DELAWARE GEOLOGICAL SURVEY
University of Delaware, Newark
John H. Talley, State Geologist

DELAWARE GEOLOGICAL SURVEY
GEOLOGIC MAP OF THE FAIRMOUNT AND REHOBOTH BEACH QUADRANGLE, DELAWARE
GEOLOGIC MAP SERIES NO. 16

GEOLOGIC MAP OF THE FAIRMOUNT AND REHOBOTH BEACH QUADRANGLES, DELAWARE

by

Kelvin W. Ramsey

2011

SCALE 1:24,000

1991 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Kilometers
Miles
Feet

10-foot Index with a 6-foot Intermediate Contour Interval
10-foot Bathymetric Contour Interval
Soundings in feet
2-foot contour data are available for this map from the Delaware DataMIL at http://datamil.delaware.gov
NORTH AMERICAN DATUM OF 1988 (NAD88)

EXPLANATION

FILL

Man-made deposits of natural earth material used to extend shore land and/or to fill a low-lying area such as where a road crosses a valley or marsh. Most of the fill in the map area is dredged marsh deposits from channel construction and deepening through the marshes. Some construction debris (concrete, bricks, etc.) may be incorporated in the unit.

NEARSHORE DEPOSITS *offshore*

Pale-yellow to light-gray, cross-bedded, very fine, silty sand to fine to coarse sand with laminae to thin beds of very coarse sand, granules, and pebbles. Shells are a common constituent of the sands and range from fragmented, granule-size pieces to whole shells. Nearshore deposits are mapped from the shoreline to where the seafloor drops from the gradual slope from the beach with water depths of less than 10 ft to water depths of greater than 20 ft. Texture of nearshore sediments is related to texture of underlying deposits from which they are reworked and are fine silty sand off the Pleistocene headland at Rehoboth Beach and fine to coarse sand off the barrier south of Dewey Beach. Nearshore deposits fine offshore from the coarse sand to gravel in the surf zone to very fine silty sand and are thin, usually less than two ft in thickness. Holocene.

FINGER SHOAL DEPOSITS *offshore*

Gray, silty, coarse, medium to fine, and fine to very fine sand that fines seaward to very fine sandy silt. In the medium sands, shell fragments and *Mercenaria* shells are common. Clay and clayey silt-lined burrows are common throughout. The sands are finely laminated with opaque heavy minerals and textural laminae of very fine silty sand and coarser sand. The deposits interfinger with the quiet-water deposits. Finger shoal deposits extend from the bathymetric break between 19 and 20 ft offshore that marks the limit of the nearshore deposits to water depths of about 50 ft. They have a characteristic bathymetric signature of shore-oblique highs that extend like fingers from the nearshore. Thickness ranges from less than 1 ft off of Rehoboth Beach to greater than 10 ft where best developed off of the Rehoboth Bay barrier. Holocene.

SHOAL DEPOSITS *offshore*

Pale-yellow to gray, fine to medium sand that grades to very fine to fine sand with increasing water depth and distance from the shoreline. Thin laminae to beds of coarse to very coarse sand are common. The deposits become siltier with increasing depth below the sea floor and grade to gray, silty, fine to medium sand with pebbles. The deposits are moderately silty to silty where they interfinger laterally with quiet-water deposits. Burrows are common in the shoal deposits; in places the sediment is completely bioturbated. Shells ranging from sand-size fragments to whole shells are rare to common. Shoal deposits are commonly over 10 ft thick and range from less than 3 ft to over 20 ft in thickness. The shoal deposits related to the deposition of Hen and Chickens Shoal. Holocene.

SHEET SAND DEPOSITS *offshore*

Pale-yellow, well-sorted, fine to medium, to coarse to very coarse sand with abundant granules, pebbles, and shell fragments. Cross-bedding is common consisting of laminae of sand, granules, and pebbles. Shells most common within the sheet sand deposits are *Spisula*, *Ensis* and *Anomia* are few to common and lesser amounts of sand dollars, echinoid spines, and solitary corals (*Astrangia*?) have been observed. Sheet sand deposits range from a few inches to over 5 ft in thickness. Where thin (<2 ft), the deposits tend to be patchy overlying shoal, finger shoal, or quiet-water deposits. Where thicker, the deposits form an extensive layer or sheet of sand on the seafloor; most commonly where the Beaverdam Fm. underlies, and was the source of sand for, the sheet sand deposits. Holocene.

