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HIGH-RESOLUTION STRATIGRAPHY AT A COASTAL DRILLHOLE

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HIGH-RESOLUTION STRATIGRAPHY AT A COASTAL DRILLHOLE DETERMINED FROM A CONTINUOUS CORE PROFILE AND A BOREHOLE GEOPHYSICAL LOG

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ABSTRACT

Lithologic descriptions of continuous core interpreted in conjunction with borehole geophysical logs were used to established high-resolution hydro- and geostratigraphic profiles and to determine thicknesses of hydrologic and geologic units at CR-622 in the coastal plain of North Carolina. Borehole geophysics was used to adjust the position of core loss within each cored interval and to supplement lithology to determine the stratigraphy of missing segments of core. The surficial aquifer has some small inclusion of clay and is thinner here than anticipated. The Yorktown confining unit rests on an unconformity, distinguishing the aquifer from the aquitard and corresponds to the geologic units. Borehole geophysics identified this anomaly which might have otherwise been missed. The Pungo River Aquifer immediately overlies the upper Castle Hayne confining unit. The Castle Hayne confining unit is comprised of the Pungo River Formation. In other areas of the Coastal Plain, the lower part of the Pungo River Formation is a confining unit on top of the River Bend Formation and separates the Pungo River Aquifer from the upper Castle Hayne Aquifer. A resulting hydrologic and stratigraphic column of the upper Cretaceous, Tertiary and Quaternary showing a generalized relation between geologic and hydrologic units beneath Cherry Point Air Station is presented. Present are the Yorktown, Pungo River and Castle Hayne Aquifers. The geologic units are Eocene – Castle Hayne, Miocene – Pungo River, Pliocene – Yorktown, Pleistocene – James City and Flanner Beach, and the topsoil is Holocene- undifferentiated. The Oligocene – River Bend Formation is absent, and an unconformity exists between the Pungo River Formation and the Castle Hayne Formation. Although some geophysical logs produce non-unique lithologic solutions, a complete normal stratigraphic profile may be obtained with the addition of continuous core. Curve characteristics within geophysical logs provide precise identification of transitional sequences and can be used to calibrate lithostratigraphy. The interpretation of borehole geophysical logs in conjunction with the lithology developed from continuous core can be used to produce high-resolution hydro- and geostratigraphic profiles.

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INTRODUCTION

Depth resolution in stratigraphy is rarely precise. In order to obtain high-resolution stratigraphic sequences, a complete geologic record is preferred. In unique geologic settings such as outcroppings, a complete geologic record is visible above the surface. Lithology in outcroppings can be discerned directly and has been used to define type sections or type cores (Clark and Miller 1912, Miller 1982, Kimrey 1964). However, this is not often the case, and often the record can only be completed with combination of outcrop and core investigations, along with additional geophysical and chemical tests (Brown et al. 1972, Morgans-Bell et al. 2001, Tipping et al. 2006). Cripps and McCann (2000) used correlations of geophysical logs across outcroppings to match lithology, providing a complete regional profile. High resolution stratigraphy has most often been applied in offshore drilling studies (Erohina et al. 2004) and in commercial applications where economic incentives for accuracy allow for increased expenditure for continuous core in efforts to establish reference sites (Gely 1996, Bartetzko et al. 2001).

Theoretically, continuous core samples provide a complete geologic record. However, loss of core in standard onshore drilling operations can result in missing lithology (Henley and Doyle 2005). Core recovery in friable, sandy, saturated, or unconsolidated substrates is generally incomplete (USBR 1980). Consequently, collection of core samples is generally restricted to select intervals of interest (Daniel et al. 1996, Gely 1996, Timms and Acworth 2002). With non-core drilling methodsthe lack of precision for determination of cuttings source depth results in potential errors in estimates of the stratigraphic unit depth and thickness. Annels (2003) suggests a method for estimating core loss and provides guidelines for acceptable levels. Although core loss is recognized as an important issue, actual levels are rarely reported. Analyses of samples exhibiting core loss should not be interpreted without accompanying borehole geophysics. Often, core is subsampled and extrapolated to represent a complete record (Lloyd and Daniel 1988).

