DEPARTMENT OF ENVIRONMENTAL PROTECTION
LAND USE MANAGEMENT
NEW JERSEY GEOLOGICAL SURVEY

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U. S. GEOLOGICAL SURVEY
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BEDROCK GEOLOGY OF THE SOUTH AMBOY QUADRANGLE MIDDLESEX AND MONMOUTH COUNTIES, NEW JERSEY

OPEN FILE MAP OFM 65

INTRODUCTION

The South Amboy quadrangle is underlain by unconsolidated Coastal Plain formations that overlie shale, siltstone, diabase, and metamorphic rocks of the Piedmont. The Coastal Plain formations include sand, silt, clay, and glauconite sand laid down in coastal, nearshore marine, and continental shelf settings 95 to 75 million years ago. The Piedmont rocks are much older. The shale and siltstone were laid down in lakes and floodplains in a continental rift basin about 230 to 185 million years ago. They were later intruded by a diabase sill. The shale, siltstone, and diabase lie on metamorphic rocks of pre-Mesozoic age. The lithology and biostratigraphy of the formations are provided in the *Description of Map Units*. Age and stratigraphic relations of the units are summarized in the *Correlation of Map Units*. Sections AA' and BB' show the subsurface geometry of the formations along the line of section. Surficial deposits of Pliocene and Quaternary age overlie the bedrock formations in much of the map area. The surficial deposits are mapped by Stanford (1993).

DESCRIPTION OF MAP UNITS

COASTAL PLAIN FORMATIONS

Kw WENONAH FORMATION -- Quartz sand, very fine to fine, and silt, weathered, pale yellowish-brown to dark yellowish-brown. Typically thick-bedded to massive. Mica, feldspar, and lignitized wood are abundant. Crops out only in the extreme southeastern part of the quadrangle. As much as 20 feet thick in the quadrangle. The contact with the underlying Marshalltown Formation is gradational and is marked by an increase in glauconite and a decrease in quartz sand and mica.

Cobban (1978) identified the upper (but not uppermost) Campanian ammonite *Trachyscaphites pulcherrimus* (Romer) from the Wenonah near Marlboro.

Kmt MARSHALLTOWN FORMATION -- Quartz glauconite sand, weathered grayish-orange to shades of yellowish-brown. Massive-bedded, burrowed, fine-grained, silty and micaceous. As much as 10 feet thick. Glauconite comprises 20 to 60 percent of the sand. The Marshalltown is the basal transgressive unit of an unconformity-bounded coarsening-upward sequence that includes the overlying Wenonah and Mount Laurel. The Marshalltown unconformably overlies the Englishtown Formation.

The Marshalltown is unfossiliferous in the South Amboy quadrangle. In the southern New Jersey Coastal Plain the Marshalltown has been assigned to calcareous nannoplankton Zones CC20/21 of Perch-Nielsen (1985), indicating a middle Campanian age (Sugarman and others, 1995). Crops out only in the southeastern corner of the quadrangle, near Morganville.

Ket ENGLISHTOWN FORMATION -- Quartz sand and clay. Sand is light-olive to olive gray where unweathered, very pale-orange to grayish-orange and pale brown where weathered, fine to medium, with mica (primarily muscovite). Clay lenses are dark gray to olive black where fresh, various shades of brown where weathered, micaceous and lignitic; and are several inches to a few feet thick. Dark lignite layers are common, and typically contain pyrite. Bedding is typically massive at the top, horizontal and cross-bedded towards the base. As much as 100 feet thick. The Englishtown is extensively eroded, forming numerous residual hills in the southeastern part of the quadrangle. Exposures are generally poor due to the sandy nature of the formation.

The Englishtown is mapped here as a single unit because exposures are poor. Recent subsurface work in the area (Gohn, 1992) has delineated two formations previously mapped as Englishtown. Sugarman and Owens (1994) recognize upper and lower parts of a single Englishtown Formation. This usage in part follows Zapecza (1989) who distinguishes an upper and lower sand unit in the Englishtown in Ocean and Monmouth Counties.

The Englishtown has been assigned an early Campanian age based on palynomorphs (Wolfe, 1976). Ostracodes suggest that its upper part is middle to late Campanian (Gohn, 1992).