QUIET-WATER DEPOSITS *offshore*

Light-gray to very-dark-gray, very fine silty sand to silt. Burrows are common to abundant. Whole to fragments of *Ensis* shell are common to abundant. Thin laminae of silt and very fine silty sand are common. These deposits are commonly found at water depths greater than 45 ft (below storm wave base). Deposits range from one to 10 ft in thickness. Holocene.

SHORELINE DEPOSITS

White to light-gray, well-sorted, very coarse to fine sand with scattered pebbles. Along the western shoreline of Rehoboth Bay, they are thin, ephemeral bodies of sand less than 3 ft thick. Along the Atlantic shoreline, the sands range up to 10 ft thick. These sands grade laterally into dune deposits and washover deposits. Holocene.

BARRIER WASHOVER DEPOSITS

White to gray, very coarse to fine sand with scattered laminae of pebbles and heavy mineral laminae. Laminae of organic fragments and thin peat layers are also common These deposits are the result of storm events transporting shoreline and dune deposits into the margin of Rehoboth Bay. The peat and organic debris layers represent established marshes that are buried by subsequent washover events. Washover deposits are up to 25 ft thick (Chrzastowski, 1986). Holocene.

SPIT DEPOSITS

Interbedded fine to coarse sand, gravelly sand, silty sand, and sandy silt. Scattered shelly beds are also present. The unit represents the spit complex of Cape Henlopen that has prograded into the mouth of Delaware Bay and overlies marine deposits. Thickness ranges from 0 to 80 ft. Holocene.

SWAMP DEPOSITS

Consist of 1 to 3 ft of gray to brown, silty and clayey, gravelly sand at the base overlain by organic-rich fine to coarse sand. In some of the larger stream valleys, the unit has several ft of organic silt at the top. Up to 15 ft thick in the larger stream valleys and less than 5 ft thick in the smaller tributaries. Holocene.

MARSH DEPOSITS

Light-gray to brown, organic-rich, clayey silt. Peat beds consisting of finely comminuted organic fragments (primarily of marsh grass) are common near the base of the unit and scattered elsewhere. Marsh deposits are generally less than 10 ft thick along the western shore of Rehoboth Bay (Schwimmer, 1999) and eastern shore along the Atlantic Barrier (Ramsey, 2002; unpublished DGS data). Radiocarbon dates from the deposits indicate that deposition began prior to 11,000 yrs B.P. (Ramsey and Baxter, 1996; McKenna and Ramsey, 2002; unpublished DGS data). Radiocarbon dates from the shoal deposits indicate that deposition rates on Hen and Chickens Shoal over the last millenia have been up to 2 ft per 100 yrs.

The extension of the margins of the paleovalleys filled with Lynch Heights Formation and Holocene lagoon deposits are shown offshore by red dashed lines. These lagoonal deposits are found beneath the surficial Holocene lithologic units (cross section C-C'). Interfluve areas within and between paleovalleys are topographic highs of Beaverdam Formation (cross section C-C') and are indicated as interfluves on the map. The lagoonal bodies are differentiated from each other by the Holocene deposits being more sand than clay and the Lynch Heights lagoon being compact silty clay. Radiocarbon dates from the Holocene lagoon are younger than 12,000 yrs B.P. and from the Lynch Heights lagoon are older than 44,000 yrs B.P. (Ramsey and Baxter, 1996; unpublished DGS data).

LAGOON DEPOSITS *on cross section*

Medium-gray to dark-gray clayey silt. Sedimentary structures are rare and consist of relict burrows or thin laminae of marsh grass fragments or very fine sand. Lagoon deposits grade laterally into marsh deposits in the subsurface. They underlie the majority of Rehoboth Bay and the tidal portions of its tributaries (Chrzastowski, 1986; Schwimmer, 1999). Holocene.

DUNE DEPOSITS

White to light-yellow, well-sorted, medium to fine sand. Laminae of coarse sand are common. Thin, brown soil lamellae are commonly found at depths of 1 to 3 ft within the dunes. Inland dune deposits range up to 15 ft thick. The deposits are eolian features related to eolia-climate processes when arboreal vegetation was scarce and winds blew sand dunes across the landscape. Latest Pleistocene to Holocene.

