DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Southeast Friends of the Pleistocene, 2nd annual field conference: Cenozoic geology and geomorphology of southern New Jersey Coastal Plain

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by

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Introduction

The USGS has been mapping Mesozoic and Cenozoic geology in the Atlantic Coastal Plain since the early 1960's; first in New Jersey, then in Virginia and Maryland around the Chesapeake Bay, and in the Carolinas and parts of Georgia. The study and application of modern depositional environments coupled with biostratigraphy has facilitated the recognition of transgressive/regressive sequences. Studies of provenance and mapping of these cyclic packages has demonstrated that the basic architecture of the emerged Coastal Plain consists of basins and arches which have been periodically uplifted and depressed. Different regions reveal different histories of alternating events of erosion and deposition. This regional pattern is supported by studies of surficial geology which indicate different depositional systems and histories of deep weathering and erosion creating unique assemblages of surficial deposits.

In 1984, the USGS and the New Jersey Geological Survey (NJGS) entered into a cooperative agreement to produce a new state geologic map at a scale of 1:100,000. From this mapping effort, a wide array of surface and subsurface information has been produced and interpreted in the context of the onshore and offshore regional framework for the middle Atlantic states.

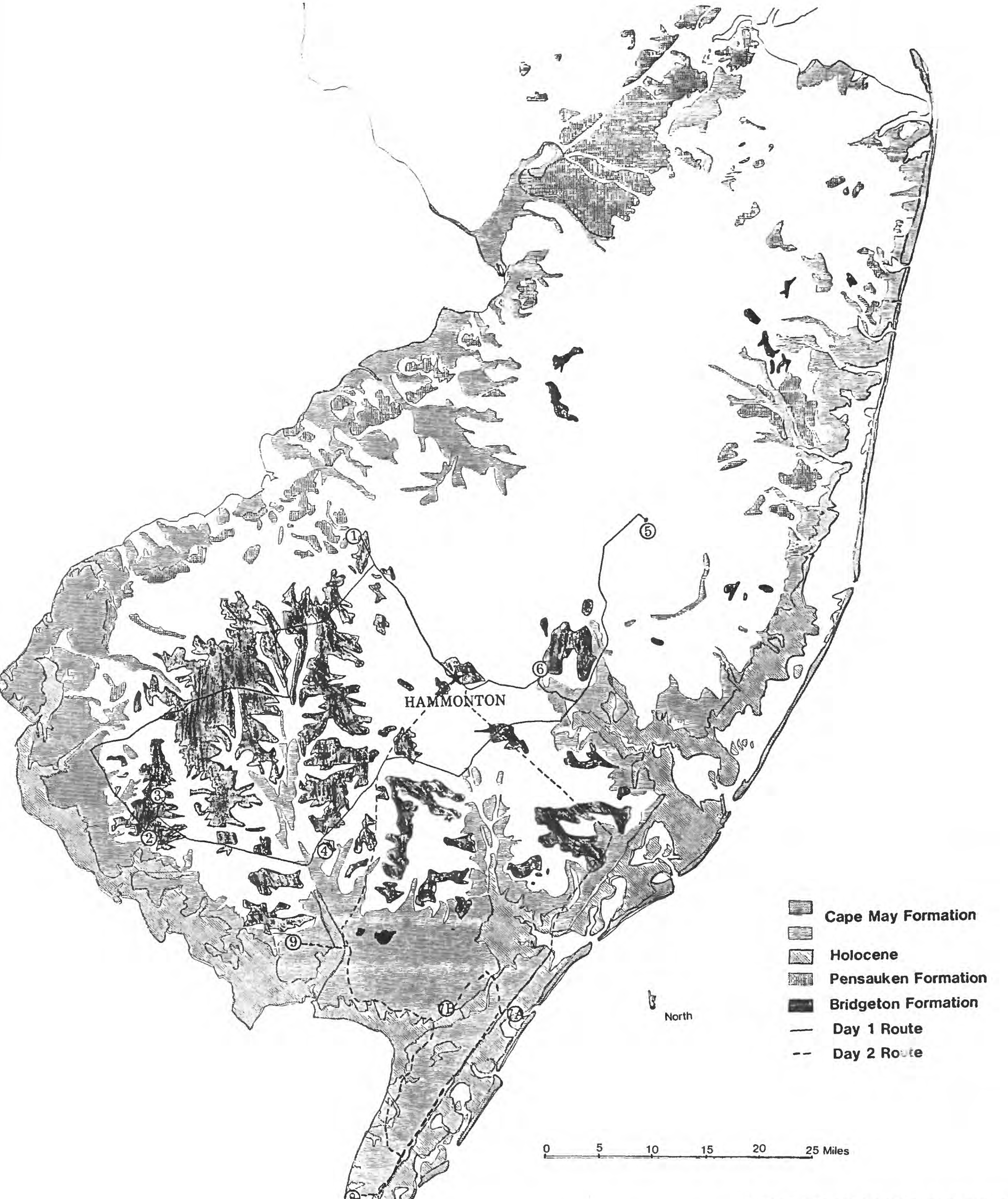
The New Jersey Coastal Plain provides a unique opportunity to examine an area that has had varying amounts of subaerial exposure since the late Miocene. Partial records of the effects of fluvial, aeolian, and geochemical processes operating through a wide range of climatic variables have been preserved and can be distinguished at many exposures. This field trip (Figure 1) in southern New Jersey seeks to elucidate the development of a landscape on an uplifted margin of a Miocene depocenter. We will look at the Miocene "bedrock", development of deep regolith, and how these parent materials were eroded and redeposited during sea-level high stands and low stands of the Pliocene and Pleistocene. In the context of geomorphic setting, geographic setting, and timing of deposition, the surficial deposits of New Jersey are strikingly different from other deposits of the Atlantic Coastal Plain.

The first day of the field trip we will examine the stratigraphy of the Bridgeton Formation and Cohansey Formation in the uplands. The framework and the distribution of the marginal-marine and fluvial deposits will be discussed. These deposits have been deeply weathered and eroded since the late Miocene. The extensive overprint of deep, intensive weathering has been modified by the development of frozen ground features such as frost wedges, and cryoturbation during Pleistocene glacial event(s). Since the late Miocene, after the deposition of the Bridgeton Formation, weathering, and erosion of the bedrock deposits under varying climatic regimes has generated a series of surficial deposits consisting of colluvium and alluvium. Under present climatic conditions, geomorphic processes are incapable of generating such deposits and the resulting landscape.

Inset against the upland Miocene deposits, Quaternary deposits form a series of low-relief marine and estuarine terraces that were developed during sea-level high stands (Pleistocene interglacial periods). On the second day, we will examine these Quaternary estuarine to marginal-marine deposits and their relationship to older Miocene formations. Evidence for the ongoing Holocene transgression will also be briefly discussed.

Regional Geology

The emerged portion of New Jersey Coastal Plain consists of a seaward thickening wedge of sediments which range from the late Mesozoic to Recent in age. The wedge extends eastward from a feather edge along crystalline Piedmont, Triassic, and Jurassic Rocks to the western margin of the Atlantic Ocean where accumulation



GEOLOGY MODIFIED FROM M.E. JOHNSON, 1950.

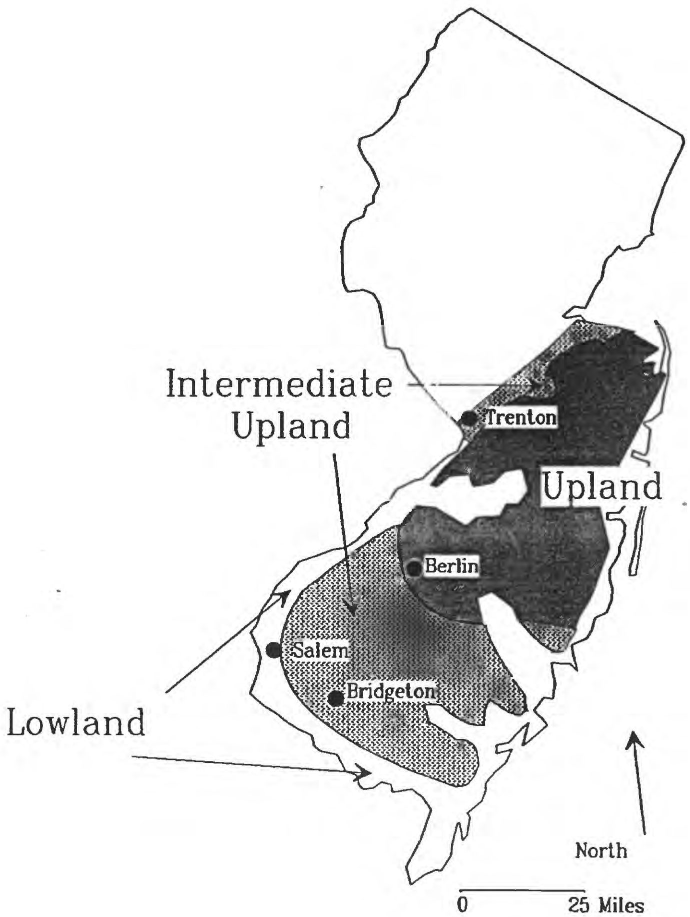
FIGURE 1. NEW JERSEY COASTAL PLAIN QUATERNARY GEOLOGY WITH LOCATIONS OF FIELD TRIP STOPS.

as much as 1953m of sediment have been found (Maher, and Applin, 1971). The New Jersey portion of the Coastal Plain Province can be subdivided into three subprovinces (Owens and Minard, 1979). The New Jersey Coastal Plain subprovinces include: the lowland, intermediate upland, and upland subrovinces (Owens and Minard, 1979). Generally, the lowland province is comprised of that area facing the Atlantic Ocean, Delaware Bay and along the Delaware River up to Trenton, New Jersey (Figure 2). Altitudes within the lowland subprovince range from 0 to 21.5m (0-70ft; Owens and Minard, 1979). The intermediate upland, characterised by Owens and Minard, 1979, is that portion of the New Jersey Coastal Plain located in southern New Jersey and is primarily underlain by the Bridgeton Formation. The intermediate upland subprovince also extends along the inner edge of the coastal plain from Trenton to Raritan Bay. The elevations of the intermediate upland province range from 15.2m to 54.9m (50ft-180ft). The upland province is bordered by the lowland and intermediate upland subprovinces. Generally, the uplands are underlain by the Cohansey Formation and the Kirkwood Formation with elevations of 61.0m to 121.9m (200ft-400ft; Owens, and Minard, 1979).

The following is a brief summary of each of the formations which will be encountered on the field trip as well as some units which will not be seen. These formations include the following: (from oldest to youngest) the Cohansey Formation, the Bridgeton Formation, Pensauken Formation, and the Cape May Formation (Figure 3).