Unlike continuous core logs, geophysical logs provide a complete borehole profile. Geophysical variables such as resistivity, self-potential, temperature and natural gamma radiation emissions provide information that is used to differentiate lithology (Keys 1971, Dahlin et al. 1999). Although natural gamma logging techniques were developed to characterize mineralogy in the subsurface (Schumberger 1934), the techniques are now used to differentiate sand and clay of aquifers and aquitards (Keys 1980, Morin 2005). Subsequent application of natural gamma logging techniques is used to identify radioactive minerals (Asfahani and Abdul-Hadi 2001). Although geophysical logs have been used to define lithology, non-unique geophysical characterizations (Kimrey 1964, Cripps and MaCann 2000) have precluded the wide-spread application to high-resolution sequence stratigraphy. Recently, hydrostratigraphic model development driven by high-resolution sequence stratigraphy is improving the understanding of basin framework (Haq et al. 1987, Duncan et al 2000, Burger et al. 2002).

The objective of this study is to precisely determine the depth and thickness of the hydro- and geostratigraphic units in a coastal plain borehole using a combination of continuous core and borehole geophysics. We further describe the depth and thickness of hydrologic and geologic units, and demonstrate the utility of continuous core to differentiate phosphates identified on the natural gamma log in aquifers and aquitards

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METHODS

A continuous-core borehole (CR-622) was drilled in the coastal plain near the Neuse River (fig. 1) at the U.S. Marine Corps Air Station, Cherry Point, North Carolina in Craven County. The well is located at latitude 34° 57' 07" and longitude 76° 55' 35". Continuous core in 10-ft lengths was acquired to a depth of 220 ft. This was done using a wireline mud-rotary drilling system with HQ rod (2 ½ in) and an extruder system. Core was washed to remove drilling mud, measured, analyzed for physical parameters, characterized for geologic and hydrologic properties, boxed, photographed and taken to the laboratory. Geophysical data were collected and a piezometer was installed.

Each of the core sections was examined visually, and a detailed lithologic log was compiled. Physical variables included grain size, sorting, induration, mineralogy, fossil content, color, structure and estimated porosity, and were measured using standard methods (Heath 1980). Color was determined semi-quantitatively using standard soil-color charts (Munsell 1975). Color was defined as hue chroma/value (e.g. 5Y 3/4), where hue is the dominant spectral color, chroma the brilliance, and value is the purity of the color. Grain size was determined according to Wentworth (1934) with some modifications (Folk and Ward 1957). Mineralogy was determined on site using physical characteristics and standard physical field methods (USBR 1980).

A geophysical survey was conducted in the open borehole and summary geophysical logs were compiled. Geophysical variables included natural-gamma