CAROLINA BAY DEPOSITS

Found in circular features in the northwestern part of the Fairmount Quadrangle. They consist of raised rims of well-sorted medium to fine sand and silty sand in the interior of the circular features. They may have contained thin organic-rich sands in the interior, but much of these deposits have been disturbed and destroyed by farming. A few of the features may contain either seasonal or year-round bodies of water where the water table is high. The deposits are less than 5 ft thick in their interiors and up to 10 ft thick where the sand rims are best developed. The features are related to eolia-climate processes during the latest Pleistocene. Latest Pleistocene to Holocene.

SCOTTS CORNERS FORMATION (YOUNGER)

Pale-yellow to light-gray, gravelly sand grading up to medium to coarse sand, to fine sand, commonly capped by 1 to 3 ft of very fine, sandy, clayey silt. Scattered beds of 1- to 3-ft thick beds of gray silty clay with organic-rich laminae are also common. These deposits are found beneath low tertiary flats less than 5 ft in elevation along the margins of Rehoboth Bay and range up to 15 ft in thickness. They are considered to be lagoon-margin deposits; the result of a high stand of sea level along the margins of an ancestral Rehoboth Bay at approximately 80,000 yrs B.P. (Ramsey, 2010a). Late Pleistocene.

SCOTTS CORNERS FORMATION (OLDER)

White to pale-yellow, well-sorted, coarse to fine sand with scattered thin clay laminae and rare beds of gray silty clay. These deposits are found beneath terrace flats between 10 and 18 ft in elevation along the margins of Rehoboth Bay and range up to 10 ft in thickness. They are primarily tidal-flat deposits related to a high stand of sea level at approximately 120,000 yrs B.P. (Ramsey, 2010a). Late Pleistocene.

LYNCH HEIGHTS FORMATION

Clean, white to pale-yellow, well-sorted, fine to coarse sand with scattered very coarse to pebble laminae and silty clay laminae overlying light-gray to greenish-gray, compact silty clay with rare laminae of *Mulinia* shells and shell fragments. The unit thickens from west to east ranging from 10 ft thick to over 60 ft in Rehoboth. The silty clay beds grade laterally to well-sorted sands with clay laminae. The deposits were deposited in a lagoon (silty clay with shell) with tidal flats (sand with clay laminae) that was prograded by spit deposits (well-sorted fine to coarse sand). The lagoonal and tidal flat deposits are considered to have been deposited during a high stand of sea level at approximately 400,000 yrs B.P. (Ramsey, 2010a). The overlying spit deposits may be related to the same event or may be related to a later high stand of sea level at 320,000 yrs B.P. (Ramsey, 2010a). Late Pleistocene.

Where shown with pattern in the western half of the Fairmount Quadrangle, the Lynch Heights Formation consists of a thin (< 10 ft and in most areas < 3 ft thick) layer of heterogeneous deposits ranging from reddish-brown, pale-yellow, and light-gray, silty, clayey, very coarse to fine sand, to pale-yellow to light-gray gravelly sand to sandy gravel. These deposits are considered to be the result of reworking and redeposition of the underlying Beaverdam Formation sediments. These deposits grade laterally into the Lynch Heights Formation (described above). Deposited in shallow water along the margins of a tidal system during a high stand of sea level at approximately 400,000 yrs B.P. that has been strongly overprinted by later cold climate and soil-forming processes. It is likely that in many places in the area mapped that this unit is absent and the Beaverdam Formation forms the surficial deposit. They are differentiated from the Beaverdam Formation in that they lack the characteristic white silt matrix and generally have a layer of coarse sand to gravel overlying typical Beaverdam sands. Late Pleistocene.

