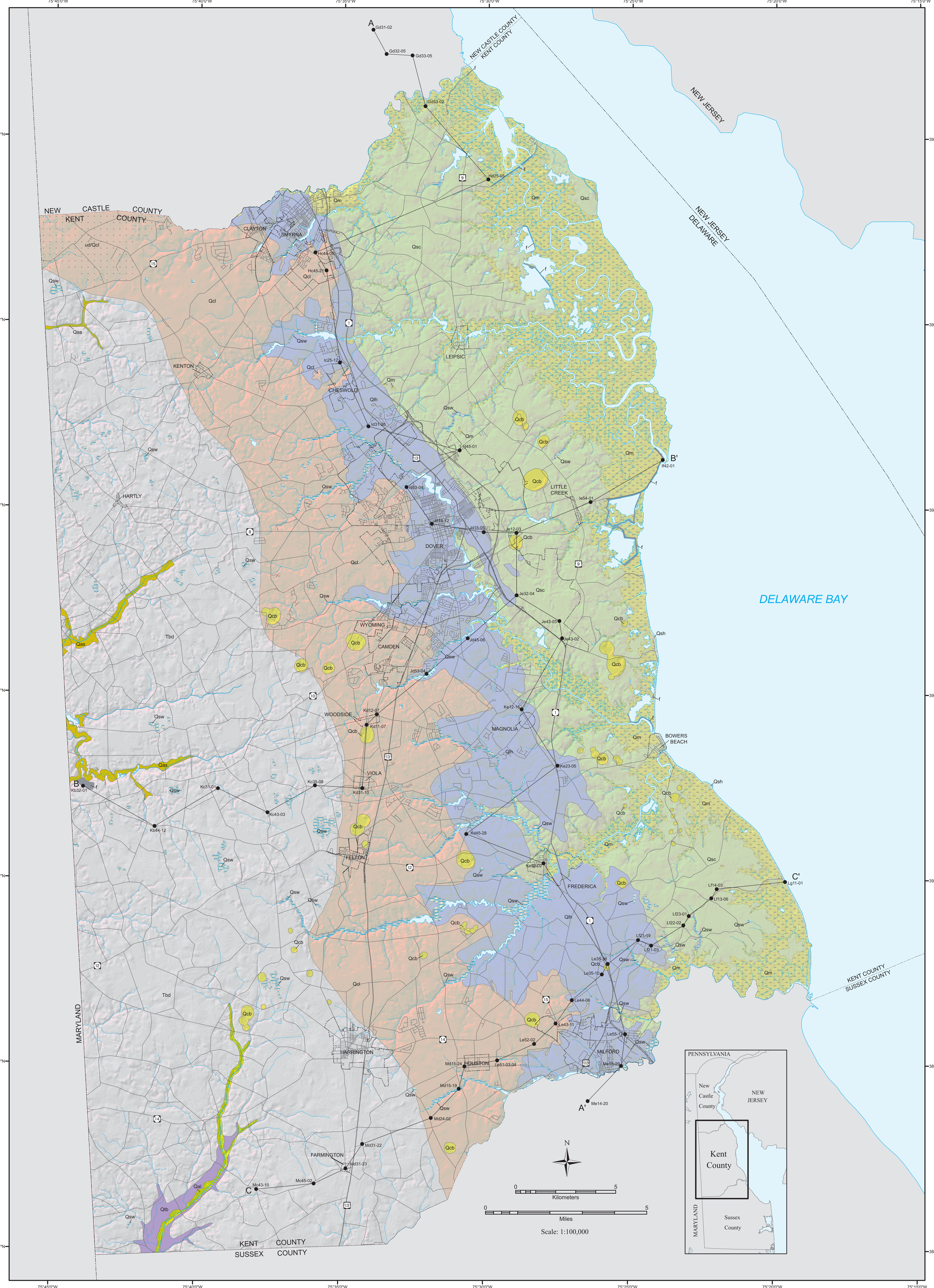

Geologic Map of Kent County, Delaware

by

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Descriptions of Map Units

COASTAL PLAIN

f — Fill
Man-made deposits of natural earth material, including dredge spoil, used to extend shore land and/or to fill a low-lying area such as where a road crosses a valley or marsh. Fill areas in Kent County are generally restricted to road grades and man-made berms in wetlands along Delaware Bay. Although technically not fill, the area covered by the refuse mounds at the Delaware Solid Waste Authority facility at Sandtown is included in this category.