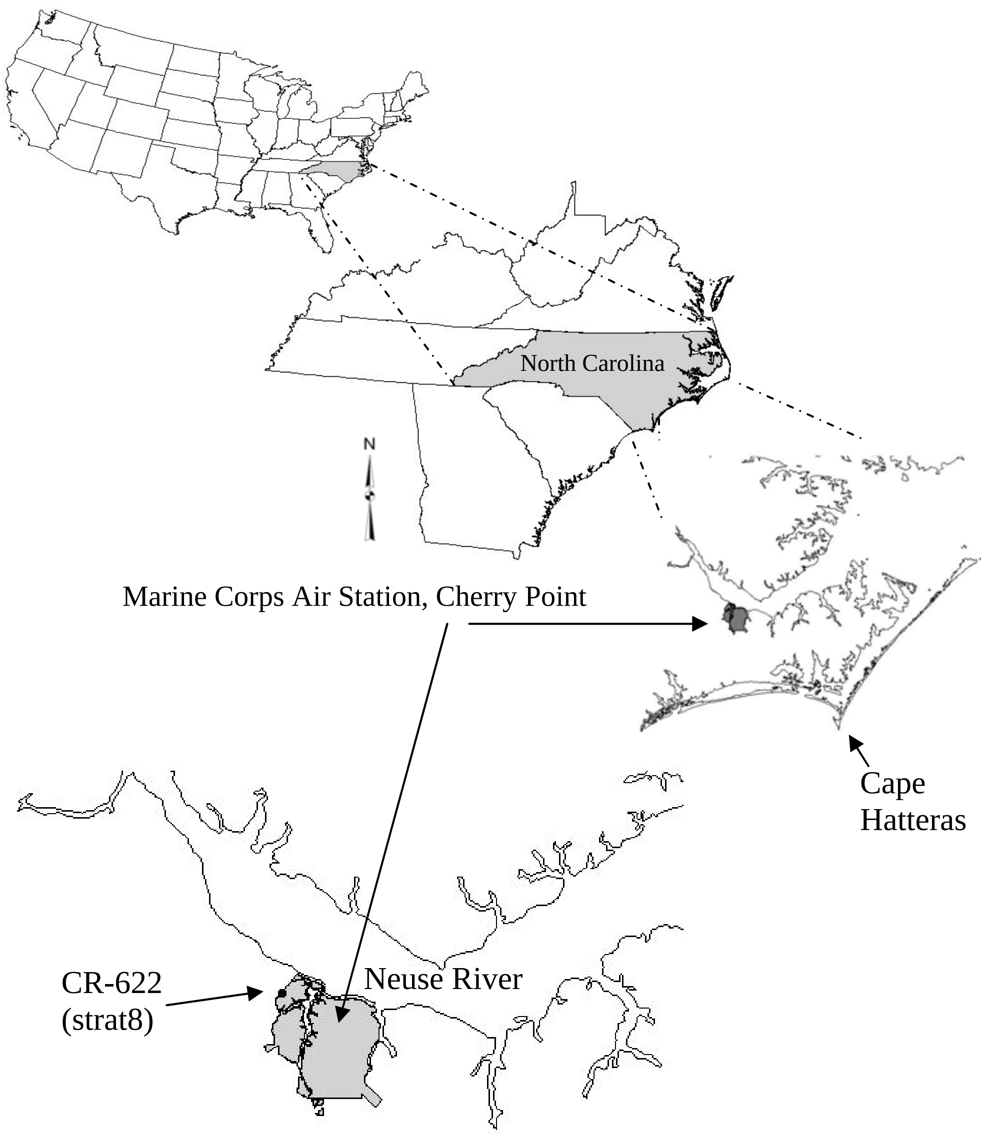

Figure 1.– Location of corehole CR-622 at the Marine Corps Air Station, Cherry Point, North Carolina, in the Atlantic Coastal Plain.

radiation emissions, conductivity, temperature and resistivity. Natural-gamma radiation emissions were logged using a Century Geophysical Corporation model 8043A induction tool and were measured using standard hydrologic settings (Keys 1989). Radioactivity was recorded at a rate of 0.02 ft/s with a time constant of 15s to a depth of 202 ft. Areas of interest in the natural gamma log were characterized by curve changes resulting in zones of sustained (more than 5-ft thick) or increased (>20 API) emissions and were used to help distinguish between clayey confining material and more permeable sands. Borehole geophysics was used to adjust the position of core loss within each cored interval, and to supplement lithology to determine the stratigraphy of missing segments of core.

The determination of hydrologic and geologic units was based on a combination of the lithologic descriptions developed from core samples, geophysical logs and water levels. More permeable and electrically resistive zones within formations were defined as aquifers; extensive, finer-grained, more clay-rich, less permeable zones are defined as confining units. Aquifers were based on the estimation of laterally extensive confining units as determined by thickness of clay zones. Confining units (aquitards) were based on thickness of the silt/clay zones or the tightness (low transmissivity) of the clay fraction and the lithology as it relates to the unit description at known type sections. The interpretation of the natural gamma logs in conjunction with the lithology was used to differentiate phosphatic sands from clays. Static water level was used to validate hydrologic units. Water level relative to land surface was obtained on 05/15/2002 using a piezometer restricted to a confined depth interval of 199.5–219 ft. Wrege and Jen (2004) provide details of the well construction.

RESULTS

Lithology

The soil layer extends 3.7-ft below the land surface and is followed by interbedded sand with some kaolinitic gray clay balls near the base to 14 ft (Table 1). A thin layer of tan silty clay, followed by a thicker layer of orange silty clay underlies the soil horizon. Surficial sands range in grain size from fine to medium, and contain fragments of carbon and charcoal.