BEAVERDAM FORMATION

Heterogeneous unit ranging from very coarse sand with pebbles to silty clay. The predominant lithologies at the land surface are white to mottled light-gray and reddish-brown, silty to clayey, fine to coarse sand. Laminae and beds of very coarse sand with pebbles to gravel are common as are laminae and beds of bluish-gray to light-gray silty clay. In a few places near land surface, but more commonly in the subsurface, beds ranging from 2 to 20 ft thick of finely laminated, very fine sand and silty clay are present. The sands of the Beaverdam Formation have a white silt matrix that gives samples a milky appearance when wet. This white silt matrix is the most distinguishing characteristic of this unit and readily differentiates the Beaverdam Formation from the adjacent cleaner sands of the Lynch Heights and Scotts Corners Formations. The Beaverdam Formation is interpreted to be a late Pliocene fluvial to estuarine deposit. The Beaverdam ranges from 50 to 100 ft thick in the map area. Late Pliocene.

Discussion

The geologic history of the surficial units of the Fairmount and Rehoboth Beach quadrangles is that of deposition of the Beaverdam Formation and its subsequent modification by erosion and deposition related to sea-level fluctuations during the Pleistocene. The geology reflects this complex history both onshore, in Rehoboth Bay, and offshore. Erosion during the late Pleistocene sea-level low stand and ongoing deposition offshore and in Rehoboth Bay during the Holocene rise in sea level represent the last of several cycles of erosion and deposition.

The Beaverdam Formation consists of stacked, one- to five-ft thick beds of very coarse sand and gravel that commonly fine upwards to fine to medium sand and rarely to very fine silty sand to silty clay. These types of deposits are typical of either fluvial or estuarine environments (Ramsey, 2010a, b). Rare burrows have been observed in the Beaverdam Formation elsewhere in Delaware that indicate at least a marginal estuarine setting (DGS unpublished data; Owens and Denny, 1979). The Beaverdam Formation in the Fairmount and Rehoboth Beach quadrangles is exposed along the sides of stream valleys to the west of Rehoboth Bay and west of Route 24 where it is at the land surface or lies beneath a thin (< 2') cover of material reworked from the Beaverdam. The Beaverdam underlies all the younger deposits of the area and extends offshore (cross sections A-A', B-B', and C-C'). The age of the Beaverdam Formation is uncertain due to the lack of age-definitive fossils within the unit. Stratigraphic relationships in Delaware indicate that it is no older than late Miocene and no younger than early Pleistocene and is most likely late Pliocene (Ramsey, 2010a, b).

The Lynch Heights Formation is a composite unit consisting of deposits related to two sea-level high stands (Ramsey, 2010a). West of Rehoboth Bay and Angola Neck (cross section A-A'), the Lynch Heights Formation is a thin unit (< 5' thick) consisting of fine to medium sand that coarsens to a coarse sand. In places, a pebbly sand to pebble gravel with abundant opaque heavy minerals is found at the base of the unit overlying the Beaverdam Formation. This portion of the Lynch Heights Formation is interpreted to be a thin, nearshore deposit consisting of sand eroded from the Beaverdam Formation as the shoreline transgressed the area and is part of the older Lynch Heights Formation of middle Pleistocene age (Ramsey, 2010a). It is possible that these deposits were partially reworked during the deposition of the younger Lynch Heights Formation (Ramsey, 2010a).

On Angola Neck, the Lynch Heights Formation consists of well-sorted, fine to medium sand with coarse sand laminae and laminae to thin beds of silty clay. These deposits thicken from a few ft thick to 20 to 30 ft thick southeast of Rehoboth Beach (cross sections A-A' and B-B'). The sands interfinger with, or are overlapped by, a body of bluish-gray, clayey silt to silty clay that contains scattered to thin beds of shell, most commonly *Mulinia*, with scattered *Ensis* and *Crassostrea*. The sands with clay laminae are interpreted as intertidal to subtidal flat deposits much like those seen on the western side of Cape Henlopen today. The muds are interpreted to be lagoonal deposits. The western margin of the lagoon extended just north of the map area (east of the present location of Cape Henlopen High School) to underneath Rehoboth Beach and offshore to the south of the present location of Hen and Chickens Shoal (cross sections A-A' and B-B'; Ramsey 1999, identified as Omar Formation). Amino-acid racemination of *Mulinia* shells indicate that the deposits fall in aminozone Ib with an approximate age of 120,000 yrs (Ramsey, 2010a; Groot, Ramsey and Wehmiller, 1990). The older Lynch Heights Formation age is approximately 400,000 yrs B.P. (Ramsey, 2010a).