Qsh — Shoreline Deposits (Holocene)
Beach and dune sediments 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 lithologies are dominated by quartz and chert (commonly containing Paleozoic fossils) with lesser amounts of quartzite, sandstone, and siltstone. Along the margin of Delaware Bay, the unit includes small dunes consisting 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. Thickness generally less than 20 feet.

Qal — Alluvial Deposits (Holocene)
Brown, light yellow-orange, and gray fine to coarse quartz sand, silt, clay, and fine to medium gravel. Usually less than 20 ft thick. Restricted to stream channels and adjacent flood plains. Continuous along stream valleys and depicted on the map where extensive enough to be shown at map scale.

Qsw — Swamp Deposits (Holocene)
Structureless, black to brown, organic-rich, silty and clayey, fine to coarse quartz sand with thin interbeds of medium to coarse quartz sand. In stream valleys, organic particles consisting of leaves, twigs, and larger fragments of deciduous plants are found in an organic muck of sandy silt. Fine upwards and grade laterally with clayey silt salt marsh deposits toward the Delaware River. Mapped primarily on the presence of deciduous vegetation (Ramsey, 1997). On uplands, consist of dark- to light-gray clayey silt and very fine to coarse sand. Characterized by areas of seasonally standing water, internal drainage, and hydrophyllic trees. Other than surficial leaf litter, recognizable organic particles are much less common than in the stream valley swamps. Organic-rich sediments in the upland swamps are an organic-rich muck composed of silt-sized particles of organics, quartz silt, and some clay. From 1 to 20 feet thick.

Qm — Marsh Deposits (Holocene)
Structureless to finely laminated, black to dark-gray, organic-rich silty clay to clayey silt with discontinuous beds of peat and rare shells (Ramsey, 1997). In-place or transported fragments of marsh grasses such as Spartina are common. Includes some clayey silts of estuarine channel origin (Ramsey, 1997). Map area is delineated on the basis of the surficial distribution of salt-tolerant marsh grasses. Thickness ranges between 1 and 40 feet.

Qas — Alluvium and Swamp Deposits (upper Pleistocene to Holocene)
Found along the headwaters of streams that drain into Chesapeake Bay. Consist of coarse sand to pebble gravel that grades upward into organic-rich fine to medium sand. Bodies of peat that have been radiocarbon dated to 28480 +/- 880 yrs BP (Jb33-a; Ramsey, 1996) are also found within this unit. Small dunes and sand bodies composed of fine to medium sand with scattered organic-rich sandy silt beds are found along the flanks of these streams but are too small in extent to represent on this map. Interpreted to be stream and swamp deposits laid down during a period of cold climate and limited arboreal vegetation during the late Pleistocene to early Holocene. Thickness is generally less than 20 feet.

Qcb — Carolina Bay Deposits (upper Pleistocene to Holocene)
Finely laminated to structureless, dark to light gray, clayey silty to fine to medium quartzose sand. Organic matter is rare to common within the sands. Found in circular to oval geomorphic features with a central depression surrounded by a raised sand rim. These features are differentiated from undrained depressions by their larger size, circular geomorphic expression with distinctive sand rims and widespread occurrence throughout Kent County. Thickness is less than 10 feet.

ud/Qcl — Undrained Depression Deposits (upper Pleistocene to lower Holocene)
A belt of upland depressions stretch across southern New Castle and northern Kent counties. Sometimes referred to as Delmarva Bays, are irregular in shape and have internal drainage not integrated with any stream network. Filled with brown organic-rich silts to gray medium to coarse quartz sand (Webb, 1990; Andres and Howard, 1998). Some have a sandy rim at their margins. During wet periods, many are filled with water. Because of the abundance and relative small size (< 500 ft. diameter), individual basins are not mapped; rather, a pattern indicates the extent of these units where they overlie the Columbia Formation. Largest depressions appear as areas of swamp on the map. Radiocarbon dates (Webb, 1990) indicate ages from 11,000 B.P. to recent. Origin is considered to be related to cold-climate periglacial conditions (Andres and Howard, 1998). Thickness is less than 10 feet.

