3,627	55			2.0	~44			~33,000	1,800	0.550	~15,000	Upper	32-055-00006	11	DARE	EDWIN F. BLAIR & ASSOCIATES	5,150		12/1/1965	SCHLUMBERGER	12/1/65	IES,FD,G-NT	T	F	F	0/5144 U; 0/5150 W	none	none	F	T	ALTERED DIORITE	5150	0	5126	-5115	Oiltest	-75.9250000	35.8638890
17	DR-OT-04-65	DA-OT-14	WEST VA. PULP & PAPER #1	3,722	44			<1.91	>44			~20,000				Upper	32-055-00006	11	DARE	EDWIN F. BLAIR & ASSOCIATES	5,150		12/1/1965	SCHLUMBERGER	12/1/65	IES,FD,G-NT	T	F	F	0/5144 U; 0/5150 W	none	none	F	T	ALTERED DIORITE	5150	0	5126	-5115	Oiltest	-75.9250000	35.8638890
17	DR-OT-04-65	DA-OT-14	WEST VA. PULP & PAPER #1	3,744									2,100	0.476	~18,000	Upper	32-055-00006																									
17	DR-OT-04-65	DA-OT-14	WEST VA. PULP & PAPER #1	4,655	105			~1.95	>44			~48,000	3,450	0.290	~16,000	Lower	32-055-00006	11	DARE	EDWIN F. BLAIR & ASSOCIATES	5,150		12/1/1965	SCHLUMBERGER	12/1/65	IES,FD,G-NT	T	F	F	0/5144 U; 0/5150 W	none	none	F	T	ALTERED DIORITE	5150	0	5126	-5115	Oiltest	-75.9250000	35.8638890
17	DR-OT-04-65	DA-OT-14	WEST VA. PULP & PAPER #1	4,655	105								3,050	0.330	~13,000	Lower	32-055-00006																									
17	DR-OT-04-65	DA-OT-14	WEST VA. PULP & PAPER #1	4,655	105								2,450	0.410	~10,000	Lower	32-055-00006																									
17	DR-OT-04-65	DA-OT-14	WEST VA. PULP & PAPER #1	4,655	105								2,650	0.380	~11,000	Lower	32-055-00006																									
17	DR-OT-04-65	DA-OT-14	WEST VA. PULP & PAPER #1	4,655	105								2,750	0.360	~13,000	Lower	32-055-00006																									
18	HY-OT-01-65	HY-OT-11	STATE OF N.C.#3 (MOBIL #3)	4,650	40	~112	~42					~70,000	3,000	0.330	~28,500	Upper	32-095-00009	24	HYDE	SOCONY MOBIL OIL CO., INC.	7,309		8/20/1965	SCHLUMBERGER	8/20/65	IES,S-G-CAL,FD-CAL,ML,CD,VEL	T	T	F	0/7309 U (INT); 0/7310 W	none	none	F	T	LEUCOGRANODIORITE	7310	0	7222	-7198	Oiltest	-75.8291670	35.3069440
18	HY-OT-01-65	HY-OT-11	STATE OF N.C.#3 (MOBIL #3)	4,880	44	~105	~36					~70,000	3,200	0.310	~30,000	Upper	32-095-00009	24	HYDE	SOCONY MOBIL OIL CO., INC.	7,309		8/20/1965	SCHLUMBERGER	8/20/65	IES,S-G-CAL,FD-CAL,ML,CD,VEL	T	T	F	0/7309 U (INT); 0/7310 W	none	none	F	T	LEUCOGRANODIORITE	7310	0	7222	-7198	Oiltest	-75.8291670	35.3069440
18	HY-OT-01-65	HY-OT-11	STATE OF N.C.#3 (MOBIL #3)	6,099	82	~85	~22					~85,000	3,200	0.320	~8,500	Lower	32-095-00009	24	HYDE	SOCONY MOBIL OIL CO., INC.	7,309		8/20/1965	SCHLUMBERGER	8/20/65	IES,S-G-CAL,FD-CAL,ML,CD,VEL	T	T	F	0/7309 U (INT); 0/7310 W	none	none	F	T	LEUCOGRANODIORITE	7310	0	7222	-7198	Oiltest	-75.8291670	35.3069440
18	HY-OT-01-65	HY-OT-11	STATE OF N.C.#3 (MOBIL #3)	6,099	82								3,400	0.290	~10,000	Lower	32-095-00009																									
18	HY-OT-01-65	HY-OT-11	STATE OF N.C.#3 (MOBIL #3)	6,099	82								2,800	0.360	~7,900	Lower	32-095-00009																									
18	HY-OT-01-65	HY-OT-11	STATE OF N.C.#3 (MOBIL #3)	6,099	82								3,050	0.330	~8,000	Lower	32-095-00009																									
19	HY-OT-02-65	HY-OT-6	OCTAVIUS BALLANCE #1	Only gamma-ray and neutron density logs available													32-095-00010	10	HYDE	EDWIN F. BLAIR & ASSOCIATES	5,570		12/22/1965	SCHLUMBERGER	12/22/65	G-NT	T	F	F	0/5570 U (INC); 0/4500 W	none	none	F	N		5570	0			Oiltest	-76.0305560	35.4569440
19	HY-OT-02-65	HY-OT-6	OCTAVIUS BALLANCE #1														32-095-00010																									
19	HY-OT-02-65	HY-OT-6	OCTAVIUS BALLANCE #1														32-095-00010																									
19	HY-OT-02-65	HY-OT-6	OCTAVIUS BALLANCE #1														32-095-00010																									
																	32-055-00011	0	DARE	ALBERT GENTLES	5,050	GENTLES DRILLING CO.		N/A	/ /	NO	T	F	F	0/5050 U (INT)			F	N		5050	0			Oiltest	-75.7727780	35.7541670

APPENDIX (see folders on DVD)

Seismic lines (digital)
Geophysical well logs (digital)
GIS project (ArcMap – North Carolina State Plane Meters, NAD83)
Almy’s 1987a,b reports