Kwb WOODBURY FORMATION -- Clayey silt with very fine quartz sand, dark gray to olive black, finely micaceous, with occasional lenses of finely disseminated pyrite, lignite, and siderite. Bedding is massive to finely laminated, with alternating layers of very fine sand and clay-silt. Glauconite sand makes up as much as 5 to 10 percent of lower part of formation. As much as 50 feet thick. Excellent exposures occur in gullies in the Matawan area.

Wolfe (1976) used palynomorph assemblages, and Gohn (1992) ostracode assemblages, to assign an early Campanian age to the Woodbury.

Kmv MERCHANTVILLE FORMATION -- Quartz-glauconite sand and clayey quartz silt; thick-to massive-bedded, highly bioturbated. Layers of fossiliferous siderite concretions are abundant. As much as 20 feet thick. The Merchantville is the basal transgressive bed of the unconformity-bounded coarsening-upward sequence which includes the overlying Woodbury and lower Englishtown Formations. The contact with the Woodbury is gradational and is arbitrarily drawn where glauconite is not a major sand constituent.

The Merchantville is best exposed in the gullies of the northwesternmost tributary of Lake Lefferts, south of Route 34.

The Merchantville is lower (but not lowermost) Campanian based on the ammonite *Scaphites hippocrepis III* (Owens and others, 1977).

Kcq CHEESEQUAKE FORMATION -- Clay-silt, glauconite (20 percent maximum, including botryoidal and accordian forms), olive to dark greenish-gray, weathering to moderate brown; massive, burrowed (with lighter colored very fine to fine sand fillings), with lignite and mica (mostly clear, with some green and brown). Grades to olive-gray and dark yellowish-brown (moderate brown where weathered), silty, very fine to fine quartz sand at top, generally laminated where not extensively burrowed. Very carbonaceous and micaceous, with glauconite (as much as 20 percent) typically in the basal few feet. Molds of gastropods and layers of large concretions (0.25-1 ft. in diameter) are common at the base of the formation. As much as 20 feet thick.

The best exposures of the Cheesequake are south of Route 34 along the northwesternmost tributary of Lake Lefferts. Good exposures also occur just north of Route 34 along the southernmost tributaries of Cheesequake Creek. The contact with the overlying Merchantville Formation is an irregular, burrowed, reworked interval approximately 3-4 feet thick, with siderite concretions concentrated near the lower part of the reworked bed.

The Cheesequake contains an uppermost Santonian to lowermost Campanian pollen assmblage in the outcrop and subsurface (Litwin and others, 1994).

MAGOTHY FORMATION -- Quartz sand, white, yellow, light gray, commonly interbedded with carbonaceous, thin to thick, dark gray clay and silt. Sand is typically cross-stratified, although laminated sequences are common. Heavy minerals are dominated by the zircon-tourmaline-rutile (ZTR) suite (Owens and Sohl, 1969). Entire thickness of the Magothy in the quadrangle is as much as 220 feet. The Magothy and underlying Raritan Formation contain alternating clayey and sandy beds which have been mapped for their economic resources (Cook, 1878; Ries and others, 1904) and hydrologic properties (Barksdale and others, 1943). The application of deltaic facies models and palynostratigraphy by Wolfe and Pakiser (1971), Owens and Sohl (1969), Owens and others (1977), and Christopher (1979) led to a chronostratigraphic framework for the Magothy and Raritan Formations. Usage follows that of Owens and others (1977), where the Magothy includes, from oldest to youngest, the following informal members: South Amboy Fire Clay, Old Bridge Sand, Amboy Stoneware Clay, Morgan beds, and Cliffwood beds. Although each of these members generally has some distinctive lithologic characteristics, numerous vertical and lateral facies changes complicate accurate mapping, especially in light of the limited exposures. Although this map depicts the informal Magothy members based on physical stratigraphy and biostratigraphy, the mapping is only an approximation because of the numerous facies changes. In the southwestern part of the quadrangle the Amboy Stoneware Clay, Morgan beds, and Cliffwood beds cannot be mapped separately owing to limited exposure, and are combined as unit Kmu.

Kmc **Cliffwood beds**--Quartz sand, white, yellow, light gray, fine to medium, commonly cross-stratified, some horizontally bedded and locally burrowed; interbedded with thin, dark gray, micaceous, carbonaceous silt containing pyrite. As much as 40 feet thick. Best exposures are in gullies north of Route 34 in the southern section of Cheesequake State Park. Siderite concretions containing fossils at the base of the Cliffwood beds in the adjacent Keyport quadrangle have been described by Weller (1907).