Qsc — Scotts Corners Formation (upper Pleistocene)
Heterogeneous unit of light-gray to brown to light-yellowish-brown, coarse to fine sand, gravelly sand and pebble gravel with rare discontinuous beds of organic-rich clayey silt, clayey silt, and pebble gravel. Sands are quartzose with some feldspar and muscovite. Commonly capped by one to two feet of silt to fine sandy silt. Laminae of opaque heavy minerals are common. Unit underlies a terrace parallel to the present Delaware River that has elevations less than 25 feet. 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 fossil pollen assemblages (Ramsey, 1997). Overall thickness of the unit rarely exceeds 20 feet.

Qlh — Lynch Heights Formation (upper Pleistocene)
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. Upper part of the unit commonly consists of fine, well-sorted sand. Small-scale cross-bedding within the sands is common. Some of the interbedded clayey silts and silty sands are burrowed. Beds of shell are rarely encountered. Sands are quartzose and slightly feldspathic, and typically micaceous where very fine to fine grained. Unit underlies a terrace parallel to the present Delaware Bay that has elevations between 50 and 30 feet. Interpreted to be a fluvial to estuarine unit of fluvial channel, tidal flat, tidal channel, beach, and bay deposits (Ramsey, 1997). Overall thickness ranges up to 50 feet.

Qtb — Turtle Branch formation (informal unit) (upper Pleistocene)
One to five feet of gray coarse sand and pebbles overlain by one to ten feet of tan to gray clayey silt to silty clay that is in turn overlain by three to five feet of fine to medium sand. Laterally, finer beds are less common away from Marshyhope Creek and the deposit is dominated by fine to medium sand with scattered beds of coarse to very coarse sand with pebbles. Sands are quartzose with some feldspar and laminae of opaque heavy minerals. Underlies a terrace with elevations ranging from 35 to 50 feet and is interpreted to be fluvial to estuarine in origin. Found in the Marshyhope Creek drainage basin in Kent County and more extensively along the Nanticoke drainage basin in Sussex County. Thickness ranges up to 20 feet closer to the valley of the Marshyhope and thins away from the river.

Qcl — Columbia Formation (middle Pleistocene)
Yellowish- to reddish-brown, fine to coarse, feldspathic quartz sand with varying amounts of gravel. Typically cross-bedded with cross-sets ranging from a few inches to over three feet in thickness. Scattered beds of tan to reddish-gray clayey silt are common. In places, the upper 5 to 25 feet consists of grayish- to reddish-brown silt to very fine sand overlying medium to coarse sand. Near the base, clasts of cobble to small boulder size have been found in a gravel bed ranging from a few inches to three feet thick. Gravel fraction primarily quartz with lesser amounts of chert. Clasts of sandstone, siltstone and shale from the Valley and Ridge, and pegmatite, micaceous schist, and amphibolite from the Piedmont are also present. Fills a topographically irregular surface, is less than 50 feet thick, and is interpreted to be primarily a body of fluvial glacial outwash sediment (Jordan, 1964; Ramsey, 1997). Pollen indicate deposition in a cold climate during the middle Pleistocene (Groot and Jordan, 1999).

Tbd — Beaverdam Formation (upper Pliocene)
Light gray to white coarse to very coarse sand with beds of fine to medium sand. Sands are quartzose, moderately feldspathic (< 20% feldspar), and often have a white silt to clayey silt matrix giving drill cuttings a milky appearance. Beds of sandy silt, clayey-sandy silt, and clayey silt are common. Beds of dark gray to brown pollen-bearing organic-rich clayey silt are rare to common (Andres and Ramsey, 1995a, 1995b). Beds of light yellow-orange medium to coarse sand, gravelly sand, sandy gravel, and dark gray or blue- to green-gray clayey silt are also rare to common. Basal beds are gravelly with pebbles of quartz and quartzite with lesser amounts of chert, sandstone, and a variety of lithic clasts. Thickness up to 75 to 100 feet in southernmost portion of the county. Interpreted to be a Pliocene fluvial to estuarine deposit (Andres and Ramsey, 1996; Groot and Jordan, 1999).