The Scotts Corners Formation consists of sand that ranges from fine to very coarse sand with scattered beds and laminae of silty clay found on flat areas adjacent to Rehoboth Bay and its tributaries. Based on geomorphology and lithologic differences, these deposits can be separated into two units designated as the older and younger Scotts Corners formations. These deposits are interpreted to be the result to two separate high stands of sea level associated with the last interglacial; the older Scotts Corners being about 120,000 yrs B.P. and the younger Scotts Corners about 80,000 yrs B.P. (Ramsey, 2010a).

Dune deposits are fine to medium, well-sorted sands that are found primarily in the southwestern portion of the map area. The dunes have a pronounced surficial expression as linear features that rise above the surrounding landscape. Some of these dunes are probably latest Pleistocene to early Holocene in age (Andres and Howard, 2000), but some could possibly be contemporaneous with deposition of the Lynch Heights or Scotts Corners Formations. Dune features are also associated with the rims of Carolina Bays that are found in the northern part of the map area. Some of the features mapped as Carolina Bays may be parabolic dunes with blow-out low areas on the windward side. Because the features are generally circular in shape and are consistent in size with Carolina Bays mapped elsewhere (Ramsey, 2001, 2003, 2010b), they are mapped as Carolina Bays. Both the dunes and the Carolina Bays are cold-climate related features located where winds moved sand across a landscape barren of forests (Ramsey, 1997). The exact process by which the distinctive circular shape of the Carolina Bays was formed is unknown.

Modern deposition includes Rehoboth Bay and its tributaries, the barrier coastline, the southernmost portion of Cape Henlopen, and offshore. The succession of deposits related to Rehoboth Bay goes from freshwater swamp deposits in the upper reaches of the tributaries, which grade into the tidal streams, marshes, and lagoonal deposits (Chrzastowski, 1986). The texture of the bottom sediments for the tidal streams and Rehoboth Bay lagoon on the map are modified from Chrzastowski (1986). The areas mapped as sand coarsen from very fine to fine to medium towards the barrier. The map shows the general distribution of the sediment textures which may have changed somewhat since 1986 but are representative of the textures one would expect to encounter on the bottom of the lagoon. The transitions between sediment textures are gradational; the lines shown on the map are approximate boundaries. The barrier that separates Rehoboth Bay from the Atlantic Ocean is composed of nearshore and shoreline (beach) deposits on the Atlantic side. The barrier itself is composed of dune deposits that overlie, and interfinger with, barrier washover deposits on the Rehoboth Bay side of the barrier. The barrier washover deposits are the result of storms that transport beach, nearshore, and dune sand across the barrier into Rehoboth Bay. On the bay side, the washover deposits are overlain by, and interfinger with, marsh and lagoon deposits that accumulate between washover (storm) events.

Spit deposits just north of Rehoboth Beach at North Shores comprise the southernmost portion of Cape Henlopen where they overlie the lagoon deposits of the Lynch Heights Formation. These deposits consist of interbedded sand, peat, and organic-rich mud that interfingers with the barrier washover deposits along the shoreline (cross section B-B'). Radiocarbon dates from these deposits just north of the map area, indicate that deposition began prior to 3,000 yrs B.P. as Cape Henlopen began prograding to the north. The spit deposits overlie a compact, organic-rich clay at an elevation of -50 ft (NJ51-02, shown in white on cross section B-B') that yielded a radiocarbon date of 28,400 yrs B.P. (Ramsey and Baxter, 1996). This indicates that there was deposition at the site when sea level was much lower than present and prior to the evolution of the modern spit. These deposits are limited in areal extent and not assigned to a stratigraphic unit. They are likely related to cold-climate marsh and bog deposition found throughout southern Delaware (Andres and Howard, 2000).