Four clay units (a, b, c and d), each consisting of >10 ft of clay or silt, were identified and classified as confining units (1, 2 and 3; fig. 2). The first confining unit (1) was composed of two clay layers (a and b) interspersed with a shelly sand layer, and was encountered from 14.0–24.8 ft. This layer is somewhat transmissive. Within this unit (1), a grey non-fossiliferous clay layer (a) containing frosted uniform quarts grains and preceded by a fossiliferous (pelecypods) clay layer was detected from 16.4-24.8 ft. Shells within the fossiliferous clay layer (a) increased in density with depth. The next clay (b) extends from 29.0–48.6 ft. The next unit (2) was comprised of a lagoonal clay (c). The lagoonal clay was gray, silty and massive and contained scattered (<5%) shells and shell fragments, as well as rare (< 3%) phosphate grains in the base of the unit. This unit (2) was composed of grayish-green silty clay (c), and extends from 81.0–89.8 ft. Very fine sand is confined to the base of the unit. The last (3) confining unit begins at 105.3 ft and ends in a green clay (d) with uniform frosted quarts sands at 130.5 ft. This >25-ft thick unit is silty, with fine sand, thin shell-hash layers and scattered (<15%) phosphate. The unit was immediately underlain by calcareous sandstone

Table 1. – Lithologic description of subsurface materials in recovered core samples at CR-622 in feet below land surface.

Depth	Lithologic Description
0.0 – 1.0	Missing.
1.0 – 3.7	Silty CLAY, tan to orange.
3.7 – 6.0	Fine to medium SAND, grayish with bits of carbon/charcoal.
6.0 – 14.0	White to light gray, very fine sand with scattered clay-silt balls, blue-gray clay balls.
14.0 – 16.4	Gray to buff non-fossiliferous CLAY with thin sand layers, storm sand layers.
16.4 – 24.0	CLAY, fossiliferous with pelecypods, silty, gray clay, fewer shells at top of interval.
24.0 – 24.4	SAND, sandy carbonate.
24.4 – 24.8	Gray CLAY, some shells.
24.8 – 29.0	Sand? Washout?
29.0 – 30.0	Shell hash, some whole shells, gray silty clay.
30.0 – 48.6	CLAY, gray silty; scattered shells and shell fragments, some fine sand toward base of interval, a few phosphate grains.
48.6 – 52.2	SAND, shells, and shell hash, **phosphate** grains, small pebbles, some silty clay toward top.
52.2 – 58.0	SAND and abundant shell hash, shells and fragments, 10–20%, small quartz pebbles 2–4 mm **phosphate**.
58.0 – 61.0	Calcareous SAND, limey some **phosphate**.
61.0 – 62.0	Sandy chert, grayish-green chips.
62.0 – 63.5	CLAY, silty, greenish.
63.5 – 66.0	Abundant quartz pebbles at base, clayey silt.
66.0 – 70.0	Calcareous SANDSTONE, fossiliferous with pelecypods, moldic in part shell fragments, 69–70 ft.
70.0 – 78.5	Silty, clayey SAND, fine to medium.
78.5 – 81.0	Cemented calcareous SAND.
81.0 – 89.8	Sandy, silty CLAY, grayish-green, very fine sand/silty at base.
89.8 – 96.5	Calcareous SANDSTONE. Moldic limestone layers, thin.
96.5 – 103.5	SAND with quartz pebble layers, calcareous. Abundant pebbles 3–6 mm diameter. Sand, partially cemented, hard zones, shell fragments, light gray.
103.5 – 105.3	Calcareous fossiliferous SANDSTONE with hard, cemented layers.
105.3 – 126.0	Greenish-gray silty CLAY with thin shell-hash layers and scattered **phosphate** grains and small pebbles 2–3 mm, shell fragments scattered through the interval.
126.0 – 129.5	Sandy, silty shell hash with shell fragments 2–3 cm.

Table 1.-- (continued).

129.5 – 130.5	Green CLAY with storm sand streaks/lenses.
130.5 – 143.9	134.5–135, sand lenses. 142.0–143, shell hash, sandy, silty, uncemented thin clay lenses near base of interval, **phosphatic** at base, large oyster shells.
143.9 – 160.0	Moldic LIMESTONE; shells have been removed by dissolution, interstitial material is silty, micritic and minor clay to 148 ft. Weakly cemented/friable to 160 ft.
160.0 – 165.5	Gray moldic LIMESTONE, indurated/hard micrite.
165.5 – 191.9	Light tan to buff moldic LIMESTONE, competent to friable, very sandy matrix, calcareous cement, small scattered **phosphate** grains, nearly all shell material removed by dissolution, calcite crystals (spar) occur as druse on mold-void surfaces. 186–191.9, sand increases.
191.9 – 210.0	Fine to very fine, well sorted SAND, subrounded to angular, abundant, fine **phosphate** grains 2–3% "salt and pepper."
210.0 – 210.4	Cemented sand/chert.
210.4 – 215.0	Fine to very fine, well sorted SAND, subrounded to angular, abundant, fine **phosphate** grains, 2–3% "salt and pepper."
215.0 – 215.3	Cemented sand/chert.
215.3 – 220.0	Fine to very fine, well sorted SAND, subrounded to angular, abundant, fine **phosphate** grains, 2–3% "salt and pepper."

