DELAWARE GEOLOGICAL SURVEY
University of Delaware, Newark
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DELAWARE GEOLOGICAL SURVEY
GEOLOGIC MAP OF THE MILFORD AND MISPILLION RIVER QUADRANGLES
GEOLOGIC MAP SERIES NO. 8

Base Maps from U.S. Geological Survey
Milford and Mispillion River Quadrangles
7.5 Minute Series, 1993

North American Datum of 1983 (NAD 83).
1927 North American Datum (NAD 27) is shown
by dashed corner ticks.

GEOLOGIC MAP OF THE MILFORD AND MISPILLION RIVER QUADRANGLES

by
Kelvin W. Ramsey
June 1993

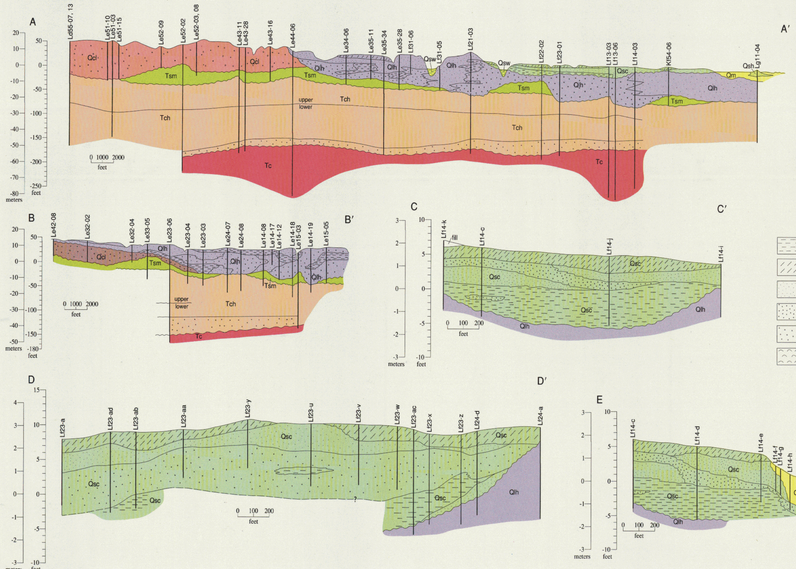
SCALE 1:24 000

1 0 1 2 KILOMETERS
1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10 000 FEET
0.5 0 0.5 1 2 MILES

CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD29)
(TO CONVERT ELEVATIONS TO THE NORTH AMERICAN VERTICAL DATUM OF 1988, SUBTRACT 1 FOOT)
DEPTH CURVES AND SOUNDINGS IN FEET, DATUM IS MEAN LOWER LOW WATER
THE RELATIONSHIP BETWEEN THE TWO DATUMS IS VARIABLE
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS 4.8 FEET