Lithologic mapping of offshore deposits used 99 vibracores, most of which are 20 ft in depth below the sea floor (McKenna and Ramsey, 2002; Williams, 1999; unpublished DGS data). Rather than creating a new stratigraphic nomenclature, the offshore lithologies were assigned names related to their depositional environments. This is in keeping with nomenclature onshore for modern deposits such as marsh, swamp, or shoreline. The offshore deposits are the result of the rise of sea level during the latest Pleistocene to Holocene and consist of deposits associated with the migration of the shoreline as sea level rose (lagoon and barrier washover and nearshore) and deposits associated with the modern marine setting (shoal, finger shoal, quiet water, and sheet sand). The two types of shoal deposits reflect the migration of sediment from onshore to offshore either from the barrier shoreline (finger shoal) or from Cape Henlopen (shoal-specifically Hen and Chickens Shoal; Terchunian, 1984). Quiet-water deposits are related to deeper-water deposition in areas sheltered from storm waves behind Hen and Chickens Shoal (quiet water) or are below storm-wave base in areas where only fine sand to silt sediments accumulate. Sheet sand deposits are found where bottom sediments are reworked by storms where a source of sand is present, commonly the Beaverdam Formation. Radiocarbon dates from offshore samples indicate sea-level rise deposits began prior to 11,000 yrs B.P. (Ramsey and Baxter, 1996; McKenna and Ramsey, 2002; unpublished DGS data). Radiocarbon dates from the shoal deposits indicate that deposition rates on Hen and Chickens Shoal over the last millenia have been up to 2 ft per 100 yrs.

The extension of the margins of the paleovalleys filled with Lynch Heights Formation and Holocene lagoon deposits are shown offshore by red dashed lines. These lagoonal deposits are found beneath the surficial Holocene lithologic units (cross section C-C'). Interfluve areas within and between paleovalleys are topographic highs of Beaverdam Formation (cross section C-C') and are indicated as interfluves on the map. The lagoonal bodies are differentiated from each other by the Holocene deposits being more sand than clay and the Lynch Heights lagoon being compact silty clay. Radiocarbon dates from the Holocene lagoon are younger than 12,000 yrs B.P. and from the Lynch Heights lagoon are older than 44,000 yrs B.P. (Ramsey and Baxter, 1996; unpublished DGS data).

Subsurface units are shown in cross sections down into the Beaverdam Formation. A summary of core hole Ph22-39, drilled at the Inland Bays Wastewater Treatment Facility, is shown as an example of subsurface units encountered at depths less than 400 ft. For deeper stratigraphy, refer to the report on drill hole QM25-02 (Benson et al., 1990).

References Cited

Andres, A.S., and Howard, C.S., 2000, The Cypress Swamp Formation, Delaware: Delaware Geological Survey Report of Investigations No. 62, 13 p.

Andres, A.S., and Klingbeil, A.D., 2006, Thickness and transmissivity of the unconfined aquifer of eastern Sussex County, Delaware: Delaware Geological Survey Report of Investigations No. 70, 19 p.

Benson, R.N., ed., with contributions by Andres, A.S., Benson, R.N., Ramsey, K.W., and Talley, J.H., 1990, Geologic and hydrologic studies of the Oligocene-Pleistocene section near Lewes, Delaware: Delaware Geological Survey Report of Investigations No. 46, 34 p.

Chrzastowski, M.J., 1986, Stratigraphy and geologic history of a Holocene lagoon: Rehoboth Bay and Indian River Bays, Delaware: Ph.D. dissertation, University of Delaware, Newark, DE, 337 p.

Groot, J.J., Ramsey, K.W., and Wehmiller, J.F., 1990, Ages of the Bethany, Beaverdam, and Omar formations of Southern Delaware: Delaware Geological Survey Report of Investigations No. 47, 19 p.

McKenna, K.K., and Ramsey, K.W., 2002, An evaluation of sand resources, Atlantic offshore, Delaware: Delaware Geological Survey Report of Investigations No. 63, 37 p.

Owens, J.P., and Denny, C.S., 1979, Upper Cenozoic deposits of the central Delmarva Peninsula, Maryland and Delaware: U.S. Geological Survey Professional Paper 1067-A, 28 p.

Ramsey, K.W., 1997, Geology of the Milford and Mispillion River Quadrangles, Delaware: Delaware Geological Survey Report of Investigations No. 55, 40 p.

_____, 1999, Cross section of Pliocene and Quaternary deposits along the Atlantic Coast of Delaware: Delaware Geological Survey Miscellaneous Map Series No. 6.