Several units of porous medium were identified between the successive thick clay units. From 25–30 ft, recovery was poor, and was limited to sand and shell hash with some whole shells in a gray clayey-silt matrix. From 49–81 ft, layered units of silt and clay were detected. Layers of sand and clay were encountered from 90–105 ft, and contained calcareous fossiliferous sandstone with hard cemented layers. The subsequent clay unit was followed by a series of sand, clay and weathered limestone zones to the depth of 220 ft.

Three phosphate-rich zones in the upper part of the hole were also identified from the core. The first phosphate zone from 30–61 ft was detected imbedded within a layer of sand extending from 48.6–62.0 ft. This zone was supported by a thin (1.5 ft) clay layer extending from 62-63.5 ft. The clay unit (d) beginning at 105.3 ft contained scattered phosphate grains and small (0.25-in diameter) phosphate pebbles concentrated from 110–115 ft. A third zone rich in phosphate was detected from 142–143 ft near the base of an interval containing large oyster shells. The lower portion of the hole had phosphates from 191-210, 210-215 and 215-220 ft.

Geophysics

Sustained high gamma emissions were identified in six depth intervals (fig. 2). A sustained high gamma emission averaging 41 API was recorded in a 7-ft thick zone from 51–58 ft. Within this interval, a peak in gamma emissions was observed from 55–58 ft. The high natural gamma emissions averaged 46.8 API at depths of 60–65 ft, and peaked above 75 API in a 4-ft thick zone at 61–64 ft. Gamma emissions averaged 65.4 API in a 8-ft thick zone from 69–77 ft and a maximum of 142 API was maintained from 72-77 ft. In an 11-ft thick zone from 78–89 ft, gamma emissions averaged 77.4 API. A maximum of 183 API was recorded within this interval from 80–88 ft. A sustained high gamma emission averaging 130 API was recorded in a 23-ft thick zone from 103–126 ft. Within this interval, a peak in gamma emissions was observed from 110–113 ft. The gamma emissions in a 6-ft thick zone from 143–149 ft averaged 27 API and within this interval from 143.5–144.5 ft. gamma averaged 40 API. A maximum of 71 API was recorded at 144.1 ft. The gamma log remains below 40 API for the remainder of the borehole.

Stratigraphy

Lithology and geophysics were jointly interpreted to produce a summary lithology log (Table 2). From this log, transitional facies and an unconformity were identified at 14.0, 16.4, 89.8 and 143.9 ft respectively.

A resulting hydrologic and stratigraphic column of the upper Cretaceous, Tertiary and Quaternary, illustrates the generalized relation between geologic and hydrologic units beneath Cherry Point Air Station (fig. 2). Present are the Yorktown, Pungo River and Castle Hayne aquifers (Table 3). The geologic units are Eocene – Castle Hayne Limestone, Miocene – Pungo River, Pliocene – Yorktown, Pleistocene – James City followed by Flanner Beach, and the topsoil is Holocene-undifferentiated (Table 4). The Oligocene – River Bend Formation is absent, and an unconformity exists between the Pungo River Formation and the Castle Hayne Formation (fig. 3, Table 4).

Table 2.-- Summary lithology of CR-622 in feet below land surface.