Kmm **Morgan beds** -- Laminated to thinly interbedded clay, light to medium gray, typically carbonacceous, and white, yellow, light gray micaceous quartz sand. Sand is massive to cross-bedded, and predominantly fine grained. As much as 90 feet thick. Excellent exposures are in the gullies and abandoned pits to the northwest of Melvins Creek and west of the Garden State Parkway.

The Cliffwood and Morgan beds have been assigned to the *?Pseudoplicapollis cuneata-Semioculopollis verrucosa* Zone by Christopher (1979), which is equivalent to the upper part of Zone VII as defined by Sirkin (1974). The *?Pseudoplicapollis cuneata-Semioculopollis verrurucosa* Zone is considered Santonian to earliest Campanian. More recent work on samples obtained in the gully south of Ernston Road and west of the Garden State Parkway indicates that Zone VII includes the entire section; no dinoflagellates indicating marine deposition were observed. Slightly to the north of the main gully bordering Cheesequake Creek, a lower cross-bedded sand facies grades into a thin-to thick-bedded carbonaceous clay-silt. This clay-silt is also assigned to Zone VII, although it contains rare dinoflagellate cysts (*Cleistosphaeridium* sp.) suggesting marginal marine conditions, and a different suite of palynomorphs, lacking signicant Zone VII markers such as *Vacuopollis* sp., *Plicapollis* cf. *incisa, Pecakipollis* sp., and *Trudopollis* sp. It did contain *Tricolporites* sp., which Doyle (1969) associated with the Amboy Soneware; we consequently place this clay in the Amboy Stoneware member.

Kma **Amboy Stoneware Clay**--Clay and silt, dark gray to grayish-brown, weathering to white; carbonaceous and micaceous, with grayish-pink fine quartz sand laminae. Fine-grained pyrite is commonly associated with the carbonaceous areas, and is less commonly massive. Owens and others (1977) note the presence in certain beds of large pieces of lignitized logs, as well as small cylindrical burrows filled with light sand. The Amboy Stoneware is as much as 30 feet thick, but is very variable in thickness along strike, and appears to have been deposited in lensoidal channels. This geometry was observed in the former sand pit near Old Bridge, where pods of the South Amboy overlie the Old Bridge Sand. The Amboy Stoneware member is exposed at the base of former clay pits on the west and northwest edge of the Cheesequake marsh.

Christopher (1979) placed the South Amboy and upper part of the Old Bridge in his *Pseudoplicapollis longiannulata-Plicapollis incisa* zone which he considered Coniacian (?) to early Santonian; this corresponds to the lower part of Sirkin's (1974) Zone VII. We are informally assigning Zone VI to the *Psuedoplicapollis longiannulata-Plicapollis incisa* zone.

Kmu **Cliffwood beds, Morgan beds, and Amboy Stoneware Clay, undivided**.

Kmo **Old Bridge Sand** -- Quartz sand, light gray, weathered to white, yellow, orange and pink, quartzose, with occasional clear mica and sand-sized lignite; extensively cross-bedded including trough and planar-tabular cross-bedding varying greatly in size; interbedded with laminated to thick-bedded, dark gray, discontinuous, carbonaceous clay beds as much as 3 ft. thick. As much as 100 feet thick. Exposures of the Old Bridge are poor due to the loose, sandy nature of the beds, and are generally restricted to abandoned pits such as those of the South River Sand and Gravel Pit, and those west of the Garden State Parkway and northeast of Phoenix, in the northern part of the quadrangle.

Kms **South Amboy Fire Clay** -- Clay, massive to laminated, locally dark gray, but typically oxidized to white and red. Contains lignitized, pyritic logs. Also contains small pieces of amber in places. The clay-silt beds generally occur in channels, and are commonly adjacent to cross-bedded, fine to medium quartz sands with thin carbonaceous layers containing varisized lignitized material including logs. As much as 30 feet thick.

The South Amboy Fire Clay is the lowermost member of the Magothy. Christopher (1979) recognized a major break in the Normapolles and triporate pollen distribution at the base of the South Amboy Fire Clay, unlike Wolfe and Pakiser (1971), who regarded the South Amboy Fire Clay as the upper member of the Raritan Formation. The South Amboy Fire Clay is consistently assigned to pollen Zone V in this study. The ecology of the palynoassemblage suggests a coastal lowland swamp with nearby mesic coniferous stands and swampside angiosperms, with some brackish effects evidenced by a few species of *Balitspaeridium*.