The Cohansey Formation was named by Knapp (Kummel and Knapp, 1904). Knapp described the Cohansey as a near-shore marine, well-sorted, siliceous sand of middle to late Miocene age. Carter, (1972) later sudivided the unit into two facies based on the sequences of sedimentary structures and lithology. Carter, (1972) postulated a barrier sequence and a back-barrier, tidal-flat sequence. Owens and others (in press) suggested that the Cohansey is a deltaic sequence which consists of an upper-delta plain to near-shore marine-shelf deposit with a whole host of environments between such as lagoonal, barrier, and tidal flat. The age of the Cohansey is thought to be middle Miocene because of its stratigraphic position between the underlying early-middle Miocene, Kirkwood Formation and the overlying Bridgeton Formation. The Cohansey is generally very easily differentiated from the Bridgeton Formation because of its orthoquartzite lithology and its marine bedforms and trace fossils.

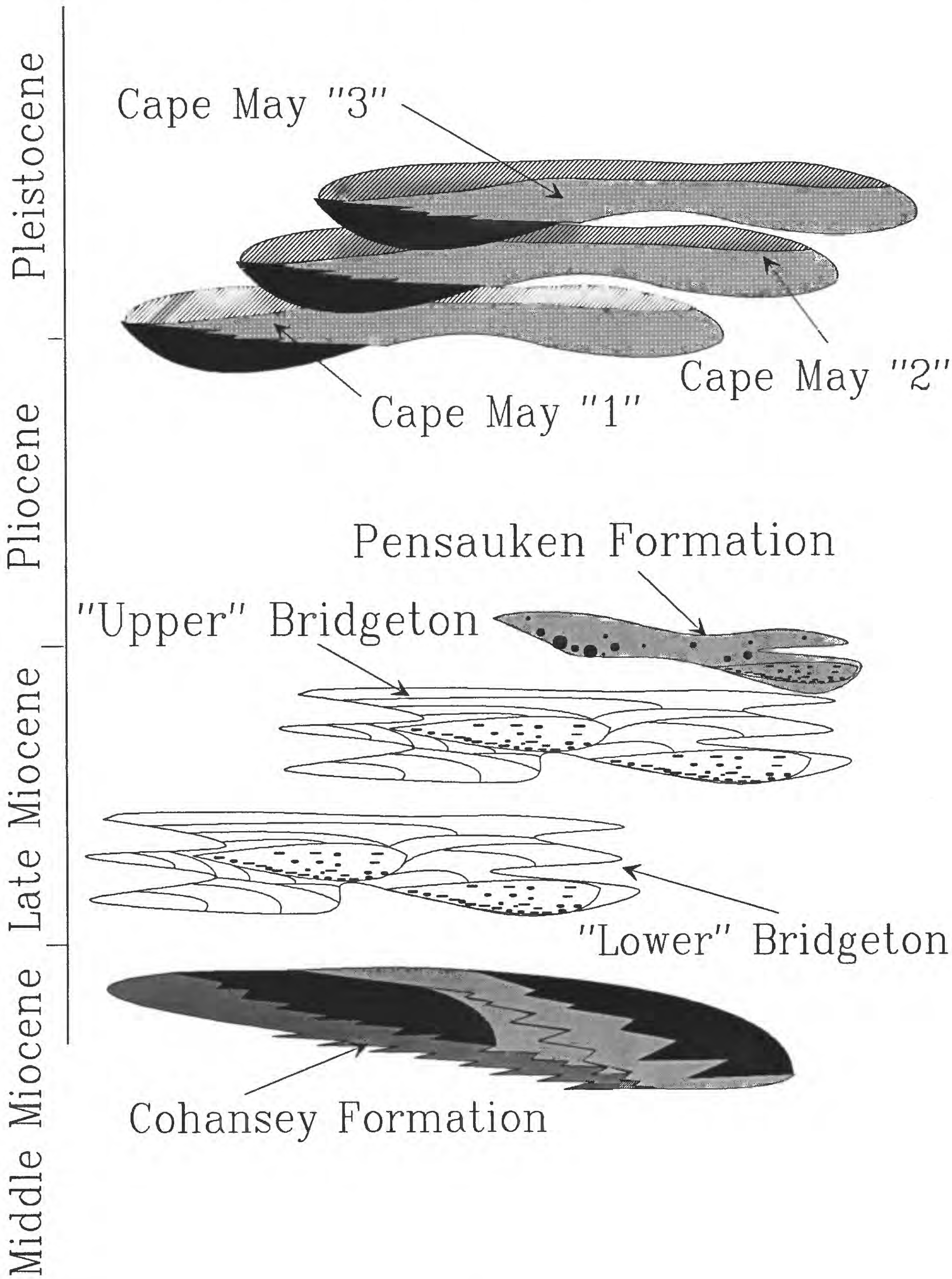
Salisbury (1898) named the Bridgeton Formation for a Pleistocene, fluvial, coarse-sand and gravel deposit. Salisbury and Knapp (1917) later subdivided the Bridgeton Formation into two units, the Woodmansie phase and the Glassboro phase. Owens and Minard (1979), who mapped several quadrangles around Trenton, New Jersey, called the Bridgeton Formation arkose 2. They recommended that arkose 2 include all of the feldspathic deposits which occured underlying the intermediate upland subprovince between Trenton and South Amboy. Owens and Minard (1979) assigned a late Miocene age to the fluvial arkose because of its stratigraphic relationship with the inset Pensauken Formation and the underlying middle Miocene, Cohansey Formation. In this report, the Bridgeton Formation is described as a fluvial arkose, comprised of two units. The lower unit consists of large tabular-crossbedded facies with interbeds of trough crossbeds, and locally it is deeply leached and oxidized. The upper Bridgeton unit unconformably overlies the older Bridgeton unit. It too is a fluvial deposit but typically includes low-amplitude, laterally-extensive, channel-gravel lags interbedded with small-scale trough and tabular crossbeds. Where the unconformable contact of the upper and lower Bridgeton units is exposed, it is always apparent that the older unit was weathered and eroded prior to the deposition of the upper Bridgeton unit. The Woodmansie phase and Glassboro phase are no longer applicable to the Bridgeton Formation because the Woodmansie phase is now recognized as much younger colluvium and alluvium. The colluvium and alluvium occur as weathered patches of yellow quartz gravels derived from the erosion of the



Modified from Owens and Minard, 1979.

Figure 2. Subprovinces in the New Jersey Coastal Plain

Figure 3
Schematic Correlation of Rock Units



upper delta-front facies of the Cohansey Formation. The distribution of these materials is common throughout the Pine Barrens, north of the area underlain by the "true" Bridgeton Formation.

Salisbury (1898) initially described the Pensauken Formation. Salisbury and Knapp later redefined the Pensauken and characterized it as consisting of two lithofacies; the first lithofacies (Woodstown lithofacies) consisted of glauconitic sediment with a small amount of feldspar. The Woodstown lithofacies was considered to be comprised of reworked Coastal Plain sediments. The second lithofacies (Swedesboro lithofacies) consisted of sediments with a variety of clasts suggesting a provenance outside the Coastal Plain. Owens and Minard (1979) described the Pensauken Formation as those fluvial sediments in the Amboy-Salem valley with surface altitudes of 15.2m to 24.4m (50ft0-80ft) Prior to Owens's and Minard's study, the Pensauken Formation was thought to be Pleistocene in age. However, Owens and Minard (1979) proposed a late Miocene age for the Pensauken Formation because of the Pensauken's interfingering relationship with the downdip very fossiliferous beds of the Eastover Formation (late Miocene early Pliocene) underlying the Delmarva Peninsula.

Salisbury (1897) also described the Cape May Formation. The Cape May Formation was later redefined by Salisbury and Knapp (1917). They characterized the Cape May as a near-shore marine to estuarine deposit of Wisconsin age. Gill (1962) subdivided the Cape May into four facies which include: deltaic-sand facies, marine-sand facies, estuarine-clay facies, and estuarine-sand facies. Present mapping of the surficial geology in conjunction with drilling and subsurface studies demonstrates the Cape May contains three separate transgressive-regressive sequences. Each sequence is comprised of an estuarine to barrier to near-shore marine genetic package of sediments. The sequences are separated by an erosional unconformity. Wayne Newell (1988, oral commun.) informally designates the sequences from oldest to youngest: Cape May 1, Cape May 2, and Cape May 3. When age data from a variety of disciplines is acquired, formal names and correlations with stratigraphy of Chesapeake Bay area will be set forth. Tentatively, the Cape May 1 is equivalent to the Omar Formation, the Cape May 2 is correlated to the Ironshire Formation, and the Cape May 3 is correlated to the Kent Island Formation. The exact age of the formation is uncertain. The Wisconsin age proposed by Salisbury and Knapp (1917) is too young. Carbon 14 data which has been gathered on several carbonaceous rich estuarine deposits found near Mays Landing, New Jersey indicate an age older than 40,000 yrs and therefore, the Cape May Formation is pre-Wisconsin.

First Day Road Log and Stop Descriptions

MILES

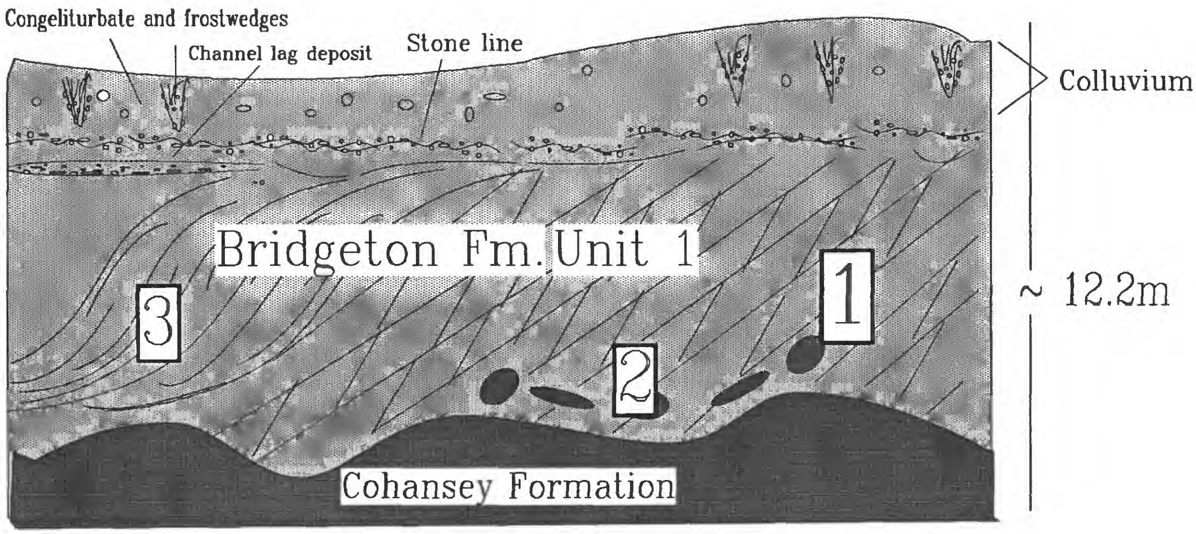
0.0 Trip begins at 8:00am at the Hammonton Motor Inn. Turn left onto Route 30, heading northeast. You are now travelling along the inner edge of the dissected Bridgeton plateau and the adjacent Mullica River valley, which eroded into the underlying Cohansey Formation. Bear right at Berlin onto Haddon Avenue passing through West Berlin. The Triboro Sand and Gravel Pit (Stop 1) will be on the left.