Depth to top of unit	**Depth to base of unit**	**Summary of Lithology**
0	1	Topsoil
1	3.7	Silty clay and sand clay lenses
3.7	6	Sand w carbon
6	14	Sand
14	16.4	Silt w fossils - pelecypods
16.4	24	Sand and shells (carbonates)
24	24.4	Sand and shells
24.4	24.8	Sand (carbonates)
24.8	29	Sand
29	30	Shell and Shell hash
30	48.6	Silt, clayey with shells and hash
48.6	52.2	Sand
52.2	58	Sand with Phosphate (30%)
58	61	Calcareous sands
61	62	Chert sandy
62	63.5	Silt
63.5	66	Clayey silt with quartz pebbles
66	70	Sandstone
70	78.5	Sand, silty
78.5	83.5	Sandstone, cemented
83.5	85	Silt, clayey
85	90	Sand with phosphate
89.8	96.5	Limestone vuggy, in a sandy matrix
96.5	103.5	Calcareous sands
103.5	107	Sandstone, calcareous
107	112	Limestone
112	115	Clay
115	125.8	Oysters interbedded with clay
125.8	144	Oysters, in a sandy matrix
144	155	Limestone (transition zone)
155	163.7	Limestone, sandy
163.7	185.5	Limestone, vuggy, w phosphate
185.5	191.9	Limestone, sandy
191.9	210	Sand with phosphate (f -v f)

Table 2.-- (continued).

210	210.4	Chert
210.4	220	Sandstone

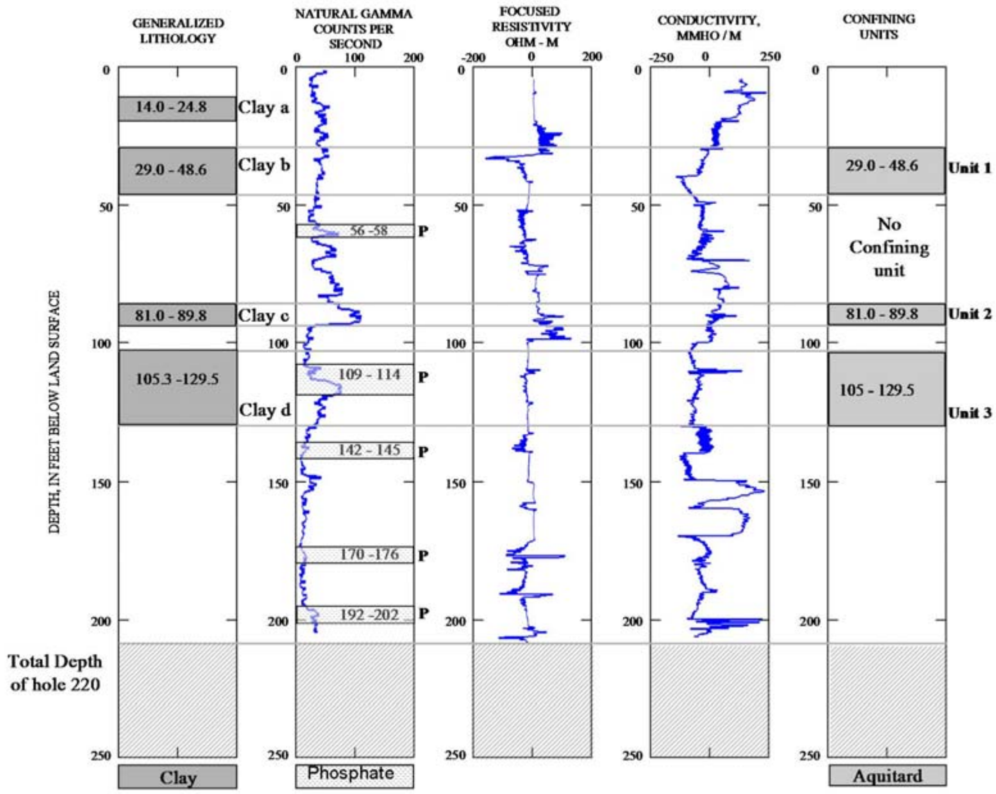

Figure 2.-- Summary clay lithology, borehole geophysics, phosphatic zones, and resultant aquifers and confining units at corehole CR-622 at the Marine Corps Air Station, Cherry Point, North Carolina, in the Atlantic Coastal Plain.

Table 3. -- Depth and thickness of aquifers and confining units at CR-622 in feet below land surface.