UTM GRID AND 1993 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

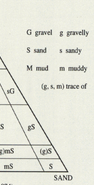
TYPE SECTIONS



SUMMARY TABLE OF PALYNOLOGICAL INTERPRETATIONS

DGSID	SAMPLE #	ALTITUDE SURFACE (FT.)	ALTITUDE SAMPLE (FT.)	CLIMATE	VEGETATION	ENV. OF DEPOSITION	FORMATION
Le25-12	25639	30	+18.5	cool temperate	conifer-hardwood	estuarine	Qlh
Lf21-19	25627	30	+14.5	cool temperate	conifer-hardwood	estuarine	Qlh
Le14-18	25706-1	28	+8	temperate	pine-oak-hickory	?	Qlh
Le14-18	25706-2	28	+7	temperate	pine-oak	?	Qlh
Le14-18	25707-1	28	+6	temperate	pine-dominant	marsh?	Qlh
Le14-18	25707-2	28	+5	temperate	pine-dominant	?	Qlh
Lf21-b	41367	18	+8.5	temperate	pine-oak	estuarine?	Qsc
Le15-g	41420	22	+12.5	cold	spruce-pine	boreal forest	Qsc
Lf23-i	41422	11	+2	temperate	pine-oak	boreal forest	Qsc
Lf13-a	40975	11	+4	temperate	oak-pine-alder-gum	marsh?	Qsc
Le14-a	41373	11	+2	temperate	pine-oak-hickory	fresh water marsh	Qsc
Lf23-i	41464	10.5	+3.5	temperate	pine-oak	?	Qsc
Lf23-i	41465	9	+1	temperate	pine-oak	estuarine	Qsc
Lf23-i	41469	9	+0.5	temperate	oak-gum	?	Qsc
Lf23-i	41472	9	-2	temperate	pine-oak-hickory	?	Qsc
Lf23-ac	41482	9.5	+0.5	temperate	oak-pine-hickory	estuarine or marine	Qsc
Lf23-ac	41485	9.5	-2	temperate	pine dominant	?	Qsc
Lf23-ad	41489	9	-2.5	temperate	pine-oak	estuarine?	Qsc
Lf14-b	41323	8	+2.5	temperate	pine-oak	estuarine	Qsc
Lf14-p	41425	8	+4	temperate	pine-oak	?	Qsc
Lf14-p	41431	8	-2.5	temperate	pine-oak-gum	?	Qsc
Lf14-p	41435	8	-3.25	temperate	oak-pine-gum	?	Qsc
Lf14-a	40976	7.5	0	temperate	pine-oak	estuarine	Qsc
Lf14-c	41330	6	-1.5	temperate	pine-oak	fresh-water marsh	Qsc
Lf14-j	41336	5	-1.5	temperate	pine-oak	tidal marsh	Qsc
Lf23-f	41344	5	-6.5	temperate	oak-pine	fresh-water deposit	Qsc
Lf14-e	41334	4	-1.5	temperate	pine-willow?	fresh-water marsh	Qsc
Lf14-n	41356	4	-4	temperate	pine-oak	fresh-water marsh	Qsc
Lf14-n	41353	3	-4	temperate	pine-oak	marsh	Qsc

OFFSHORE BOTTOM SEDIMENT TEXTURE



(adapted from Folk, 1974)

G gravel g gravelly
S sand s sandy
M mud m muddy
(g, s, m) trace of

EXPLANATION

SHORELINE DEPOSITS — Qsh

Composed of beach and dune deposits found along the shoreline of Delaware Bay. Beach deposits consist of medium to coarse quartz sand with pebbles and cobbles. Laminae of opaque heavy minerals and very coarse sand to pebbles are common. Pebble and cobble lithology dominated by quartz and chert (commonly containing Paleozoic fossils) with lesser amounts of quartzite, sandstone, and siltstone. Dune deposits consist of fine to medium, well sorted sand with discontinuous opaque heavy mineral laminae. Shoreline deposits interfinger with or unconformably overlie organic-rich mud of the marsh and swamp deposits or sands of the Scotts Corners Formation. Holocene.

MARSH AND SWAMP DEPOSITS — Qm, Qsw

Marsh deposits consist of structureless to finely laminated, black to dark gray, organic-rich silty clay to clayey silt with discontinuous beds of peat and with rare shells. In place or transported fragments of marsh grasses such as *Spartina* are common. Up to 40 feet in thickness. Includes some clayey silts of estuarine channel origin. Interfingers with swamp deposits and unconformably overlies sands of the Scotts Corners, Lynch Heights, and St. Marys formations. Map area delineated on the basis of distribution of salt-tolerant marsh grasses. Holocene.

Swamp deposits consist of structureless, black to brown, organic-rich, silty and clayey, fine to coarse quartz sand with thin interbeds of medium to coarse quartz sand. Organic particles consists of leaves, twigs, and larger fragments of deciduous plants. The swamp deposits fine vertically and grade laterally with marsh deposits. Overlies the Scotts Corners, Lynch Heights, Columbia, and St. Marys formations. Up to 20 feet in thickness. Map area defined primarily on the basis of presence of deciduous vegetation in stream valleys. In the upper reaches of streams, contains alluvial deposits consisting of fine to coarse quartz sand with pebbles. These alluvial deposits are too areally restricted to show as individual map units. Holocene.