_____, 2001, Geologic Map of the Ellendale and Milton Quadrangles, Delaware: Delaware Geologic Map Series No.11, Scale 1:24,000.

_____, 2003, Geologic map of the Lewes and Cape Henlopen Quadrangles, Delaware: Delaware Geological Survey Geologic Map Series No. 12, scale 1:24,000.

_____, 2010a, Stratigraphy of the middle to late Pleistocene deposits of Delaware: Delaware Geological Survey Report of Investigations, 43 p.

_____, 2010b, Geologic map of the Georgetown Quadrangle, Delaware: Delaware Geological Survey Geologic Map Series No. 15, scale 1:24,000.

Ramsey, K.W., and Baxter, S.J., 1996, Radiocarbon dates from Delaware: a compilation: Delaware Geological Survey Report of Investigations No. 54, 18 p.

Schwimmer, R.A., 1999, Sea-level rise, progradation, and shoreline erosion: a history of Horse Island Marsh, Rehoboth Bay, Delaware, 200 p.

Shepard, F. P., 1954, Nomenclature based on sand-silt-clay ratios: Jour. Sed. Pet., v. 24, pp.151-158.

Terchunian, A.V., 1984, Hen and Chickens Shoal, Delaware; evolution of a modern nearshore marine feature: M.S. Thesis, University of Delaware, Newark, DE, 144 p.

Williams, C.P., 1999, Late Pleistocene and Holocene stratigraphy of the Delaware Inner Continental Shelf: M.S. Thesis, University of Delaware, Newark, DE, 175 p.

Acknowledgements

The project was funded in part by the cooperative agreement between the Association of American State Geologists and U.S. Geological Survey under STATEMAP program grants 07HQAG0086. Offshore mapping was funded as part of sand resource evaluation projects for the MMS (now the Bureau of Ocean Energy Management, Regulation and Enforcement) of the U.S. Department of the Interior and the Delaware Department of Natural Resources and Environmental Control. The U.S. Army Corps of Engineers, Philadelphia District, is acknowledged for providing core descriptions and cores from projects in the area. Kimberly McKenna did much of the work in acquisition of the offshore cores, data collection, and data analysis of the cores. John C. Kraft and his students from the Dept. of Geological Sciences at the Univ. of Delaware generated much of the data related to the coastal and offshore deposits. This project would not have been possible without the cooperation of the staff of the Redden State Forest, Sussex County Engineering Dept., Inland Bays Regional Wastewater Facility, and the DNREC Wildlife Areas. Paul S. McCrory coordinated and conducted the drilling for the project. DGS project personnel and students who assisted in field work and data collection included Elizabeth Gahrman and David Hynes. Laserscan roadway recharge and water table mapping by A.S. Andres and Andrew Klingbeil (Andres and Klingbeil, 2006) generated much of the subsurface data for the area. DGS staff and students who helped in the drilling of the Ph22-39 core hole included Peter McLaughlin, David Hynes, Charles Smith, Matthew Aumpd, Chenyu Clark, and Changming He. John Talley, William Schenck and Wendy Carey provided thoughtful reviews of this publication.