Depth to top of unit	**Depth to base of unit**	**Thickness of unit**	**Hydrologic Unit**
0	-	1	Topsoil
1	14	13	Surficial Aquifer
14	49	35	Yorktown Confining Unit
49	81	32	Yorktown Aquifer
81	90	9	Pungo River Confining Unit
90	105	15	Pungo River Aquifer
105	126	21	Castle Hayne Confining Unit
126	220	94 +	Castle Hayne Aquifer

Table 4. -- Depth and thickness of geologic formations at CR-622 in feet below land surface.

Depth to top of unit	Depth to base of unit	Thickness of unit	Geologic Formation
0	16.4	16.4	Holocene - undifferentiated
16.4	29.0	12.6	Pliestocene - Flanner Beach (lagoonal)
29.0	48.6	19.6	Pliestocene - James City
48.6	89.8	41.2	Pliocene - Yorktown
89.8	143.9	54.4	Miocene - Pungo River
143.9	143.9	0	Oliogocene - River Bend (limestone)
143.9	220	76.1	Eocene - Castle Hayne (limestone)

<table>
<tr><td colspan="2">Geologic Units

Phanerozoic Eon
Cenozoic Era
Neogene Epoch</td><td>Hydrologic Units</td></tr>
<tr><td>Series</td><td>Formation</td><td>Aquifers and Confining Units</td></tr>
<tr><td>Holocene</td><td>Undifferentiated</td><td rowspan="3">Surficial aquifer</td></tr>
<tr><td rowspan="3">Pleistocene</td><td>Flanner Beach</td></tr>
<tr><td rowspan="2">James City</td></tr>
<tr><td>Yorktown Confining Unit</td></tr>
<tr><td rowspan="2">Pliocene</td><td rowspan="2">Yorktown</td><td>Yorktown Aquifer</td></tr>
<tr><td>Pungo River Confining Unit</td></tr>
<tr><td rowspan="2">Miocene

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Eocene</td><td rowspan="2">Pungo River

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Castle Hayne</td><td>Pungo River Aquifer</td></tr>
<tr><td>Upper Castle Hayne Confining Unit

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Upper Castle Hayne Aquifer</td></tr>
</table>

Figure 3.-- Geologic and hydrologic units at CR-622 showing unconformity between the Miocene and Eocene geologic units of the absent Oligocene/River Bend Formation and the upper portion of the Castle Hayne Aquifer.

Water level

A water level of 22.94-ft below land surface was measured at the confined depth interval. Land surface altitude at the drill location was 28.00-ft NGVD29 datum.

DISCUSSION

Lithologic descriptions of continuous core interpreted in conjunction with borehole geophysical logs were used to established high-resolution hydrostratigraphic and geostratigraphic profiles and to determine thicknesses of hydrologic and geologic units at CR-622 in the coastal plain of North Carolina.

Surficial aquifer

All of the sedimentary deposits from the top of the basement rocks to about 15-ft below land surface are saturated with ground water (Lloyd and Daniel 1988). The soil horizon and surficial sands extend to a depth of 14 ft, and comprise the surficial aquifer. Coastal Plain sediments characterized by interbedded sands, clays, calcareous clays, shell beds, sandstone, and limestone deposited in marine or near-shore environments ranging in age from Cretaceous to Holocene (Brown et al. 1972, Winner and Coble 1989). At CR-622 the surficial aquifer has some small inclusion of clay. The surficial aquifer is thinner here than anticipated. The observed thickness of the surficial aquifer elsewhere on the base ranges from 31–68 ft. The aquifer is thinnest and could be absent where it is eroded by the Neuse River and its tributaries (Lloyd and Daniel 1988, Eimers et al. 1994, Daniel et al. 1995)

Yorktown confining unit

The depth interval of the Yorktown confining unit was based on the geophysical log (top) and stratigraphy (bottom). The sandy shell sequence interbedded between the two clay layers was not hydrologically significant and likely resulted from a transitional facies. This 8-ft thick section is saturated, has moderate porosity and low transmissivity, but not low enough to be confining. The Yorktown confining unit has been identified as the uppermost sediments of the Yorktown Formation of Pliocene age (Ward and Blackwelder 1980). The second clay layer within this confining unit is geologically consistent with the James City formation (Ward and Blackwelder 1980). These findings are consistent with interpretations by Keoughan (1988) and Murray and Keoughan (1990), who assigned the Yorktown confining unit to the James City Formation. For purposes of this report, the Yorktown confining unit is considered Pleistocene in age (Dubar and Solliday 1963). The Yorktown confining unit rests on an unconformity (erosional surface) distinguishing the aquifer for the aquitard and corresponding to the geologic units. Borehole geophysics identified this anomaly which might have otherwise been missed.