14.04 Stop 1 The Triboro Sand and Gravel Pit.

This stop will establish the geologic framework of the Bridgeton Formation (Figure 4). However, at this locality only the lower unit of the Bridgeton Formation can be seen. As exposed, the lower unit is a highly weathered, red to orange-brown, poorly-sorted, crossbedded, arkosic, fine-gravel, coarse-sand deposit which gradually grades downward to a large scale tabular-crossbedded, arkosic, pebbly, coarse sand.

Figure 4

Composite Diagram of the Triboro Pit showing relative position of the photographs and geologic features



Typically, the Bridgeton Formation is a fluvial deposit comprised of two units consisting of a wide variety of clast lithologies, sizes and bedforms resulting from a variety of source rocks and varying flow regimes.

In the upper unit, bedforms are smaller with bed cosets having average amplitudes of about 12cm. The gravel lag deposits indicate deposition in shallow and wide channels, with approximate channel widths of 9.144m (30ft). The lower Bridgeton unit (unit 1), exposed at the Triboro locality, is composed dominantly of large tabular- and trough-crossbeds, suggesting deposition by migrating megaripples and bedforms within a larger channel system. The height of the foresets averages about 1.8m and they are laterally extensive over several meters. At other stops, we will see the two Bridgeton units separated by an erosional unconformity. Evidence is present which suggests that the lower Bridgeton unit underwent a period of exposure and weathering prior to the deposition of the upper Bridgeton unit. (Photo 1, Photo 2 Photo 3).

The upper Bridgeton unit is intensely weathered. Feldspars and labile-heavy minerals appear etched and corroded. Clay coatings on the framework grains are common. The upper Bridgeton unit ranges from 2.4m to 6.1m (8ft-20ft) in thickness. Surface exposures of both Bridgeton units display well developed periglacial features which include frost wedges and congeliturbate. The frost wedges and involutions display vertically oriented clasts and a chaotic fabric as a result of the frost action. In some cases, light-colored soil-horizon material can be seen infolded into these features. The congeliturbated zone is a homogenized layer that is primarily composed of reddish-brown sand with scattered and "floating" gravel and pebbles. This zone varies in thickness, commonly ranging from .3m to .9m (1ft-3ft) thick.

The Triboro exposure is cut into an erosional remnant which projects above the Bridgeton plain. Overall, the Bridgeton unconformably overlies the middle Miocene Cohansey Formation. At the Triboro locality the Bridgeton-Cohansey unconformity is well exposed appearing as at an erosional, bevelled contact marked by gravel lag and locally by rip-up clasts of Cohansey Formation incorporated within the base of the Bridgeton Formation (Photo 2). The Cohansey Formation is a marginal-marine deposit consisting of a variety of facies. Two facies are apparent at stop 1: a trough-crossbedded facies of interbedded-coarse to medium sand with ghosts of clam shells, and a burrowed fine- to coarse-quartz sand. Some remnants of bedding have survived bioturbation. In contrast to the Bridgeton Formation the Cohansey Formation is an orthoquartzite.

14.04 Retracing our steps back to Route 30, at the intersection in the town of West Berlin, turn right after crossing over railroad, heading southwest on the Berlin-Cross Keys Road (Route 689). We will be riding along the up-dip edge of the Bridgeton Formation; note here the extensive amount of wind blown sand; locally these windblown-sand deposits are referred to as sugar sand because of the white and granular texture. This sand was once mined for use in the glass industry because of its high silica content (hence the town name of Glassboro). Most modern glass sand mining is now confined to the marine shelf facies of the Cohansey Formation. Upon entering the village of Crosskeys, go through intersection of Glassboro-Crosskeys road and enter the town of Glassboro. At Glassboro turn left onto Route 553, crossing Route 332 and Route 47. Continue along Route 553 (Monroeville-Glassboro Road), and turn right at the intersection of Routes 40 and 553. After a short distance, passing over Elmer Lake, turn left at Elmer onto Route 611 (Shirlie Road) heading southwest. After passing Shirlie and crossing over Route 77, continue on

Photo 1, Stop 1. Large foreset beds in core of a channel bar within the lower unit of the Bridgeton Formation.

Photo 2, Stop 1. Unconformity between the arkosic Bridgeton Formation and the underlying ortho-quartzitic marine sand of the Cohansey Formation. Note lag of rip-up clasts composed of Cohansey. This indicates exposure, weathering and minor induration by colloidal oxides and clay minerals.

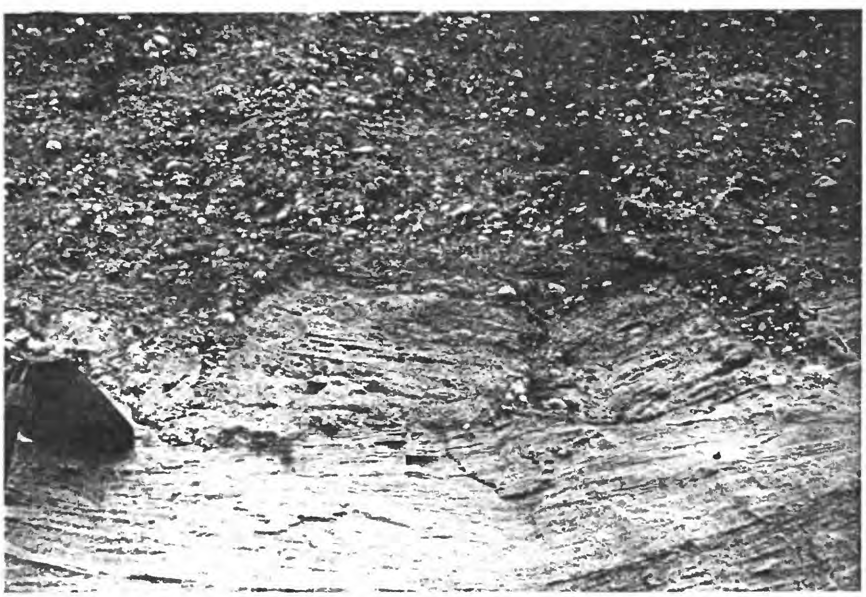


Photo 3, Stop 1. Clay drapes on distal portion of channel bar within the lower Bridgeton unit indicating wanning current velocities following flood events.

Quinton-Elmer Road (Route 611). Pass through the town of Alloway heading west on Route 581 (Quinton-Alloway Rd.) into the town of Quinton. To the south the land becomes more suitable for agriculture. This reflects the thickening cover of the Chilum Silt-Loam soil, a fertile loess blanket that has good soil moisture characteristics (Soil Survey, 1969). The sand and silt apparently were derived from Quaternary terraces to the west along the Delaware River. At Route 49 bear left and then right onto Route 626 (Tattletown-Jericho Rd.), going through Woodmere to Stop 2 on the left.

55.08 **Stop 2 Lower Alloway Township Pit.**

At this stop, exposures of the Cohansey Formation show a well preserved regressive, marginal-marine sequence (Figure 5). Three to four facies can be distinguished at this locality. The basal facies consists of an 2.4m (8ft) thick, massive, extremely burrowed, moderately well-sorted, medium ortho-quartzitic sand. The massive-burrowed sand is a typical nearshore deposit that formed below wave base (Photo 4).

Above the massive, burrowed-sand facies is a 1.2m (4ft) thick tabular-crossbedded facies. The cosets are approximately .20m (8in) thick. Well preserved Ophiomorphia nodosa burrows can be seen within this facies (Photo 6). Locally, there are scattered ghosts of shell fragments including Spisula (surf clams). Macrofossil remains such as these are very rare in the Cohansey Formation. This facies represents Clifton's, 1976, outer-planar zone environment of deposition.

The tabular-crossbedded facies grades upward into a trough-crossbedded and lunate-megaripple facies (Photo 5). The troughs display a size transition from small narrow troughs to wide, low amplitude, laterally extensive troughs suggesting shoaling and a greater current influence. Paleocurrent indicators such as ripple marks also indicate unidirectional and bidirectional current directions. Sediment sorting becomes progressively poorer upwards with the introduction of coarse sand and pebbles within the trough crossbeds. This deposit represents the inner-rough depositional environment of Clifton, (1976).

Immediately overlying the trough-crossbedded facies is a laterally extensive, relict, iron oxide-rich sand with abundant shell molds and casts indicative of what was once a shell lag. The remnant shell lag layer is overlain by a varicolored, laminated clay-silt with intraformational rip-up clasts (Photo 7). The laminated clay-silt facies is approximately 1.8m (6ft) thick and was deposited in a supratidal environment of deposition.

Unconformably overlying the laminated clay-silt facies is the Bridgeton Formation. The Bridgeton Formation at the Alloway Township Pit is approximately 9.1m (30ft) thick and is easily distinguished from the marginal marine Cohansey Formation because of the Bridgeton's arkosic lithology, fluvial bedforms, and deep red, oxidized, weathering profile. A thin veneer of windblown, gray, granular, well-sorted, and rounded sand can be observed at the top of the profile.

55.08 Continuing southeast on Route 626 and cross Stowe Creek. At the village of Roadstown turn left onto Shiloh Road heading into Shiloh. At Shiloh continue north on Route 49 to stop 3 which is just after the first intersection past the intersection of Route 49 and Cohansey Road. Linear bar forms dominate the subtle geomorphology of the southeastern New Jersey Coastal Plain intermediate uplands subprovince. Nearby topographic ridges are underlain by long linear channel bars. These deposits are now positive landscape features suggesting

Figure 5
Composite stratigraphic column showing the Bridgeton and Cohansey Formations