CAROLINA BAY DEPOSITS — Qcb

Finely laminated to structureless, dark to light gray, clayey silts to fine to medium quartzose sand. Organic matter common within the deposits. Found in elliptical to circular features rimmed by fine to coarse, moderately well-sorted sand. Unconformably overlies the Columbia, Lynch Heights, and Scotts Corners formations. Up to 10 feet in thickness. Pleistocene and Holocene.

SCOTTS CORNERS FORMATION — Qsc

New formation. Heterogeneous unit of light gray to brown to light yellowish brown, coarse to fine sand with discontinuous beds of organic-rich clayey silt, clayey silt, coarse to very coarse quartz sand, and pebble gravel. In a complete sequence (type section Lf14-p), the unit consists of a thin, cross-bedded, clean to muddy, pebbly coarse sand at the base overlain by an organic-rich clayey silt in turn overlain by a medium to coarse, cross-bedded sand that fines upward and is capped by light gray to light yellowish brown silt (cross-sections C-C', D-D', E-E'). Sands are quartzose with some feldspar and muscovite. Laminae of opaque heavy minerals are common. Unconformably overlies the Lynch Heights Formation. The basal contact is marked by a coarse sand to gravelly sand bed overlying an oxidized, compact horizon (paleosol) at the top of the Lynch Heights. Overall thickness of the unit rarely exceeds 15 feet.

The Scotts Corners is interpreted to be a transgressive unit consisting of swamp, marsh, estuarine channel, beach, and bay deposits. Climate during the time of deposition was temperate to warm temperate as interpreted from the fossil pollen assemblages. Late Pleistocene.

LYNCH HEIGHTS FORMATION — Qlh

New formation. Heterogeneous unit of light gray to brown to light yellowish brown, medium to fine sand with discontinuous beds of coarse sand, gravel, silt, fine to very fine sand, and organic-rich clayey silt to silty sand. Vertical sequences are variable, but generally consist of a lower medium to coarse sand, a middle interbedded clayey silt and fine to medium sand, and an upper medium sand fining upward to a fine sand to fine sandy silt (type section Lf21-19; cross-sections A-A', B-B'). Small-scale cross-bedding within the sands is common. Some of the interbedded clayey silts and silty sands are burrowed. Sands are quartzose and slightly feldspathic, and typically micaceous where very fine to fine grained. The unit is up to 50 feet thick to the east and thins to the west. The Lynch Heights is distinguished from the Scotts Corners by its greater thickness, characteristic interbedded sands and silts (primarily in areas where it is the surficial unit), its unique pollen assemblage, and a general lack of a well-defined silt cap that characterizes the Scotts Corners.

The Lynch Heights is interpreted to be a fluvial to estuarine unit of fluvial channel, tidal flat, tidal channel, beach, and bay deposits. It unconformably overlies the Columbia, St. Marys, and Choptank formations. Climate during deposition was cool-temperate, slightly cooler than that indicated for the Scotts Corners. Late Pleistocene.

COLUMBIA FORMATION — Qcl

Light reddish brown, cross-bedded, medium to coarse sand with scattered thin beds of pebbles and gravel. Discontinuous thin beds of reddish brown clayey silt and fine to medium sand are common. Beds of greenish gray clayey silt to silty very fine sand are rare. Sands are quartzose with less than 25 percent feldspar (Jordan, 1964). It is distinguished from the Lynch Heights Formation by its greater homogeneity of lithology, larger scale cross-bedding, lack of burrowing within the sands, the oxidized state of mud beds within the unit, and the lack of extensive organic-rich muds. Unconformably overlies the St. Marys and Choptank formations. Thickness ranges from 15 to 50 feet. Early Pleistocene.