Yorktown Aquifer

The Yorktown Aquifer underlies the Yorktown confining unit. The Yorktown Aquifer consists of unconsolidated fine sand, silty and clayey sand, and clay; shell beds also occur in the unit and indicate a marine depositional environment. Winner and Coble (1989) estimated the Yorktown Aquifer to contain 70-80% sand in the vicinity of the Air Station. The altitude at the top of the Yorktown Aquifer reportedly ranges from <35 to >50-ft below sea level (Eimers et al. 1994) and dips southeast at about 4.5 ft/mi. Apparent inconsistencies between the lithologic and gamma emission logs are due to the presence of collophanite, a phosphate mineral found in the Yorktown and Pungo River Formations (Lloyd and Daniel 1988). This mineral emits a substantial amount of gamma radiation (Kimrey 1965). Our corresponding lithologic logs made identification of this phosphatic sand layer possible.

Pungo River confining unit

Below the Yorktown Aquifer is the Pungo River Aquifer (Wrege et al. 2001); therefore, the confining clay unit underlying the Yorktown Aquifer is the Pungo River confining unit. Definition of the Pungo River confining unit is supported by the natural gamma log. The Pungo River confining unit overlies the Pungo River Aquifer and is composed of contiguous sandy clays of the lowermost Yorktown Formation and the upper clay (including clay containing some phosphatic sand) and sandy silt beds of the Pungo River Formation of middle Miocene age (Kimrey 1964, 1965). The confining-unit thickness ranges from 7–33 ft (Eimers et al. 1994).

Pungo River Aquifer

The Pungo River Aquifer consists of fine- to medium-grained sand with lenses of silt, clay, shell, shell hash and phosphatic sand. Although recovery of unconsolidated shell hash is technically difficult, this material is regionally indicative of the Pungo River Formation. Eimers et al. (1994) estimated that the Pungo River Aquifer contains about 70% sand based on analyses of geophysical logs. Winner and Coble (1989) estimated that the Pungo River Aquifer contains 80–90% sand at a nearby location. A marker layer composed of thin beds of chert and chert-cemented sand has been encountered in several nearby wells, and was identified in our samples. Depth of the Pungo River Aquifer is consistent with other reported values (Eimers et al. 1994).

Castle Hayne confining unit

The Pungo River Aquifer immediately overlies the upper Castle Hayne confining unit. The Castle Hayne confining unit is comprised of the Pungo River Formation. Regionally, the upper Castle Hayne confining unit consists of interbedded clays, sandy clays, silts, sands and phosphatic and non-phosphatic limestones that occur in the basal unit of the Pungo River Formation. Locally, however, this confining unit consists of sand, silty sand, and abundant shells and shell fragments. Thin beds of sand also are present. In the region, the observed thickness of the confining unit ranges from 12–45 ft (Eimers et al. 1994).

Castle Hayne Aquifer

In other areas of the Coastal Plain, the lower part of the Pungo River Formation is a confining unit on top of the River Bend Formation and separates the Pungo River Aquifer from the upper Castle Hayne Aquifer. The hydrogeologic unit previously described as the Castle Hayne Aquifer by Lloyd and Daniel (1988) included the middle and lower units of the Pungo River Formation of Miocene age, the River Bend Formation of Oligocene age, and the Castle Hayne Limestone of middle Eocene age (Ward et al. 1978). In our samples, the clay sequence of the River Bend Formation is noticeably absent and has been replaced with a transitional sequence. Consequently, the unit offers little confinement to the underlying River Bend Formation (a voidic limestone), and functions hydrologically as part of the upper Castle Hayne Aquifer. The Castle Hayne Aquifer thus contains both the limestones of the River Bend and Castle Hayne Formations in our samples.

Conclusions

The interpretation of borehole geophysical logs in conjunction with lithology developed from continuous core can be used to produce high-resolution hydro- and geostratigraphic profiles. Although some geophysical logs produce non-unique lithologic solutions, a complete normal stratigraphic profile may be obtained with the addition of continuous core. Curve characteristics within geophysical logs provide precise identification of transitional sequences and can be used to calibrate lithostratigraphy.

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