CROSS-SECTION UNITS (not shown on map)

Tsm — St. Marys Formation (upper Miocene) *subsurface only*
Light reddish-brown to gray, fine to very fine, silty sand and clayey silt. Discontinuous beds of fine to medium quartz sand are common. Base of unit in the Milford area (Ramsey, 1997) is a medium sand bed ranging from 10 to 15 feet thick. Found in the southeastern portion of Kent County. Patchy in distribution where it occurs beneath Quaternary deposits. Thickness ranges up to 30 feet. Interpreted to be a shallow marine deposit.

Tch — Choptank Formation (middle to upper Miocene) *primarily subsurface*
Light gray to blue gray, fine to medium, shelly, silty, quartz sand and clayey silt. Discontinuous beds of fine sand and medium to coarse quartz sand are common. Base of the unit is marked by a coarse to granule sand that fines upwards to a medium to fine silty sand. This sand is the Milford aquifer (Ramsey, 1997; McLaughlin and Velez, 2006). In southern Kent County, can be subdivided into upper and lower units (cross sections A-A' and C-C'). Lower unit consists of the fining-upward sequence from the basal sand to a hard clayey silt to silty clay that ranges in color from grayish brown to bluish gray. Upper unit consists of clean to silty, fine to medium, moderately shelly sands with thin silty clay beds. Rarely found in outcrop in the upper reaches of some of the more deeply incised streams. Outcrops are too small to be shown on this map. Found in the southern half of Kent County. Up to 140 feet thick in the southernmost part of the county.

Tc — Calvert Formation (lower to middle Miocene) *primarily subsurface*
Gray to grayish-brown, clayey silt to silty clay interbedded with gray to light-gray silty to fine to coarse quartz sands. Discontinuous beds of shell are common in the sands and in the clayey silts. Found in the subsurface throughout Kent County. Interpreted to be a marine deposit. Rarely the surficial unit on the uplands in northwestern Kent County where the Columbia or Beaverdam Formations are absent. Outcrops are patchy and are too small to be shown on this map. Three major aquifers are found within the Calvert Formation in Kent County: the Frederica, Federalsburg, and Cheswold, from top to bottom, respectively (McLaughlin and Velez, 2006). Ranges up to 425 feet thick.

Tpp — Piney Point Formation (upper Eocene) *subsurface only*
Bright green, fine to coarse, shelly, glauconitic (20 to 40% glauconite), quartz sand. Silty and clayey toward the bottom and coarsens upwards. Considered to be a marine deposit (Benson, Jordan and Spoljaric, 1985). The Piney Point aquifer coincides with the sandier portion of the unit. Ranges up to 250 feet thick in the southern portion of Kent County.

DISCUSSION OF MAP

This map shows the surficial geology of Kent County, Delaware at a scale of 1:100,000. Maps at this scale are useful for viewing the general geologic framework on a county-wide basis, determining the geology of watersheds, and recognizing the relationship of geology to regional or county-wide environmental or land-use issues. This map, when combined with the subsurface geologic information, provides a basis for locating water supplies, mapping ground-water recharge areas, and protecting ground and surface water. Geologic maps are also used to identify geologic hazards, such as flood-prone areas, to identify sand and gravel resources, and to support state, county, and local land-use planning decisions.

The map was generated by compilation of geologic data in the form of topographic and geologic maps, geologists' and drillers' logs, geophysical logs, soils maps, and sample descriptions. Samples from drill holes and outcrops were examined for comparison with previous descriptions. Surficial geologic units in southern New Castle County (Ramsey, 2005) were mapped into northern Kent County. The southwest corner of Kent County (Milford and Mispillion River Quadrangles; Ramsey, 1993, 1997) was previously published at a scale of 1:24,000. The map of the remainder of the county represents the first surficial geologic map produced for the area. Any unreferenced descriptions of geologic units were generated by the author after examination of cores, outcrops, or other samples from the map area.