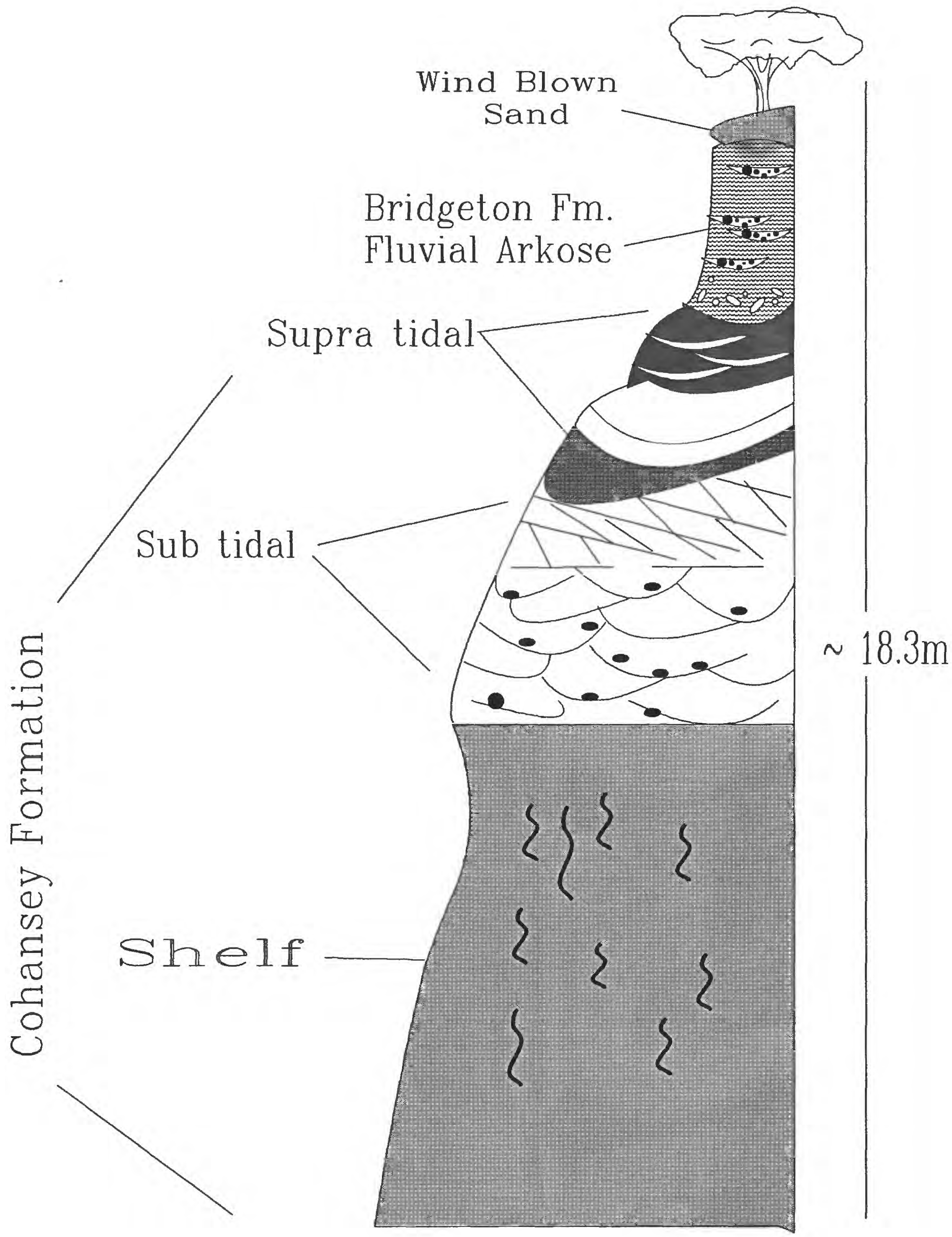


Photo 4, Stop 2. Massive bioturbated facies overlain by lunate megaripples of the intertidal littoral facies within the Cohansey Formation.

Photo 5, Stop 2. Intertidal to littoral facies within the Cohansey Formation. Note complex assemblages of lunate megaripples of outer rough zone and inclined beds of outer planar zone of Clifton, 1976.

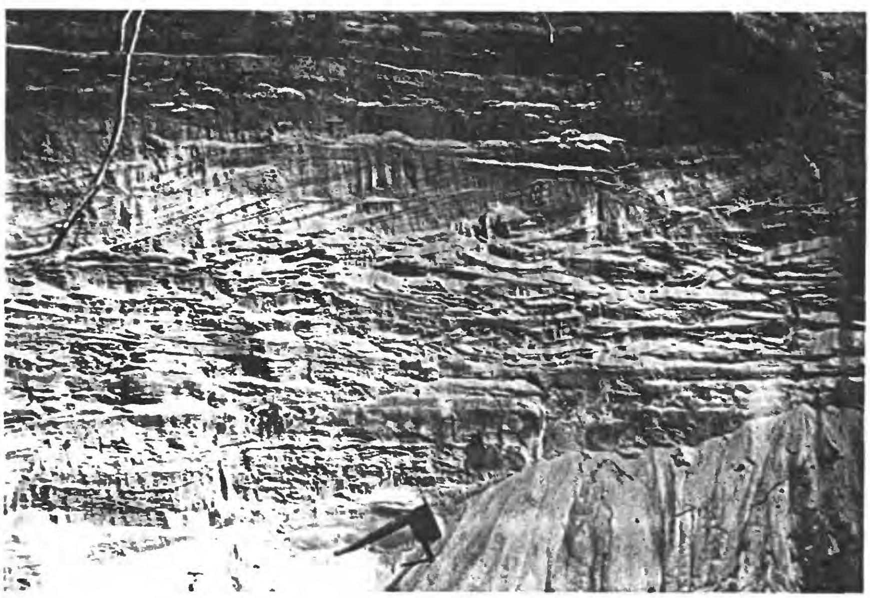
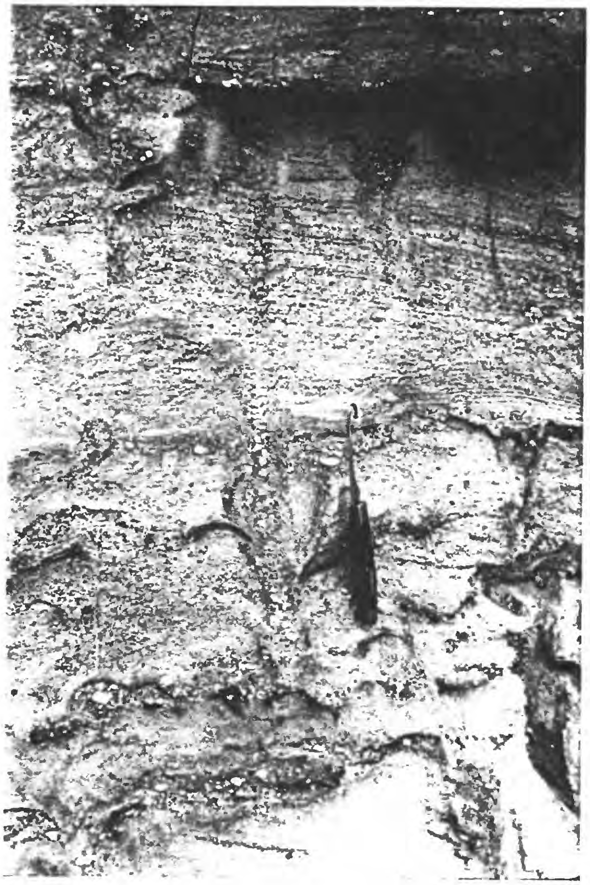


Photo 6, Stop 2. Clay-lined burrows and ghosts of surf clams suggesting littoral zone environment of deposition.

Photo 7, Stop 2. Clay drapes and flasers in tidal channel fills above the littoral facies within the Cohansey. Note the laminated, mottled bed above knife, it was a shell hash before leaching of the carbonate and replaced with iron oxides.



that the fine-grained flood-plain sediments have been preferentially removed.

62.37 **Stop 3, Mr. Halter's Pit.**

At Stop 3 we will examine another exposure of the highly weathered, laterally extensive Bridgeton Formation. The Cohansey Formation is present at or just below the bottom surface of the gravel pit. Unconformably overlying the Cohansey Formation is the lower unit of the Bridgeton Formation which is comprised of a large laterally extensive tabular-crossbedded facies. The tabular-crossbedded facies grades upawards to a poorly-sorted, pebbly, coarse sand of the trough-crossbedded facies (stop 1) (Photo 8). An unconformity separates the two Bridgeton units. Oxidized and weathered rip-up clasts of the lower Bridgeton unit can be seen at the base of the upper Bridgeton unit (Photo 9). The younger Bridgeton unit consists of a highly oxidized red to brown coarse sand and gravel with fine-grained clay-silt matrix coating most of the detrital grains. Within the younger Bridgeton unit, frozen ground features are present. Overlying the unit is the Chilum silt-loam which is a massive, prismatic, brownish-gray, well-sorted silt with a small percentage of fine sand (Soil Survey, 1969).

The sedimentary structures of the fluvial deposits, which comprise the Bridgeton Formation, have become more visible in outcrop because of weathering and erosion. At Stop 3, details of the deep weathering within the Bridgeton can be seen (Photo 10). Within the deeply oxidized profile, the open framework of the coarse-sand foresets permitted extensive illuviation of clay and silt from leached and oxidized horizons above. Locally, the clay is concentrated in fine-grained beds, closing voids and forming clay caps on upper surfaces of the coarse clasts. Most of the chert and sandstone clasts are very friable.

62.37 Head southeast on Route 49, into the town of Bridgeton, and cross the headwaters of Cohansey Creek. Continuing along Route 49, enter the town of Millville. At the center of town, turn left onto Route 47, go 6 blocks and turn right at Broad Street (Route 552). After 2 blocks turn right onto Route 555 (Wheaton Ave.), cross over Route 55 and bear right onto Lincoln Avenue. The Goff Pit (Stop 4) entrance is on the east side of Lincoln Ave.

79.11 **Stop 4. Goff Sand and Gravel Pit.**

At stop 4, both units of the Bridgeton and the contact between the Bridgeton Formation and the Cohansey Formation are exposed. The contact is uneven and filled with unidirectional, crossbedded, arkosic sand, and gravel deposits of the Bridgeton Formation inset in the marine sediments of the Cohansey Formation (Photo 12).

At this locality the poorly exposed Cohansey shows a variety of facies. Several spoil piles of blackish-gray, kaolinitic, organic-rich clays and silts of the Cohansey Formation suggest a back swamp or lagoonal environment of deposition. In the last century clay from the Cohansey and from the weathered Bridgeton at the surface was used for pottery and making bricks. Other exposures of Cohansey, at this locality, exhibit large tabular-crossbeds with <u>Ophiomorphia</u> burrows. Several good exposures of the contact between the Cohansey and the overlying Bridgeton are present.

Exposures of both Bridgeton units are similar to those seen at the last three stops. The unidirectional cross-bedded sediments of the lower Bridgeton unit are deeply weathered. The overlying younger unit is much less weathered, appearing

Photo 8, Stop 3. Below floor of pit is Cohansey Formation. Large exposure of foresets in channel bars of lower unit of the Bridgeton Formation. Pebble lag near the top of the profile marks the base of the upper unit of the Bridgeton Formation. At the top of the pit is the Chillum silt loam (loess).

Photo 9, Stop 3. Detail of weathered blocks of lower Bridgeton unit in the base of the upper Bridgeton unit (note vertically aligned clasts in stone line above basal beds of upper Bridgeton).

Photo 10, Stop 3. Detail of the upper Bridgeton unit, above the unconformity with lower Bridgeton unit, from a nearby locality to the south. Clay caps formed in-situ over pebbles during intense weathering of lower Bridgeton unit. Channel scour and deposition of the upper Bridgeton bedload reoriented the pebbles and dislocated the caps in the same flow vector as the imbricated clasts.