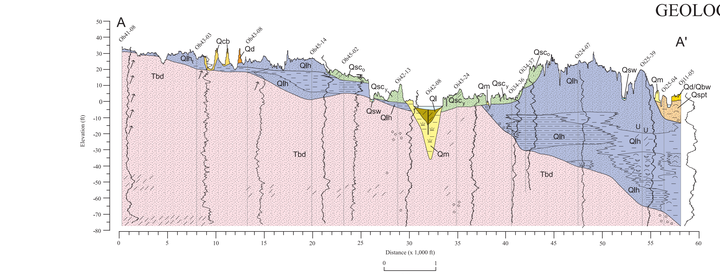
MAP CREDITS

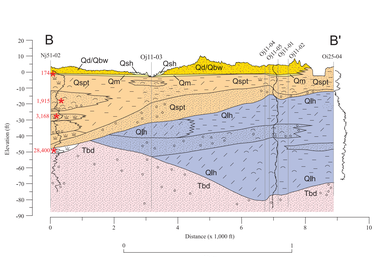
Base Map

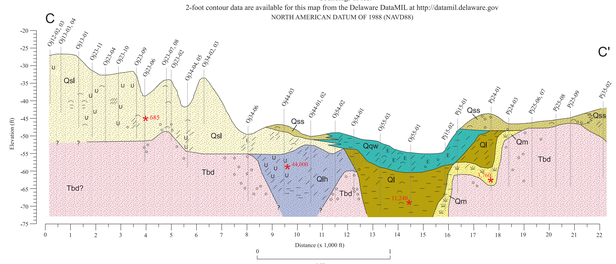
Delaware state plane coordinate system
Transverse mercator projection
North American Datum of 1983 (NAD83) HARN
The Delaware Department of Transportation Centerline and Railroads for Delaware, 2009
The Delaware Office of State Planning Coordination Delaware Municipal Boundaries, 2009
USGS National Hydrography Dataset, 2009
USGS Delaware LiDAR Contours, 2005
USGS Delaware Miscellaneous Features, 1993
http://datamil.delaware.gov
Delaware Department of Agriculture State Forest Areas, 2009
Delaware Division of Natural Resources and Environmental Control Park Areas, 2009
NOAA National Geophysical Data Center, U.S. Coastal Relief Model Bathymetry, volume 02, version 1.0, 1999

Other

Cartography by Lillian T. Wang, Delaware Geological Survey
Edited by Stefanie J. Baxter, Delaware Geological Survey







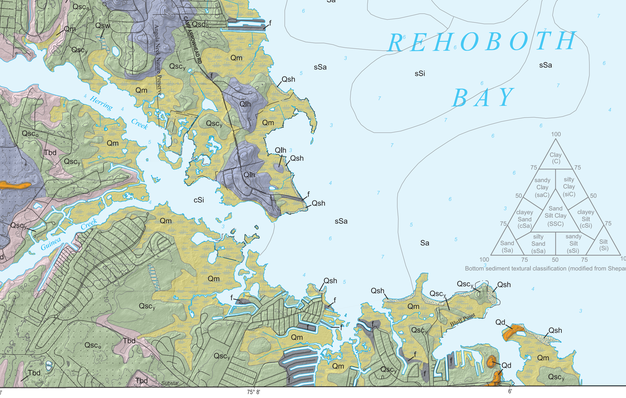
LITHOLOGIC SYMBOLS *(on cross sections)*

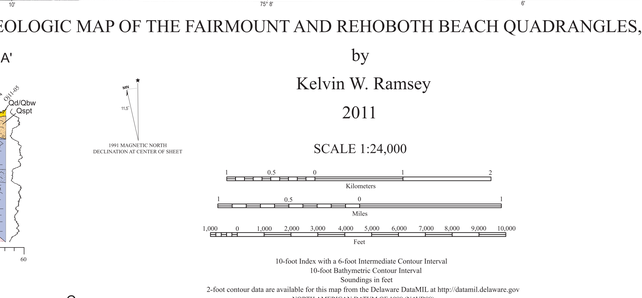
- pebble
- silt
- silt lamination
- clay
- clay lamination
- fining-up bed
- plant fragments
- burrows
- shell
- sand lenses
- *Ensis* (razor clam)
- interlaminated clay and sand
- sand
- gamma log
- Radiocarbon date (calibrated yrs BP)

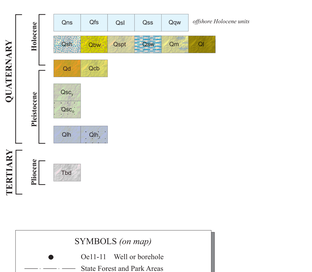
Colors for geologic formations on the cross sections appear lighter than shown on the map explanation and stratigraphic chart because they do not include the shading effect of the DEM used on the map.

To delineate the relationships between the offshore units shown beneath the water on the map, colors were added to the cross sections to illustrate Shoal Deposits (Qsl), Sheet Sand Deposits (Qss), and Quiet-Water Deposits (Qqw).

The small area without any color on the left axis of B-B' is discussed in the text.







SYMBOLS *(on map)*

- Oz11-11 Well or borehole
- State Forest and Park Areas
- Municipal Boundary
- Contact
- Inferred contact
- Offshore extension of Holocene lagoon at depth
- Offshore extension of Lynch Heights Formation lagoon at depth