Kent County is located within the Atlantic Coastal Plain which is composed of seaward-dipping strata of sand, silt, and clay. The surficial geology consists of units ranging in age from late Tertiary (Pliocene Beaverdam Formation) to Holocene (swamp, marsh, and alluvium). The surficial units are primarily composed of sand. Differentiation between surficial units and separation from underlying, older sand bodies is not always possible. There are areas in Kent County where units of Miocene age crop out both along streams and on uplands but are limited in extent and could not be represented on a map of this scale. Likewise, small dunes, patches of upland swamp, and small areas of surficial units along stream valleys are not shown on the map because their extent was too limited to be shown on a map at a scale of 1:100,000.

Prior to this map, the area shown as the Beaverdam Formation was considered to be part of the Columbia Formation (Jordan, 1964; Pickett and Benson, 1977, 1983; Benson and Pickett, 1986). More recent mapping in New Castle County and Sussex County has allowed for extensive examination of the deposits mapped as the Beaverdam Formation (Andres and Ramsey, 1995; Ramsey, 2001, 2003). As a result of this work, it is now possible to differentiate between the Columbia and Beaverdam Formations using lithology, geomorphology, and soils. In Kent County, the Beaverdam Formation is characterized as a coarse to very coarse sand with scattered laminae and thin beds of pebbles that is light gray to white in color with a white silty to clayey matrix. The Columbia Formation is a fine to medium sand with some laminae to thin beds of coarse sand with scattered pebbles. Unfortunately, neither unit contains fossiliferous material other than rare mud beds that have yielded fossil pollen (Groot and Jordan, 1999) that would aid in distinguishing between the units. The Columbia Formation topography tends to have a series of low-lying linear ridges oriented northwest to southeast that are best expressed from Clayton to Woodside. The Beaverdam Formation is more flat-lying with a somewhat irregular topography. Soils associations (Matthews and Ireland, 1971) also differ between the two units. The Columbia Formation's surface is marked by a Sassafras-Fallsington soil association (permeable subsoil of sandy loam to sandy clay loam) where that of the Beaverdam Formation is marked by a Pocomoke-Fallsington-Sassafras association (moderately permeable subsoil of clay loam to sandy loam) in northern Kent County and a Fallsington-Sassafras-Woodstown association (moderately permeable subsoil of sandy loam to sandy clay loam) in central and southern Kent County. The soils formed on the Columbia Formation, therefore, are more permeable and have less clay than those formed on the Beaverdam Formation. This is consistent with the Beaverdam Formation having a silty to clayey matrix that is rarely found in the Columbia Formation.

The oldest surficial unit of any great extent in Kent County is the Beaverdam Formation. The Beaverdam represents a major period of fluvial deposition in the region that followed a period of erosion in the late Miocene. The Beaverdam rests on an unconformity that intersects progressively older units as one goes from south to north in Kent County (cross sections B-B', C-C'). This indicates that there was some period of time when the Miocene marine units (Calvert, Choptank, and St. Marys Formations) were exposed and eroded prior to deposition of the Beaverdam. The age of the Beaverdam is problematic due to the paucity of fossils found within the unit. Groot and Jordan (1999) considered the unit to be Pliocene in age on the basis of pollen found within the Beaverdam clays. Ramsey (1992) considered it to be late Pliocene based on regional geomorphology and correlation with the late Pliocene Bacons Castle Formation in Virginia. Pollen biostratigraphy, however, is not very definitive in separating the late Miocene from the Pliocene and the Beaverdam could possibly be as old as Miocene. The Beaverdam represents an influx of sand and gravel brought down by rivers ancestral to the present Susquehanna and Delaware Rivers that was deposited across the area between the highlands of the western shore of the Chesapeake Bay and present New Jersey.