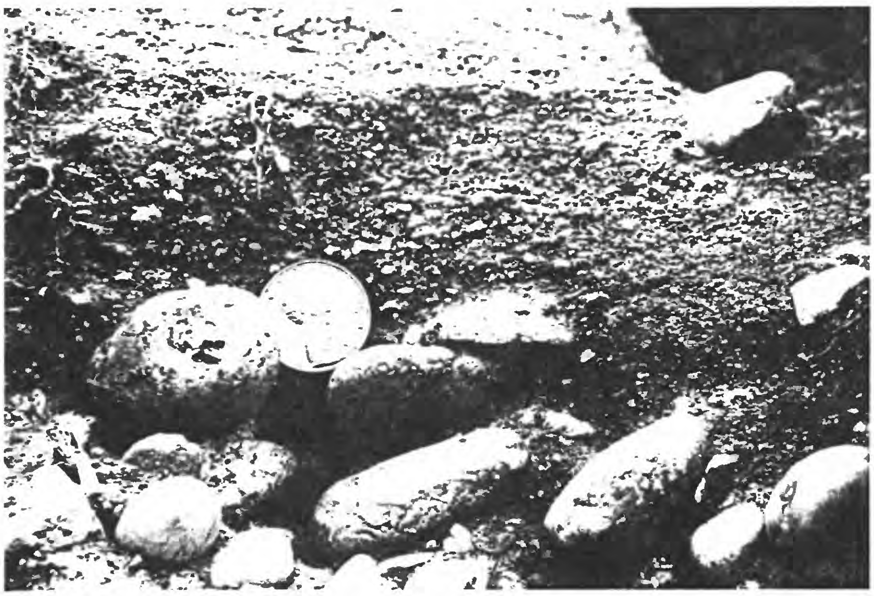


Photo 11, Stop 4. Unconformity between the upper and lower units of the Bridgeton Formation. Upper unit is weathered buff to pink. Sand grains include etched labile heavy minerals, kaolinitized pseudomorphs of feldspars, and degraded mica flakes. Large clasts include rock fragments such as red Mesozoic siltstone and shale fragments and crystalline Piedmont clasts. Bedforms consist of small-scale trough crossbeds and thin horizontal-clay laminations and clay-silt plugs in old channels. The lower unit is intensely eroded and oxidized yellow-brown. Crusts of limonite bridge the grains and partially fill the interstices. Feldspar pseudomorphs are difficult to find, heavy-mineral alteration is more developed, and only larger books of degraded mica remain intact from what were originally Piedmont schists, gniesses and granites. The sediments are characterized as coarse sand and well sorted gravel with unidirectional-planar crossbeds dipping to the southeast.

Photo 12, Stop 4. View of bar, in the lower unit of the Bridgeton Formation which is inset into a channel cut on top of the Cohansey Formation.

buff to pale pink. The lower unit of the Bridgeton apparently was subaerially exposed and deeply weathered prior to deposition of the upper Bridgeton unit (Photo 11).

Lunch at Union Lake.

81.98 At the exit of the Goff Pits turn left onto Lincoln Ave (Route 655). Head back into Millville on Route 555 (Wheaton Ave.) and retrace the trip back to Route 49. At Route 49 head west and find a place to eat along the bank of Union Lake. After eating lunch, retrace steps back to Route 655 passing through Millville. Continuing north-northeast on Route 655 cross Route 40 onto Route 54 and bear right onto Weymouth-Malaga Road heading east into Weymouth, onto Black Horse Pike (Route 322). At the first clover leaf heading east go northeast onto Route 632, Weymouth-Elwood road. Pass Makepiece Lake on the right, and Cranberry Bogs on the left. Pass through the town of Elwood, crossing over the Atlantic City Expressway. Continue straight across White Horse Pike (Route 30) and bear right on Elwood-Weekstown Road, entering the village of Weekstown. Heading northeast on Route 563, cross over the Mullica River and enter Wharton State Forest. Note changes in vegetation, the presence of underfit streams, extensive swamps, and thin surficial deposits of low relief. All of the landscape features are within a broad, low valley which is eroded into the marine facies of the Cohansey Formation. After passing through the town of Maxwell continue on Route 563, north, through Jenkins, Speedwell, and at Chatsworth turn right onto Route 532. Bearing northeast, continue on Route 532 to Route 72 and turn left. After a short distance on 72, pass beneath railroad tracks and turn right onto a rough asphalt one-lane road. Travel on the road for a mile and the entrance to the pit (Stop 5) will be on your right.

112.23 **Stop 5 Woodmansie: Hess Brother's Pit.**

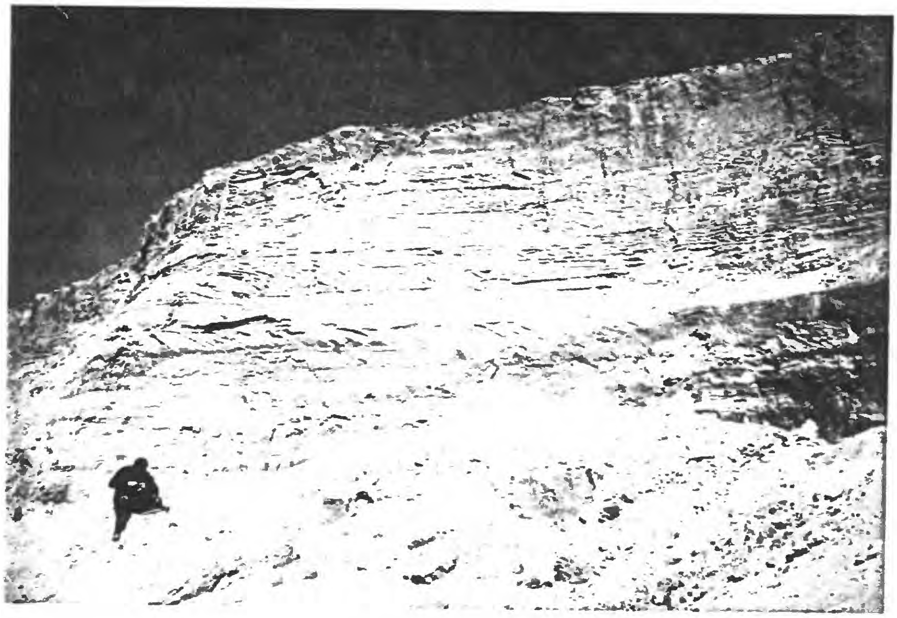
Thick sections of several facies within the Cohansey Formation are exposed here at the Woodmansie pit. Depending on mining operations, several different facies within the Cohansey Formation can be observed. At the base of the pit, large, laterally extensive, tabular crossbeds grade laterally and vertically into large trough crossbeds and in some instances these two facies are interbedded; these two facies are the result of migrating megaripples with changes in current direction during aggrading deposition (Photo 13). Each crossbed set has an average thickness of .25m (10in) and extends over several meters. Along the western portion of the pit, a thick exposure of interbedded sequences of clay, silt, sand, and gravel are preserved. Many of the fine-grained clay to sand couplets contain clay-lined burrows as well as clay drapes over small bedforms suggesting diminishing current velocity (Photo 14 and 15). Conversely, the coarser couplets display very little bioturbation and soft sediment deformation features are more abundant suggesting higher current velocities and rapid deposition causing loading and dewatering of sediments.

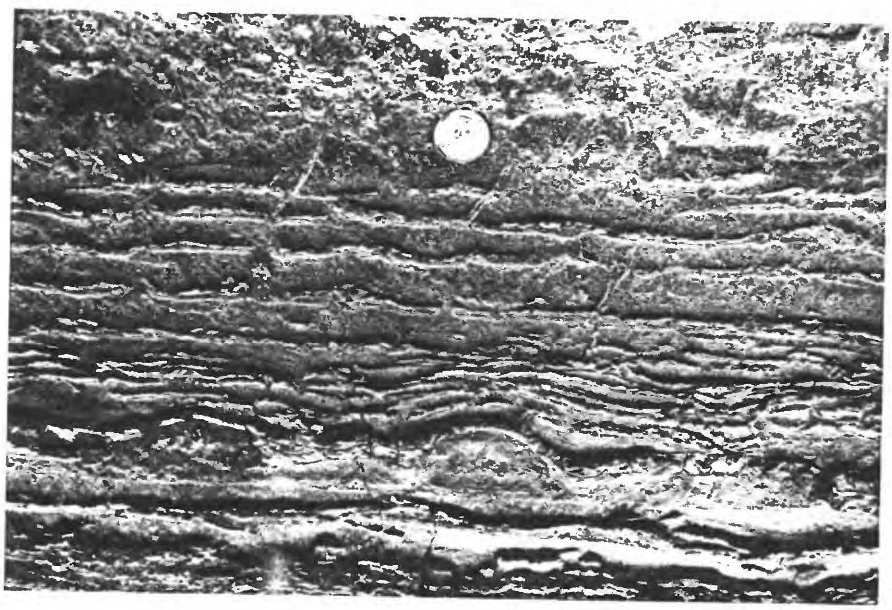
All of the above facies associations suggest a near shore marine prograding deltaic system. The wide array of bedforms and textures reflects the interaction between marine and fluvial processes such as tides, waves, and channel abandonment (Photo 16) .

The Cohansey Formation reflects the the influence of a fluctuating

Photo 13, Stop 5. Complex stack of delta-front sediments which include couplets of sand and gravel, unidirectional-planar crossbeds, burrows, well-sorted, marine sand beds and silty-clay horizontal laminations. All are laterally discontinuous and comprise a conformable sequence (aggrading deposition) on top of massive, burrowed, and well sorted marine sand.

Photo 14, Stop 5. Detail of clay-lined burrows punctuating thin clay laminae and flasers.





groundwater table. At some exposures, the accumulation of fine-grained illuviated material almost obliterates the original depositional fabric. At such localities, the bedding appears massive. This phenomenon is of great concern to the gravel and sand mining industry. Much of the sand has to be washed before use to remove the high percentage of clay and silt. Similarly, iron-oxide lamellae are also common in the upper levels of the permeable horizons, suggesting periodic changes in the elevation of the groundwater table.

Another important aspect to recognize here is the presence of yellow-quartz gravels both within the Cohansey Formation and within the broad thin, surficial deposits which are widespread throughout the Pine Barrens. Thin veneers of the yellow, deeply etched, and oxide-coated quartz gravels with a small percentage of chert size gravel, occur on the ridge crests, broad gentle slopes, and valley bottoms. The exposures in the Woodmansie uplands reveal the parent materials which were the sediment source for the surficial deposits that cover much of the Pine Barrens. The surficial deposits have been reworked from the upper delta-plain facies and fluvial facies of the Cohansey Formation. The upper delta-plain and fluvial facies are no longer present due the extensive amount of erosion which has taken place since the middle Miocene. The surficial deposits lie unconformably on the marine shelf facies of the Cohansey (Figure 6). At the next stop we will examine examples of these surficial deposits.

112.23 Retracing our steps southward back to Route 72, to Route 532, and Route 563: at Greenbank turn right heading west along the north bank of the Mullica River on the outskirts of Wharton State Forest to Batsto Village. Continue northward bearing right. The tower (Stop 6) is located 3/4 mile northeast of Batsto.