In the southern part of the Milford Quadrangle, the Columbia may unconformably overlie the Beaverdam Formation. Because of similarities in lithology (both units are typically sand) and the lack of fossil data from either unit in the map area, the Beaverdam cannot be identified with certainty; therefore, the deposits are all mapped as the Columbia Formation.

ST. MARY'S FORMATION — Tsm

Light reddish brown to gray, fine to very fine, silty sand and clayey silt. Discontinuous beds of fine to medium quartz sand and shelly quartz sand are common. Unconformably overlies the Choptank Formation. Basal contact marked by a medium sand with pebbles. Borehole gamma ray logs of the unit within the map area show a fining-upward sequence with a basal sand grading upward into a silty fine sand then to clayey silt with discontinuous thin sand beds. Distribution of the St. Marys within the area is patchy owing to erosion prior to deposition of the overlying Quaternary units. Thickness of the unit ranges up to 30 feet. Late Miocene.

CHOPTANK FORMATION — Tch

Light gray to blue gray, fine to medium, silty quartz sand and clayey silt. Discontinuous beds of fine sand and medium to coarse sand are common. Unconformably overlies the Calvert Formation. Basal contact is marked by a granular to very coarse sand of the Choptank overlying a distinctive brown silty clay at the top of the Calvert. Analysis of gamma logs and drillers' logs from the map area shows a lower sequence that fines upward from a coarse sand to a shelly sand to a shelly muddy sand capped by a hard silty clay, and an upper sequence of interbedded medium to fine sand and clayey silt to silty clay with discontinuous shell beds. The contact between these two sequences is shown on cross-sections A-A' and B-B'. Thickness ranges between 130 and 200 feet. Middle to late Miocene.

CALVERT FORMATION — Tc

Light gray to gray to brown clayey silt and fine to medium silty quartz sand. Discontinuous beds of shelly sand and shelly clayey silt are common. Many of the clayey silt beds have a distinctive brown color. Analyses of logs and samples from well Mi15-29 in Milford indicate that the Calvert rests unconformably on glauconitic sands of Oligocene age at a depth of 642 feet (Benson, 1990). Thickness of the unit is on the order of 350 feet in the map area. Radiolarians and diatoms are common in some of the finer beds. Early to middle Miocene.

DISCUSSION

INTRODUCTION

This map is the first detailed surficial geologic map in southern Kent and northern Sussex counties. Other maps covering the same or adjacent areas have focused on subsurface geology (Benson and Pickett, 1986), hydrogeology (Talley, 1982), or surficial geology on a regional scale (Jordan, 1964; Owens and Denny, 1979; Ramsey and Schenck, 1990). The purpose of this map is to show the distribution of geologic units found at or near the present land surface. These units are composed of the geologic materials that support agriculture and development, are mined for sand and gravel resources, and are the surface-to-subsurface pathway for water.

Initial work in the area of Milford assigned surficial deposits to the Pleistocene (Marine and Rasmussen, 1955) without formational designation. Rasmussen et al. (1960) recognized near-surface units just south of Milford to be the Brandywine Formation, the Beaverdam Sand, and the Walston Silt. Jordan (1964, 1974), assigned these units in the map area to the Columbia Formation. Owens and Minard (1979) extended stratigraphic designations recognized in New Jersey into Delaware and mapped the area as Pensauken Formation (roughly equivalent to the Columbia of Jordan, 1964), with a fringe of deposits labeled as Spring Lake and Van Sciver Lake beds adjacent to Delaware Bay. Owens and Denny (1979) presented a different stratigraphy in a regional map showing the Beaverdam Sand as the dominant surficial deposit with a fringe along Delaware Bay of, from west to east, the Omar Formation and the Ironshire Formation. Talley (1982) considered the entire area of the Milford Quadrangle to be covered by the Columbia Formation. Ramsey and Schenck (1990) mapped the Columbia Formation as the major surficial deposit with a younger Pleistocene unit along Delaware Bay given the informal designation of Delaware Bay deposits.