After deposition of the Beaverdam, the first major glaciations occurred in northeastern North America during the early Pleistocene. As these glaciers melted, huge volumes of meltwater flowed from the headwaters of the Delaware and Susquehanna rivers eroding away much of the Beaverdam Formation in what is now southern New Castle County. These meltwater rivers transported large volumes of sediment that were deposited as the Columbia Formation. Over the central Delmarva Peninsula in what is now Kent and Sussex counties, the Beaverdam remained, forming the core of the Delmarva Peninsula as the Delaware and Susquehanna rivers began to occupy their present courses toward the Atlantic Ocean.

Since the deposition of the Columbia, sea level has risen and fallen several times. During interglacial high stands of sea level, at about 325,000 and 100,000 years ago, the Lynch Heights and Scotts Corners Formations, respectively, were deposited on the margins of an ancestral Delaware Bay (Ramsey, 1997). The relatively flat surfaces (treads) of these units, which slope toward the present Delaware Bay, represent the bay-bottom topography at the time of maximum sea level. The breaks in topography (scarps) between the surfaces of the Columbia Formation and the Lynch Heights Formation and the Lynch Heights Formation and the Scotts Corners Formation are interpreted to be the bay shoreline when sea level was at its highest. Refer to the cross sections for a visual representation of these relationships.

DISCUSSION (cont.)

During the glacial periods of the Pleistocene, Delaware was subjected to cold climate and periglacial conditions that modified the landscape with cold-climate features such as undrained depressions, upland dunes, Carolina Bays, and alluvium and swamp deposits. Andres and Howard (1998) documented the association of freeze-thaw features in the subsurface with the surficial undrained depressions found in southern New Castle County and northwestern Kent County. Scattered upland dunes, which are too small to show on the map in Kent County are found on the southwest side of many stream valleys and are likely the result of sand being blown across a treeless landscape during the colder glacial periods. Likewise, Carolina Bays, circular features with sandy rims, are likely the result of windy conditions and ground-water fluctuations during the glacial periods. Carolina Bays are differentiated from the undrained depressions by their characteristic circular shape, larger areal extent, and well-developed sand rims. Alluvium and swamp deposits are found along the upper reaches of some of the stream valleys draining to the Chesapeake Bay. They represent a time, probably prior to the development of a forest cover during the early Holocene, when there was a period of erosion during which stream valleys were carved, and deposition during which sand and gravel were deposited. These stream valleys are wider than can be explained by erosion and deposition associated with the present stream. The location of these deposits can be recognized by a drop of five to ten feet from the surrounding upland onto a flat valley floor, into which a small stream is incised (or now often ditched).

The rise of sea level during the past 12,000 years has resulted in the development of the Holocene swamps, marshes, and shoreline deposits. On the uplands, ponding in undrained depressions, upland swamps, and Carolina Bays contributes to the present deposition of fine-grained, organic swamp sediments.

DISCUSSION OF CROSS SECTIONS

Three cross sections show the relationship of surficial and subsurface stratigraphic units. Sections A-A' and B-B', which follow almost the same path as sections E-E' and S2-S2' of McLaughlin and Velez (2006), show the principal aquifers of Kent County. Section C-C' is a west-east section showing the stratigraphic units in the southern portion of Kent County, which extends section A-A' of Ramsey (1993) to the west. For explanation of the deeper stratigraphy of Kent County refer to McLaughlin and Velez (2006) and Benson (1996).

Surface topography of the cross sections was constructed by taking a data slice along the line of cross-section from the digital elevation model (DEM) using Surfer software. Correlation of stratigraphic units was done by using geophysical logs, lithologic descriptions from drillers' and geologists' logs, and examination of samples. Correlation within the cross-sections is to a depth which shows the base of the Calvert Formation. The Calvert Formation in northern and central Kent County lies beneath the surficial deposits.