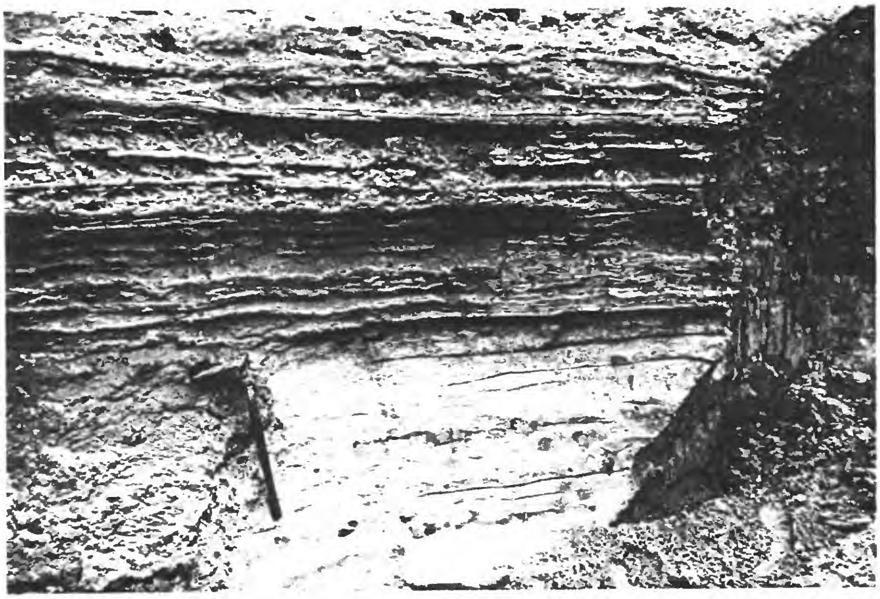
149.85 **Stop 6 Batsto Fire Tower.**

This stop shows a typical exposure of the surficial deposits, which overlie the Cohansey Formation, within the Pine Barrens. These deposits occur as massive, orange-brown, medium to coarse, poorly-sorted colluvial, and alluvial sand with scattered yellow-quartz gravels. Although similar in texture, the alluvium is better sorted and has fluvial bedforms; conversely, the colluvium is poorly-sorted and massive. The surficial deposits occur beneath broad-gentle slopes and valley bottoms, and as erosional remnants capping ridges. The surficial deposits form a series of colluvial and alluvial sheet like deposits which suggests dissection of one surficial deposit and the creation of another surficial deposit, generally preserving the coarse channel alluvial lag deposits as remnant outliers. All of the surficial deposits except the most modern (Holocene) display permafrost features such as a cryoturbated layer and frost wedges (Photo 17). The surficial deposits have a soil profile consisting of a thick grayish-white A horizon suggesting a great amount of leaching. The Cohansey Formation, 2.1m (7ft) beneath the colluvium, is generally characterized as a yellow-brown to gray, massive, moderately well-sorted, medium-grained quartz sand of marine origin. Clay-lined burrows are locally common. Both the Cohansey Formation and the surficial deposits show features such as abundant iron-oxide lamallae, indicating a fluctuating groundwater table.

Valleys cut into the marine-shelf facies of the Cohansey exhibit a thin covering of windblown-fine sand. The windblown deposits vary in thickness; however, at some localities these deposits may be as much as .61m (2ft) thick. All of the surficial material that overlies the Cohansey in the upper Mullica, Batsto, and Wading river basins has been reworked out of the marine-shelf and delta-front facies of the Cohansey Formation. The mineralogy of the sands and the lithology of the gravels support this conclusion. The low relief landscape with isolated

Photo 15, Stop 5. Laminar-clay interbeds with couplets sand and gravel with burrows.

Photo 16, Stop 5. Detail from a nearby pit west of Chatsworth showing crevasse splay deposits which are part of an upper-delta plain. Note coarse-grained, poorly-sorted avalanche facies and climbing ripples near the top of exposure (under the feet of the person in the photo). These represent wanning current-velocity deposits. The crevasse splay sediments are bounded by surrounding peaty backswamp deposits.



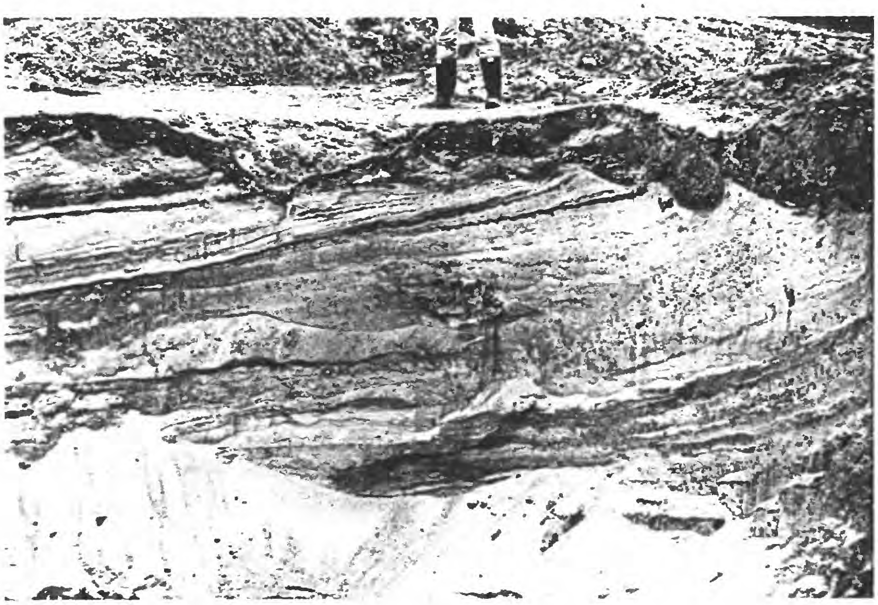


Photo 17, Stop 6. Complex of yellow colluvial/alluvial cherty, quartz gravels overlying the marine facies of the Cohansey Formation. Gravels have been reworked and concentrated from the delta-front facies of the Cohansey Formation. These weathered surficial deposits were deposited in broad valley bottom land but now cap low ridges and upland slopes as a result of topographic inversion.

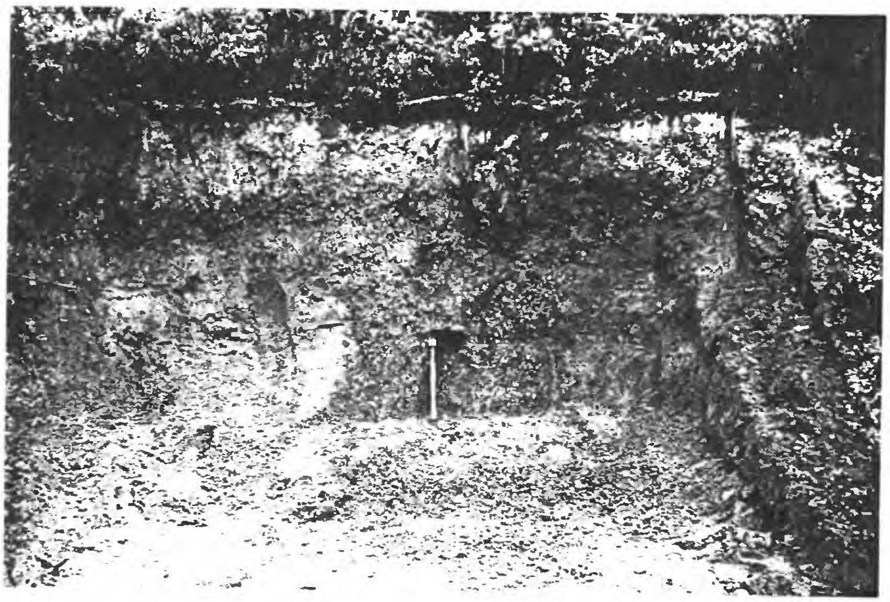
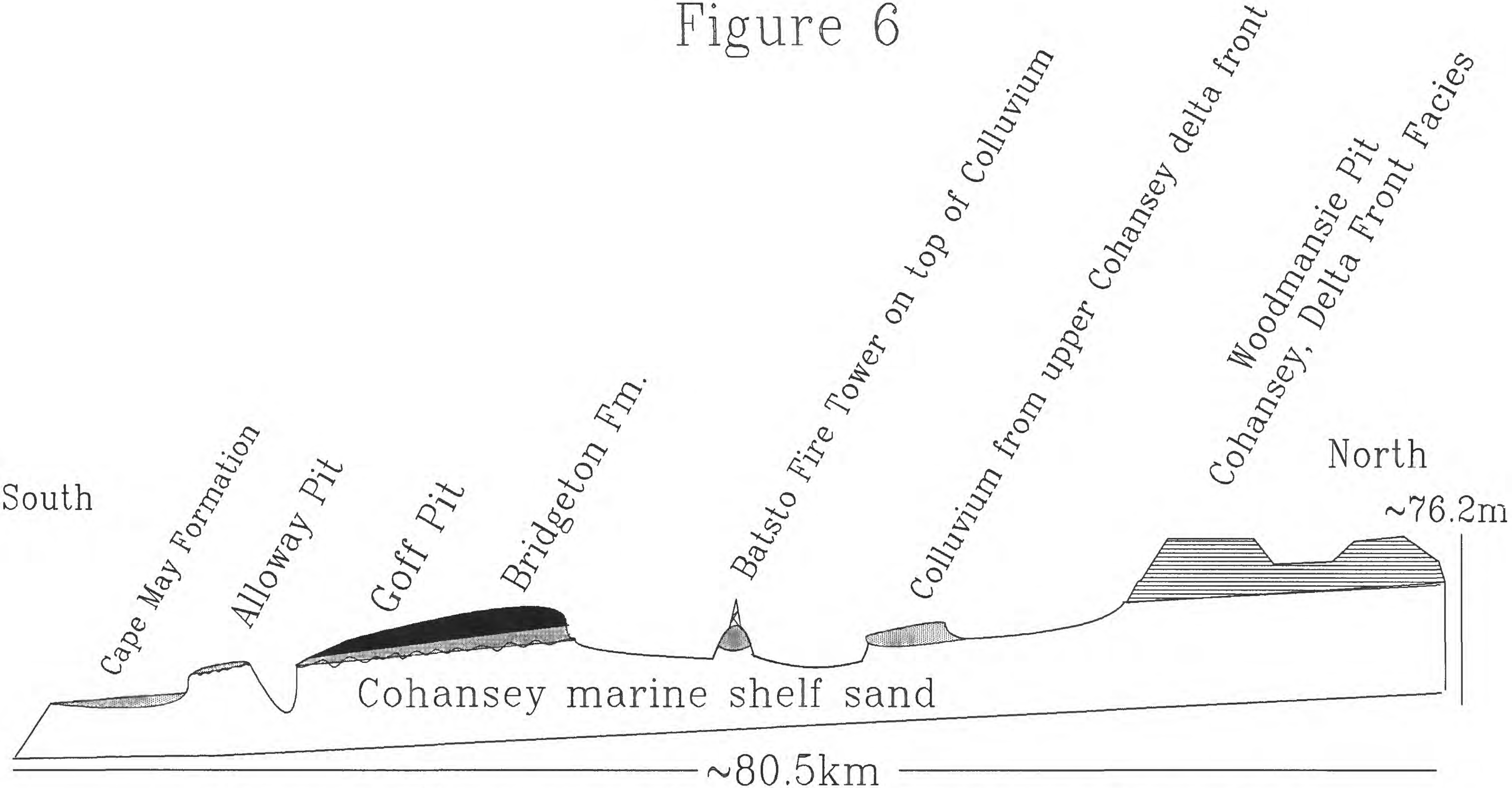


Figure 6



Diagramatic composite geologic cross section from Woodmansie to Cape May (North to South) erosional remnants capped by colluvium and alluvium indicates that an extended period of erosion has taken place. Some of these erosional remnants show as much as 24.4m (80ft) of local relief.