The South Amboy Fire Clay is assigned to the *Complexiopollis exigua-Santalacites minor* Zone (Christopher, 1979); this zone was formerly considered Turonian to Coniacian (Christopher, 1979), and later revised to post-Coniacian (Christopher, 1982).

Kr RARITAN FORMATION -- Includes two informal members in this quadrangle: the Farrington Sand and the Woodbridge Clay. In the subsurface, downdip from outcrop, the members are not mapped (section AA'). Total thickness of the Raritan Formation in the quadrangle is as much as 150 feet. Owens and others (1977) included the Sayreville Sand of Barksdale and others (1943) as an informal member of the Magothy. This is the "Feldspar"-"Kaolin" Sand Bed of Ries and others (1904). Because the Sayreville is very discontinuous, irregular in thickness, and not recognizable over a large area, it is not mapped on this quadrangle. The South Amboy Fire Clay includes a localized cross-bedded sand facies (see preceding discussion), and the limited exposures in this quadrangle make it difficult to separate the Sayreville from the cross-bedded sand facies of the South Amboy. Consequently, all the beds above the Woodbridge Clay and below or immediately adjacent to the true clay in the South Amboy Fire Clay are included here in the South Amboy Fire Clay Member. The contact of the South Amboy and the Woodbridge Clay was best exposed in the former clay pit in Sayreville (south of Washington School). There is more than 25 feet of relief at the contact here. The contact is marked by a thin (0.5-1 ft.) bed of gravel and clay (white kaolinite) which consists of weathered ripup clasts. An ironstone layer typically overlies this bed.

Krw **Woodbridge Clay** -- Clay and silt, dark gray, massive, with mica (clear, brown, and green), wood (typically fine grained), and pyrite. Occasionally interlaminated with light gray to white sand. Small (<3-foot-thick) beds and slabs of gray to brown siderite are common. As much as 110 feet thick. Lignitized trees in growth position have been observed in the Woodbridge in the former clay pit in Sayreville (Owens and Sohl, 1969), where it was best exposed. Fossil imprints also occur near the top of the formation in cemented slabs.

The Woodbridge has been assigned to the Complexiopollis-Atlantopollis assemblage Zone of Cenomanian age (Christopher, 1979), or Zone IV of Sirkin (1974). It has also been assigned to the upper Cenomanian based the ammonites *Metoicoceras bergquisti* and *Metengonoceras* sp. recovered from the former clay pit in Sayreville (Cobban and Kennedy, 1990). The Woodbridge Clay is interpreted as a lowland swamp deposit with considerable marine influence, transitional to prodelta and/or marine inner shelf (Owens and Sohl, 1969). Dinoflagellate cysts, including *Cyclonephelium distinctum* and *Hystrichospheridium recurvatum*, are contained in the Woodbridge.

Krf **Farrington Sand** -- Quartz sand, white, yellow, red, light gray, micaceous, commonly interbedded with thin gravel beds and thin to thick dark gray silt beds. As much as 50 feet thick. Crops out only in the northwestern corner of the quadrangle. The Farrington rests unconformably on Piedmont rocks.

Kp3 POTOMAC FORMATION, UNIT 3 -- Interbedded sand and silty clay. Sand commonly white, yellow, light gray, poorly sorted, cross-stratified, and thin-to thick-bedded. Clay is thin-to thick-bedded, white, red, yellow where oxidized, gray where unoxidized, and contains abundant lignite. The Potomac is inferred to extend into the subsurface in the South Amboy quadrangle, based on updip projections from boreholes in the adjacent Marlboro and Freehold quadrangles; it has not been verified despite analysis of limited core material for this quadrangle.

The Potomac is assigned to pollen Zone III in the northern New Jersey Coastal Plain. This zone is considered to be lower Cenomanian (Doyle and Robbins, 1977).

PIEDMONT ROCKS

Rocks of the Piedmont are shown on the map and in cross sections, based on logs of wells and borings. Only the weathered zone of the Passaic and Lockatong formations are exposed at the surface, in the northwest corner of the quadrangle.

Jd DIABASE -- Medium-grained, dark gray to dark greenish-gray diabase. Massive-textured, hard, and sparsely fractured. Composed dominantly of plagioclase, clinopyroxene, and opaque minerals. Weathered to white, red, gray, brown, or olive clay to sandy clay. Intruded as a sill in the Lockatong Formation. About 100-200 stratigraphic feet of the enclosing Lockatong Formation are metamorphosed into bluish-gray hornfels. Lower Jurassic in age.