The surficial units on this map were recognized on their lithologic characteristics and internal stratigraphy from examination of over 600 lithologic logs from water well and test hole borings as well as outcrop information and shallow soil auger borings. The map units were compared to previously named units to determine the stratigraphic nomenclature. The Columbia Formation is retained in the sense of Jordan (1974). Other previously used names were rejected because of lithologic characteristics different from those units found in the map area. This map includes two new lithostratigraphic units, the Lynch Heights Formation and the Scotts Corners Formation. These units are refinements based on additional geologic information about the Delaware Bay deposits of Ramsey and Schenck (1990). Palynological data proved to be useful in support of differentiation of the two units, especially the stratigraphic distribution of *Quercus* (oak) species (Johan J. Groot, pers. comm.). Interpretations of climate and vegetation based on the palynology are in the adjoining table.

SYMBOLS

- Le32-02 Well or borehole
- Lf14-p Outcrop or soil auger boring
- Borrow pit (most are inactive)
- Offshore data point
- 1954 shoreline
- 1981 shoreline

The type section for the Scotts Corners is designated as Lf14-p (adjoining figure). Reference sections are designated as Lf23-i, Mf25-a, and Mq33-g. The type section for the Lynch Heights Formation is designated as Lf21-19 (adjoining figure). Reference sections are Le14-18, Le25-12, and boring Lf53-a. Descriptions of reference sections are available from the Delaware Geological Survey (DGS) upon request and will be published along with other data in support of this map as part of a DGS Report of Investigations.

Recognition of subsurface units (the Calvert, Choptank and St. Marys formations) is an extension of the work of Benson et al. (1985), Benson and Pickett (1986), Andres (1986), Groot et al. (1990), Benson (1990), and Ramsey and Schenck (1990). Published (Groot, 1992) and unpublished palynostratigraphic data were used as aids in recognition of these units.

Distribution of Holocene deposits of swamp, marsh, and beach were mapped on the basis of vegetation observed on aerial photographs and spot checked in the field for accuracy. Mapped areas are not to be used for wetlands designation as they represent distribution of lithologies deposited in environments characterized by vegetation rather than the environments themselves. Offshore distribution of bottom sediment type is based on unpublished data from the Delaware Geological Survey as well as data from Marx (1981), Maley (1981), Strom (1972), and Wethe (1984). Historical shoreline positions are based on data from aerial photographs (1954) and topographic maps (1981).

GEOMORPHOLOGY

The land surface topography and morphology of the map area reflect both processes active during deposition of the surficial geologic units and those that have occurred since deposition. Recognition of specific morphologic features has proven to be useful in mapping the distribution of the surficial geologic units and in understanding the geologic history of the area. Mapping of outcrop and subsurface geologic data led to the recognition of three major surficial lithologic units within the map area, the Columbia, the Lynch Heights, and the Scotts Corners formations. On the bases of sedimentary structures, lithology, and analysis of pollen assemblages, the Scotts Corners Formation is interpreted to be a transgressive sequence of swamp, marsh, shoreline, and bay deposits much like that seen in the Holocene deposits of the same area. The deposits at the land surface are silts and sandy silts interpreted to be bay bottom sediments much like those found offshore at present (the vfmS as mapped). In the area of Milford Neck, the deposits of the Scotts Corners Formation are associated with a relatively flat surface that ranges over most of the area between 5 and 15 feet and that decreases in elevation roughly from west to east. This morphology is similar to that found presently offshore: a flat, gently eastward-sloping surface. The surface morphology of the Scotts Corners is interpreted to represent an ancestral Delaware Bay bottom, the shoreline of which is marked by a change in slope (scarp) between the 15- and 30-foot levels. The area of this change has a persistent, but discontinuous trend, roughly parallel to and 4 to 6 miles inland of the present shoreline of Delaware Bay. The scarp was produced by erosion of the land along the shoreline of the ancient bay that resulted in a subdued wave-cut feature.