149.85 After stop 6, retrace steps back toward Batsto and head west on Route 542 into Hammonton, turning right onto Route 30. After a short distance turn left into the Hammonton Motor Inn.

157.68 **Hammonton Motor Inn, end of the First day**

Second Day Road Log and Stop Descriptions

0.0 8:00 am. Trip begins at the Hammonton Motor Inn. Turn right out of the parking lot heading southeast on White Horse Pike (U.S. Route 30). We are proceeding down the dipslope of the Bridgeton plain (intermediate upland), descending off the Tertiary plateau onto the Quaternary marine-littoral deposits (Units of the Cape May Formation). Continue to the Garden State Parkway and head south on the Parkway exiting at exit number 30. Proceed on Route 9 south across the mouth of the Great Egg Harbor River into Palermo. You are now on top of the "Seaville Bar". (Stop 7A) a relic geomorphic feature cored with the oldest unit of the Cape May Formation, Cape May 1.

34.56 **Stop 7A, Seaville Bar at Palermo.**

This stop is an introduction to the Cape May Formation. Three estuarine, barrier-bar, near-shore marine units constitute the outcropping, Pleistocene, Cape May Formation. The Cape May Formation cores the entire Cape May Peninsula. At the Seaville bar locality, a seaward dipping foreshore facies of the oldest unit in the Cape May Formation (Cape May 1) is exposed (Photo 18). The unit is composed of packages of interbedded planar to lunate megaripples of coarse to fine sand. Locally, burrows and ghosts of surf clams, (Spisula) are present. Mineralogically, the Cape May Formation is a cherty quartz sand with a mature heavy mineral suite consisting of zircon, rutile, and tourmaline suggesting that the sediment source for the Cape May Formation is reworked Cohansey and Bridgeton sediments from the uplands to the west. The friable clasts in the Bridgeton, including Triassic, Jurassic, and Paleozoic sandstone clasts have not been observed in the Cape May suggesting that labile minerals and clasts were obliterated as a result of reworking prior to the deposition of Cape May Formation.

34.56 Continue south along Route 9 for a few miles and turn right onto Route 50 heading northwest across the Great Cedar Swamp. This deeply eroded valley in the Cohansey Sand is filled with Holocene sediments, peat, and old cedar trees; some of the trees were formerly mined for shingles. At Tuckahoe take a sharp left and proceed south on Dennisville Road to stop 7B which will be on the right.

Photo 18, Stop 7A. Jerry Camp's Pit near Palermo. Exposure in oldest Cape May unit (CM1) in the top of the Seaville Bar. The elevation of the bar is 30 ft. above present sea level. Note the long, gently seaward dipping shoreface beds suggesting an outer planer environment of deposition.

46.17 Stop 7B Tuckahoe Sand and Gravel (Pits east of Woodbine)

Pits east of Woodbine show excellent exposures of the Bridgeton Formation. At the Tuckahoe Pit, large well-sorted gravel deposits form channel fills which have been extensively mined. The fluvial characteristics of the Bridgeton are well displayed at this locality. Originally, deposits underlying this surface were mapped as a fluvial deposit of the Cape May Formation. However, the deposit is slightly higher than the Seaville Bar and is an arkosic, coarse-grained fluvial sand and cherty-quartz gravel (Figure 7 and 8). The deposit contains a variety of lithologic clasts such as Paleozoic and Mesozoic clasts indicative of the Bridgeton Formation and not the Cape May Formation.

46.17 After Stop 7B, proceed back to Route 9 heading towards the Garden State Parkway. Proceed south to Cape May. At the termination of the parkway turn right onto Cold Spring Road passing through the intersection of Route 9. At Seashore Road turn left. Pass over the Cape May Intra Coastal Waterway and turn right just over the bridge to Stop 8.

Stop 8, Cape May Intra Coastal Waterway.

Development of the New Jersey Atlantic seaboard has diminished the abundance of exposures and outcrops. The Cape May Canal affords one of the few opportunities to examine the late Pleistocene, Cape May Formation. The outcropping Cape May Formation can be divided into three units: Cape May 1 consisting of the Seaville Bar Complex of near-shore marine sediments and planar beds; Cape May 2, which is inset in the Cape May 1, consisting of a littoral facies; and Cape May 3 which consists of low lying dissected estuarine terraces with a thin overlying layer of alluvium and colluvium. Much of the canal has been riprapped by the Army Corps of Engineers to reduce bank erosion resulting from the wake of small watercraft.

Exposures along the canal show a barrier-bar sequence with seaward dipping planar-bed facies overlying a dark greenish-gray, very fine-grained marine-shelf sand facies. The planar-bed facies or foreshore facies contain ghosts of surf clams in a moderately well-sorted medium-gray sand (Photo 19). The planar-bedded facies coarsens upward into a yellow-brown bimodal package of sediment consisting of medium sand and well-rounded disk or oblate-shaped quartz pebbles which display good imbrication. The sedimentologic character of the gravel and sand deposits reflects a gradational change in environments of deposition from the outer-rough to inner-planar environments of Clifton (1976).

The Cape May Canal also affords the opportunity to examine a cross sectional view of some of the landscape features in the Cape May area. Such features include circular depressions which are laterally extensive having diameters over several tens of meters and local relief of only a few meters (Photo 20). In cross sectional view, the depressions are underlain by complexly involuted sediments. The tabular-planar beds of the Cape May Formation are injected into the more competent overlying dark silty fine sand layer. There are ball and pillow structures as well as boudinage-like fabrics (Photo 21). Overlying the slumped and deformed sediments is a relatively thick blanket of windblown sand. The deformation and resulting depressions may be thermokarst features resulting from hydraulic piping, uplift and depression during freezing and thawing.

46.17 Lunch Stop. After stop 8 proceed southward parallel with the canal to the end of the road. Eat lunch at Higbee Beach, a restricted area which is now under the state wildlife and fish

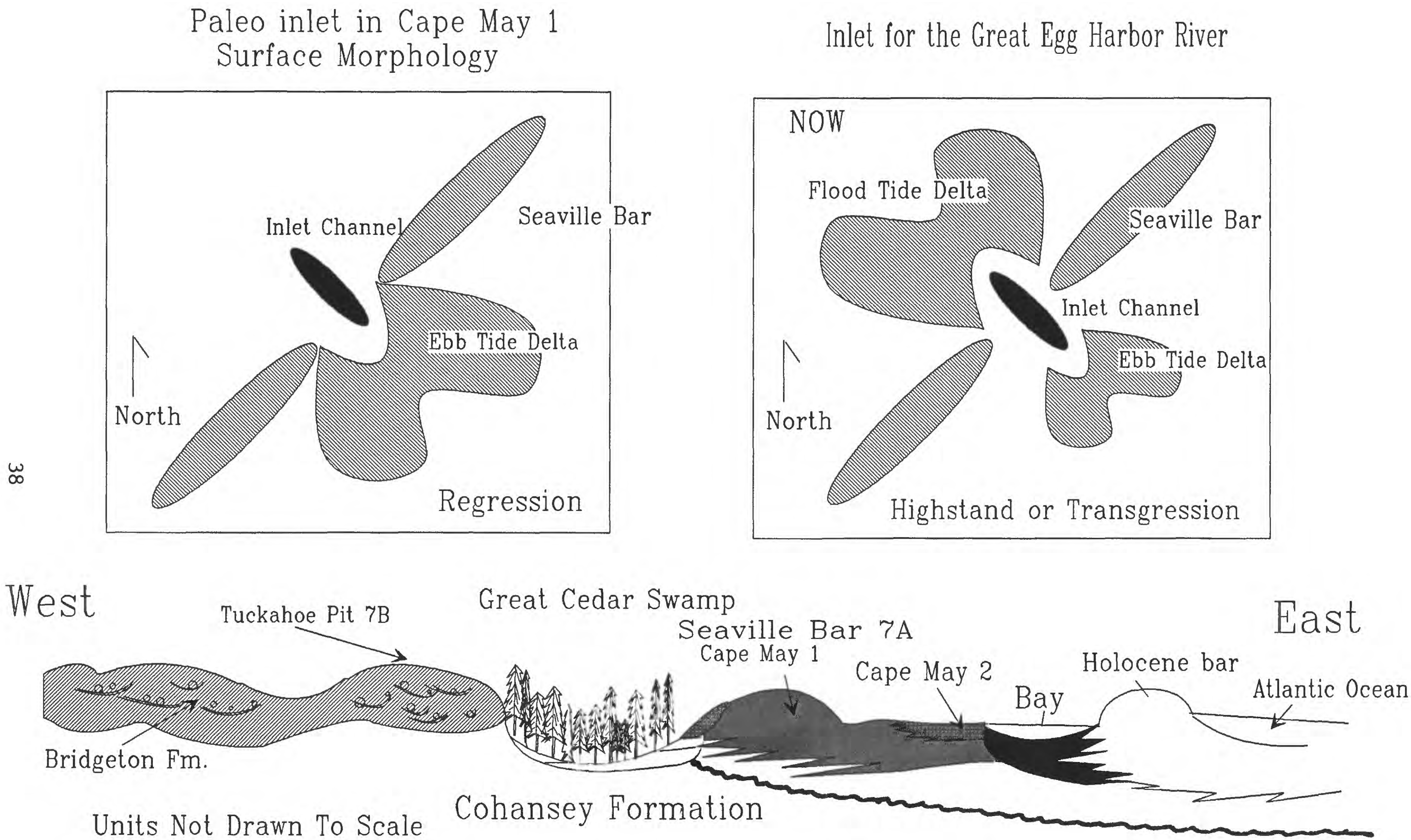
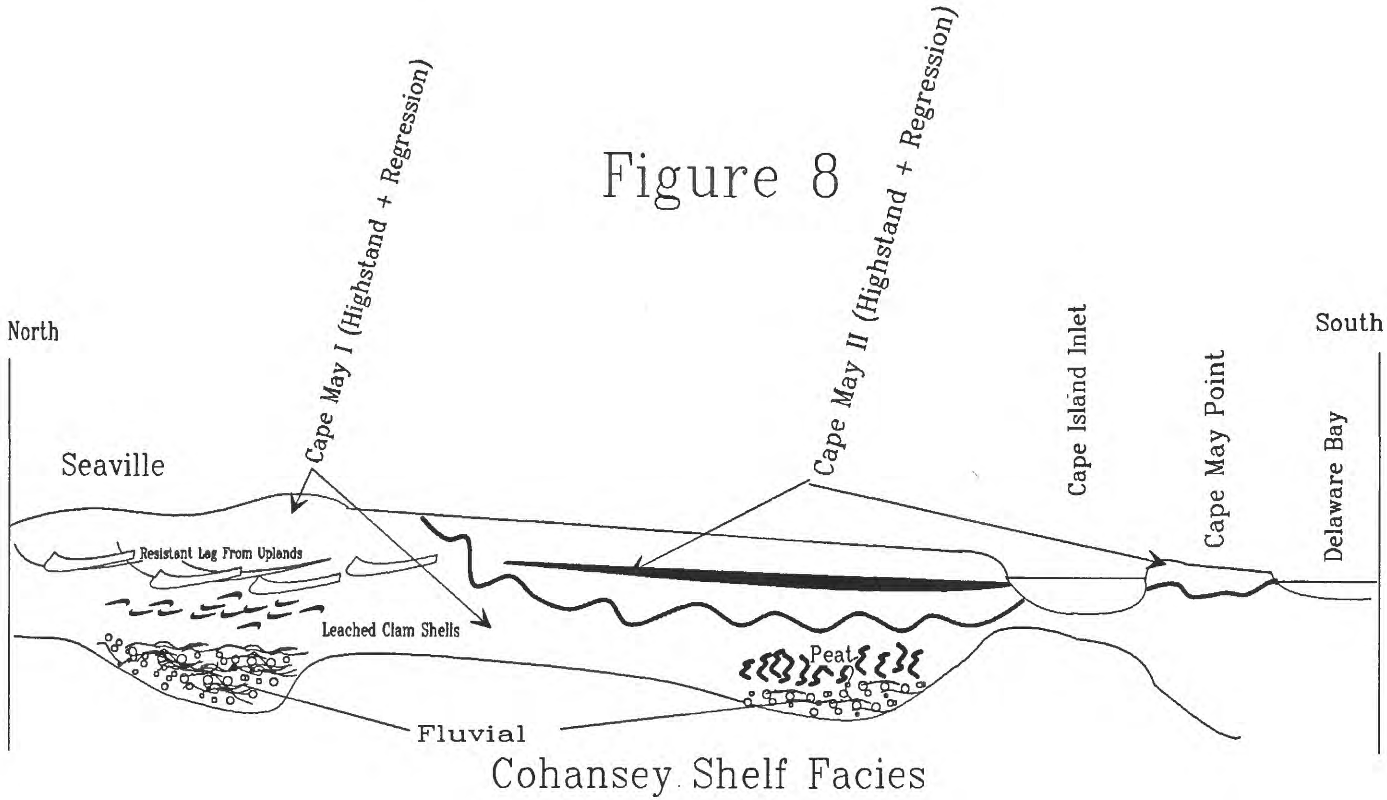