JTrp PASSAIC FORMATION -- Shale and siltstone, reddish-brown to brownish-purple; red, reddish-brown, light gray, olive clay where weathered. Early Jurassic and Late Triassic in age (Olsen, 1980). The clayey weathered zone was mapped as the "Raritan fire and potter's clay" member of the Raritan Formation by Cook (1878) and Ries and others (1904) but is included here with the Passaic Formation.

Trl LOCKATONG FORMATION -- Argillite, dark gray to black, brown to gray clay where weathered. Late Triassic in age.

Trs STOCKTON FORMATION -- Sandstone and siltstone, reddish-brown to gray. Late Triassic in age.

CZYu PRE-MESOZOIC METAMORPHIC ROCKS -- Gray, medium-to coarse-grained schist and gneiss dominantly composed of quartz, feldspar, and mica; commonly weathered to a clayey micaceous saprolite. Cambrian to Middle Proterozoic (?) in age (Volkert and others, 1996).

MAP SYMBOLS

Contact--Approximately located. Dashed where interfingered, transitional, or covered by thick surficial deposits.

Formation observed in outcrop, excavation, or hand-auger hole.

Boring or well penetrating bedrock--Log information used to map formations. For logs and identifers, see Stanford (1993).

47 Boring or well with log used to construct section--Identifiers of the form "xx" are from Stanford (1993). Identifiers of the form "23-xxx" are from Gronberg and others (1989).

Surficial deposits--Shown by shading where continuous and more than 10 feet thick.

zone V Pollen zone--Circle indicates approximate location of sample.

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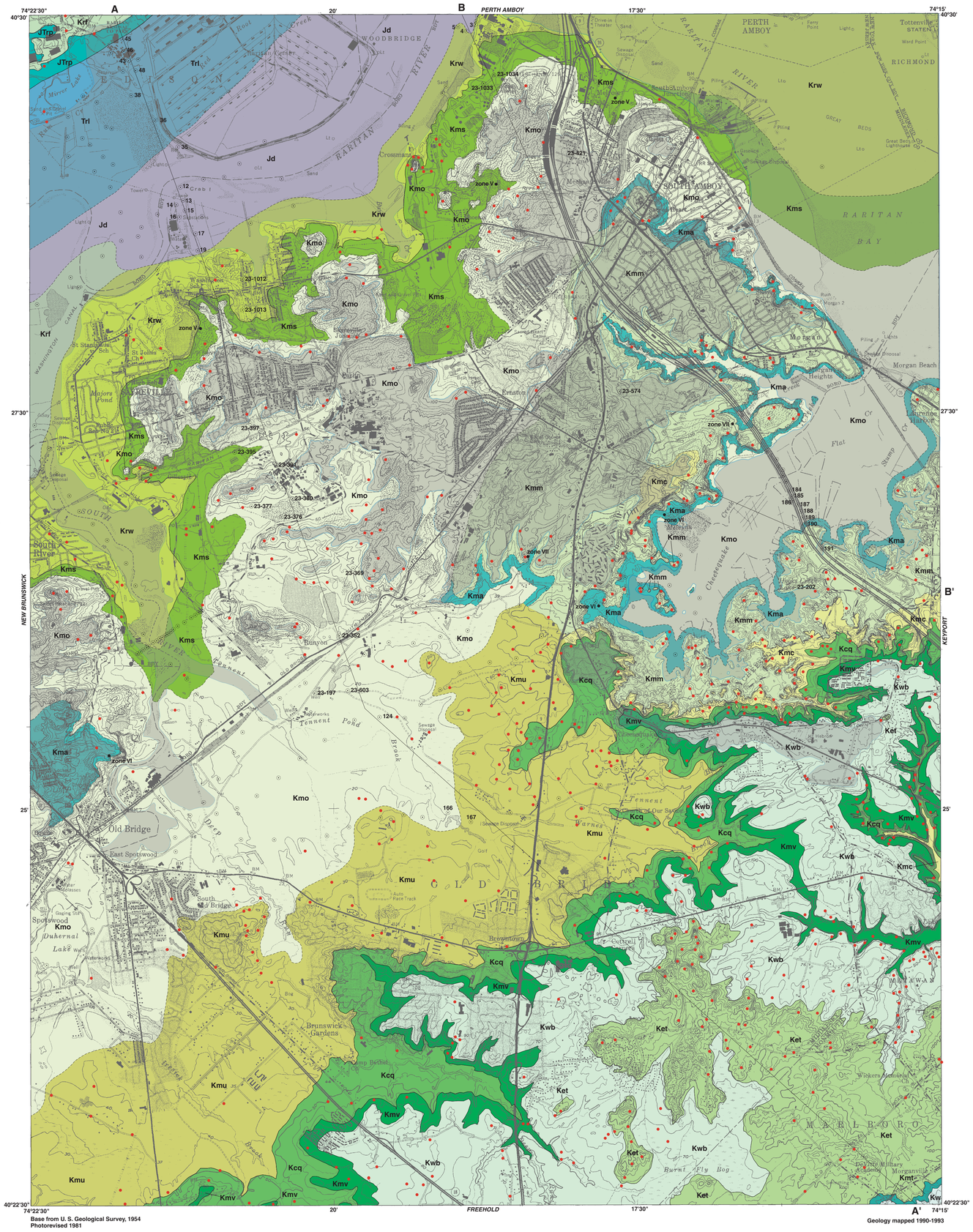