If the surface of the Scotts Corners represents for the most part a depositional surface, then the areal extent of that surface coincides at least locally with the the distribution of the Scotts Corners Formation, and the scarp (shoreline) is approximately its landward limit. It should be emphasized that the distribution of the surface topography is not the sole criterion for determining the map distribution of the unit.

In a like manner, the Lynch Heights Formation is a lithologic unit that, on the bases of lithologic characteristics and interpretations of sedimentary structures, pollen assemblages, and internal stratigraphy, is interpreted to be a succession from a fluvial to an estuarine system. It too has a distinctive relatively flat surface that slopes from west to east from an elevation of approximately 45 feet to about 30 feet. This surface likewise is interpreted to be a depositional surface of an ancient estuary. The shoreline is marked by a break in topography from a surface at about 40 feet to one at about 50 to 60 feet which is underlain by the Columbia Formation. This break in topography is not as distinctive as the one previously described and in places is expressed by only subtle changes in elevation.

GEOLOGIC HISTORY

The Calvert, Choptank, and St. Marys formations were deposited in shallow marine to marginal marine environments as parts of a deltaic system during the Miocene. In the Milford area, the boundaries between the units are unconformities that represent erosion and/or nondeposition. The overall sequence from the Calvert to the St. Marys represents a shallowing-upward sequence as the deltaic system prograded seaward (Benson, 1990). During the late Miocene through the Pliocene, most of the deposition in the region was seaward of the map area, where the Manokin and Bethany formations were deposited in marginal marine and deltaic environments (Andres, 1986; Groot, et al., 1990; Benson, 1990). By the time of deposition of the Beaverdam Formation in the Pliocene, the deltaic system was dominated by fluvial processes with some wave and tide reworking (Ramsey, 1992).

The Columbia Formation represents deposition following early Pleistocene (Johan J. Groot, pers. comm.) glaciations in the northeastern Appalachians. The deposits are characteristically coarse sands with gravel that represent the distal outwash from glaciers in a fluvial system choked by sediment (Jordan, 1974). These deposits cover most of northern and central Delaware to just south of the map area (Ramsey and Schenck, 1990). Following the deposition of the Columbia, sea level fell with renewed glaciations, and streams such as the Delaware River became deeply incised. During successive rises of sea level, erosion of the Columbia Formation occurred marginal to the valley of the Delaware River and its tributaries, and sediments from the Columbia were reworked into bay, beach, marsh, and swamp deposits marginal to and within an ancestral Delaware Bay. The cycle of erosion and deposition related to sea-level fluctuations has occurred several times since the deposition of the Columbia. The oldest deposits of this type in the map area are preserved in the Lynch Heights Formation that, based on fossil pollen analysis, are considered to be older than oxygen-isotope stage 7 (250,000 years ago). The Scotts Corners Formation represents a more recent time of sedimentation that, on the basis of pollen analysis, was deposited during oxygen isotope stage 5 between 120,000 and 90,000 years ago (Johan J. Groot, pers. comm.). At some point after the deposition of the Scotts Corners, the Carolina bays were formed and their associated sediments laid down. The most recent period of deposition began in the area about 12,000 years ago and is continuing at present with the modern swamp, marsh, beach, and bay deposits (Kraebel, Fletcher, and Krulf, 1988).

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QUATERNARY / TERTIARY

HOLOCENE	Qsh	shoreline deposits	
	Qm	marsh deposits	
	Qsw	swamp deposits	
unconformity			
PLEISTOCENE	Qsc	Scotts Corners Fm.	
	Qlh	Lynch Heights Fm.	
unconformity			unconformity
	Qcl	Columbia Fm.	Qcb Carolina Bay deposits (Pleistocene and Holocene)
unconformity			
MIOCENE	Tsm	Saint Marys Fm.	
unconformity			
	Tch	Choptank Fm.	
unconformity			
	Tc	Calvert Fm.	