Recognition of Quaternary units presents a challenge because all of the units are predominately sand. The units also commonly overlie sands of the Miocene Choptank and Calvert Formations that are texturally similar to the Quaternary sands. Use of gamma log response offers only a limited tool for separation of the sands. Subcropping Miocene sands were correlated from down dip where the sands are bounded by fine-grained beds, to up dip where the sands are recognized by their geophysical log character and lithology. Separation of the Quaternary units was based on examination of cores and geomorphic expression of the surface of the units. The base of the Quaternary units is more irregular in topography than shown on the cross-sections. Most problematic is the thick sandy section shown as the Lynch Heights Formation on section B-B' east of Je32-04. Limited sample data were available for this area that would aid in differentiating the stratigraphic units. The lower sandy section beneath the surficial Lynch Heights Formation shown on section B-B' could be either Columbia Formation or Beaverdam Formation.

Surface topography shown on the cross sections also shows the relationship between the land surface and underlying surficial units. Cross-section A-A' shows the cut and fill relationship between the Columbia Formation and younger units including the Lynch Heights and Scotts Corners Formations. Cross-sections B-B' and C-C' show the topographic relationships between the Beaverdam, Columbia, Lynch Heights, Scotts Corners, and Holocene swamp, marsh, and shoreline deposits. Each of these unit's surfaces are found beneath terraces that step down in elevation from central Kent County to Delaware Bay.