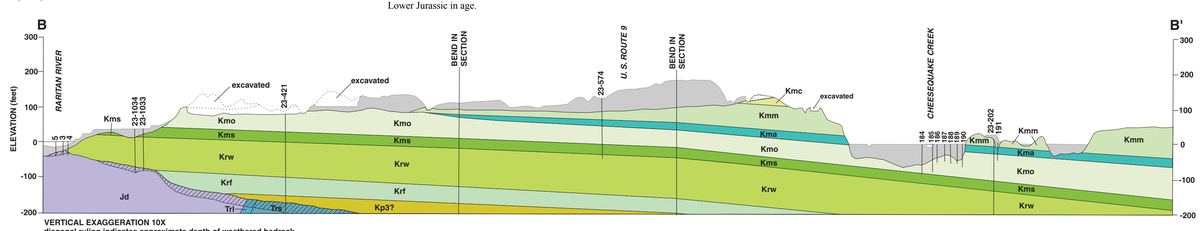

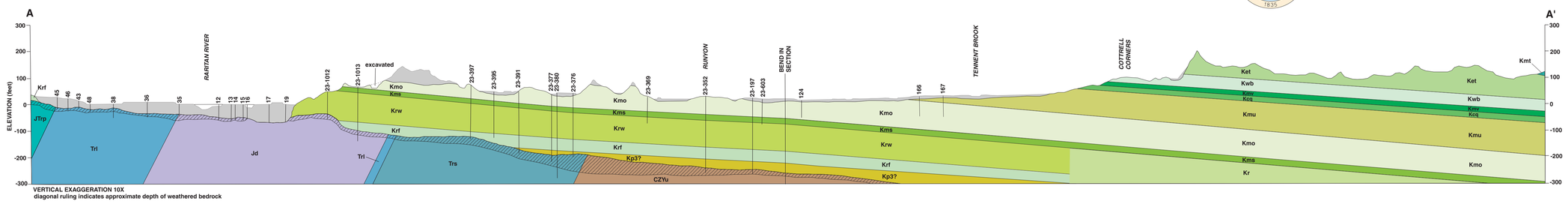

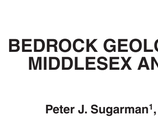

BEDROCK GEOLOGY OF THE SOUTH AMBOY QUADRANGLE MIDDLESEX AND MONMOUTH COUNTIES, NEW JERSEY

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SCALE 1:24 000

1 1/2 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

NEW JERSEY GEOLOGICAL SURVEY 1835

CORRELATION OF MAP UNITS

Kw, Kmt		CAMPANIAN	CRETACEOUS
UNCONFORMITY			
Ket, Kwb, Kmv			
UNCONFORMITY			
Kcq		TURONIAN (?)-CONIACIAN-SANTONIAN	
UNCONFORMITY			
Kmc, Kmm, Kma, Kmo, Kms	Kmu		
UNCONFORMITY			
Krw, Krf	Kr	CENOMANIAN	
UNCONFORMITY			
Kp3			
UNCONFORMITY			
Jd		INTRUSIVE CONTACT	JURASSIC
JTrp			TRIASSIC
Trl			
Trs			
UNCONFORMITY			
CZYu		CAMBRIAN TO MIDDLE PROTEROZOIC	