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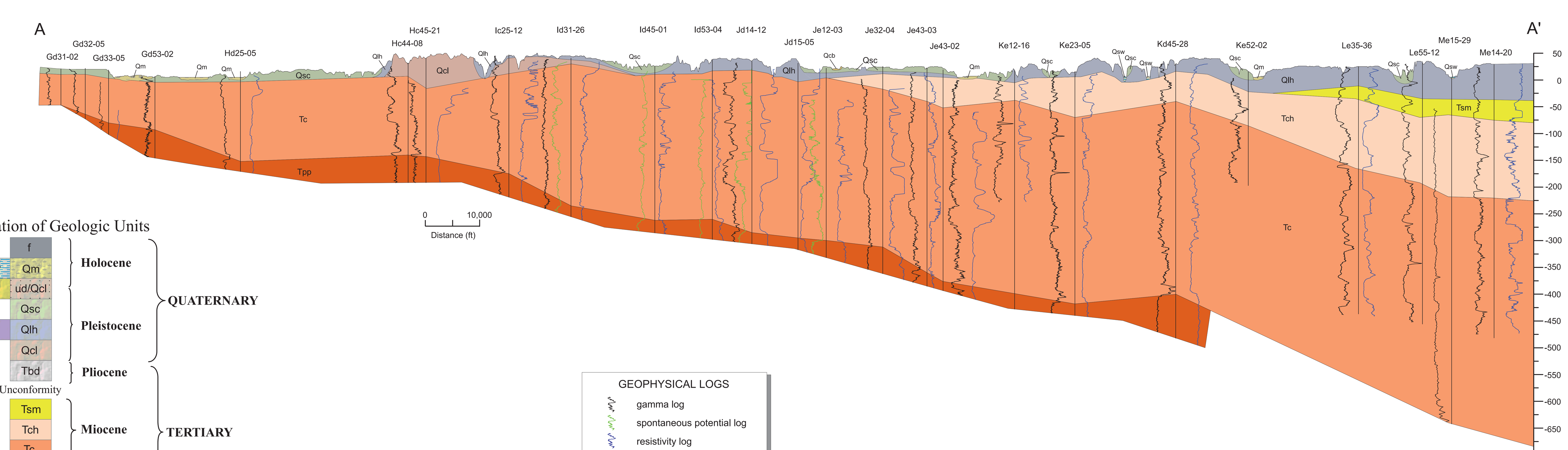
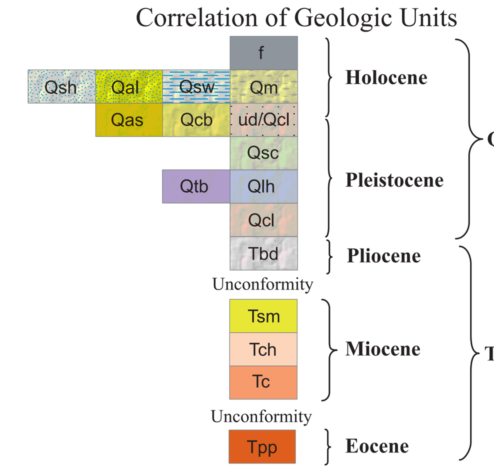
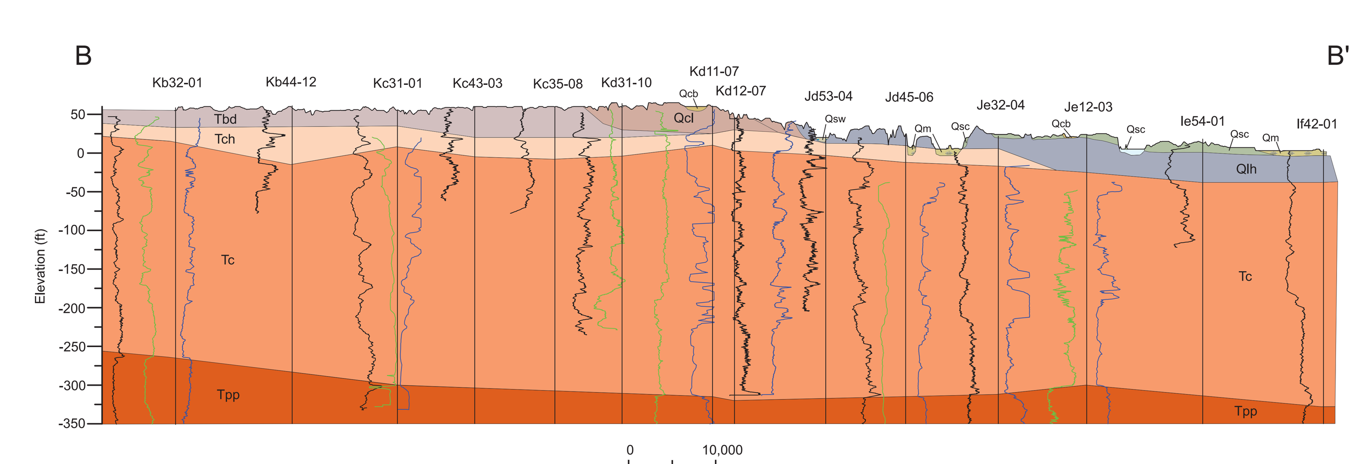
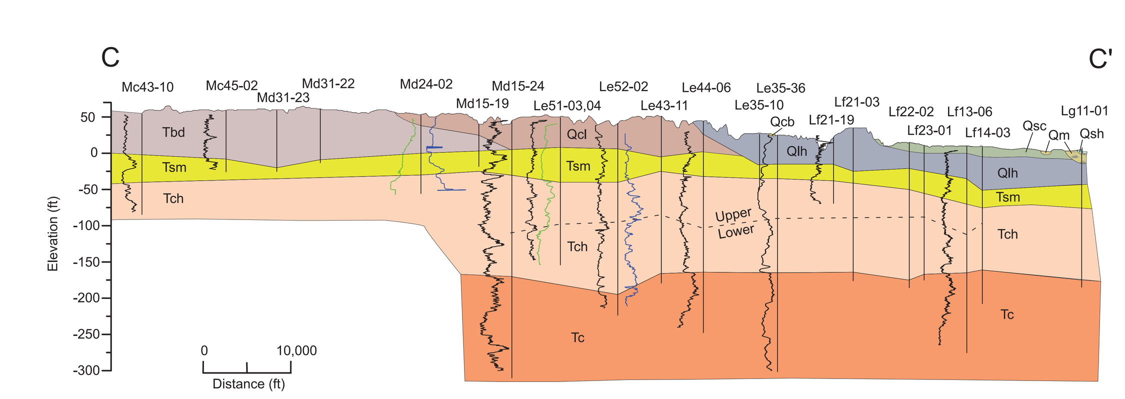


Correlation of Geologic Units







MAP CREDITS
Base Map
Projection: Universal Transverse Mercator, Zone 18
North American Datum of 1983 (NAD83)
USGS Delaware Hydrography Lines 2002, http://maps.udel.edu/metadata
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Other
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