Figure 7. Schematic Cross Section From Seaville to Atlantic Ocean

Figure 8

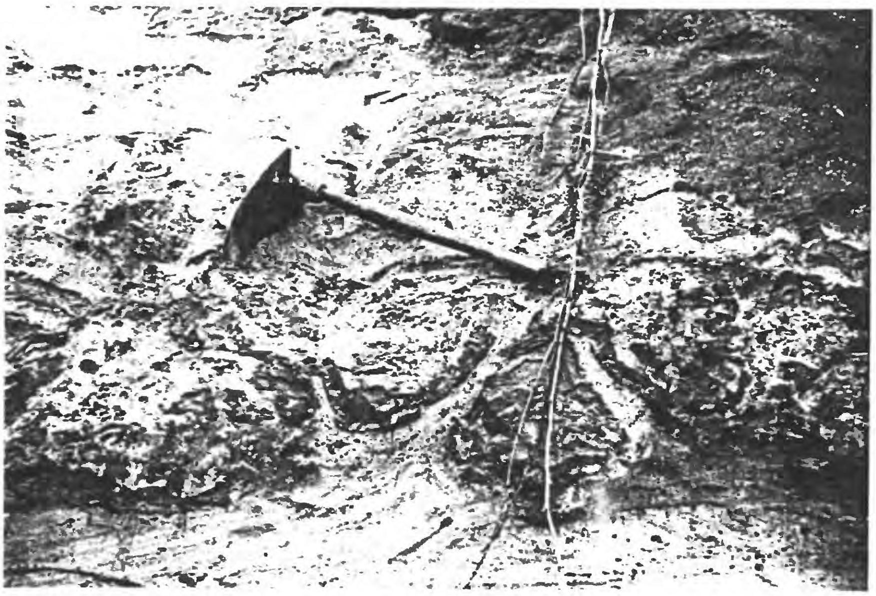


Schematic Geologic Cross Section Showing the Distribution of Facies
From Seaville to Delaware Bay
Not Drawn To Scale

Photo 19 , Stop 8. Detail of the Cape May II littoral facies over Cape May I. Note ghosts of Spisula (surf clam) and rip-up clasts of Cape May I which consists of planar well sorted medium-fine sand with abundant heavy minerals.

Photo 20, Stop 8. Aerial view of a closed depression in the Cape May vicinity.

Photo 21, Stop 8. Detail of soft-sediment deformation in core of closed depression.



management program. Excellent exposures of Holocene beach deposits can be seen. This stop provides an opportunity to see the interaction between erosion and stabilization by vegetation during the ongoing Holocene sea-level rise.

After eating lunch head back to Route 9 and proceed north. Turn right onto Route 47 and head northeast. Bear left off Route 47 onto Route 548 (west). Cross over the Maurice River. The Commercial Township Dump (Stop 9) is on the right side of the road just east of Haleyville. Note views of marsh and tidal creeks.

69.05 **Stop 9, Commercial Township Dump**

At the township dump, three pits expose materials at the top of the hill, middle of the slope, and at the toe of the scarp. The top-most pit exposes the Bridgeton Formation. The mid-slope pit reveals colluvium over Cohansey Formation and the toe of the scarp exposes colluvium and estuarine terrace sediments (late Pleistocene) overlying the Cohansey Formation. Windblown material locally caps the profiles (Figure 9).

The Bridgeton Formation at the top of the hill overlies the Cohansey, and is a highly weathered, interbedded-coarse sand and fine-pebble deposit. The interbedded nature of the deposit is accentuated in outcrop as a result of the weathering and the accumulation of fine-grained interstitial material in the fine-sand beds and the absence of similar material in the coarser beds. Most of the chert clasts are corroded and friable, as are the other weatherable clasts such as Mesozoic red-shale and Paleozoic sandstone clasts.

The Cohansey Formation is well exposed at the mid-slope pit and displays a laminated, planar-bedded clay-silt to medium reddish-brown to gray sand facies. Overlying the Cohansey is a .1m to .9m thick layer of colluvium which is characterized as massive dark-brown to yellowish-brown, poorly-sorted, silty, coarse sand. A stone line separates the underlying Cohansey Formation from the overlying colluvial deposits. The clasts which comprise the stone line are up to 6cm in diameter (Photo 22, and 23).

In the lowest pit, the Cape May III of the Cape May Formation is exposed (Photo 24). The unit is a loose, light-colored crossbedded sand which underlies the toe of a scarp facing Delaware Bay. In Maryland, Owens and others (1979) characterized a similar unit, the Kent Island Formation, as an estuarine unit which was deposited at a time when sea level was higher than it is now. Surficial deposits overlie both the Kent Island Formation and Cape May III. The colluvium overlying the Cohansey and Cape May III displays a chaotic fabric suggesting a debris-flow deposit.

Head Back to Hammonton along Route 47. At Port Elizabeth bear right onto Route 617 and travel north on Route 54 heading into Hammonton. At Route 30 head east and the Hammonton Motor Inn will be on your right.

105.94 **End of field trip at the parking lot of the Hammonton**

COMMERCIAL TOWNSHIP DUMP

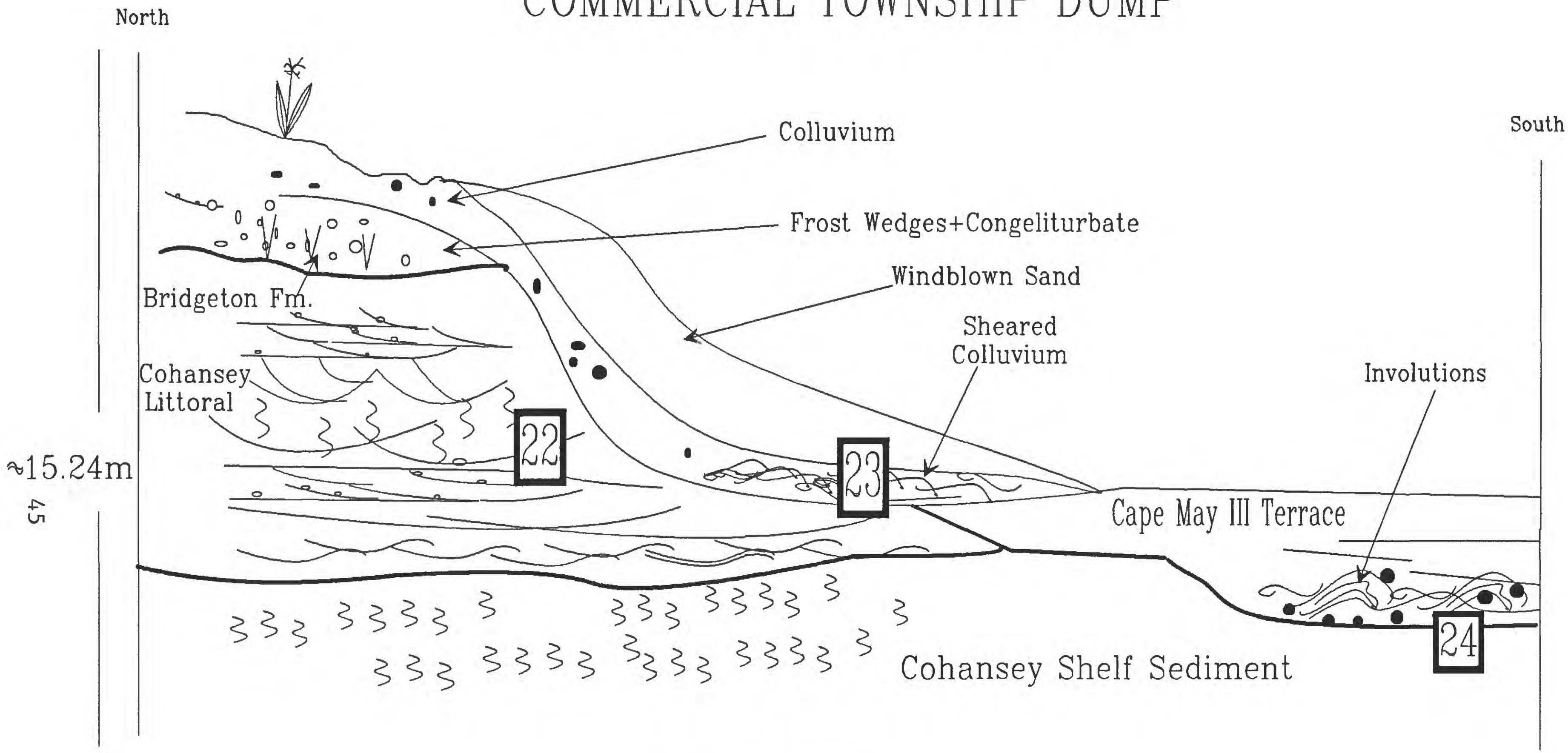
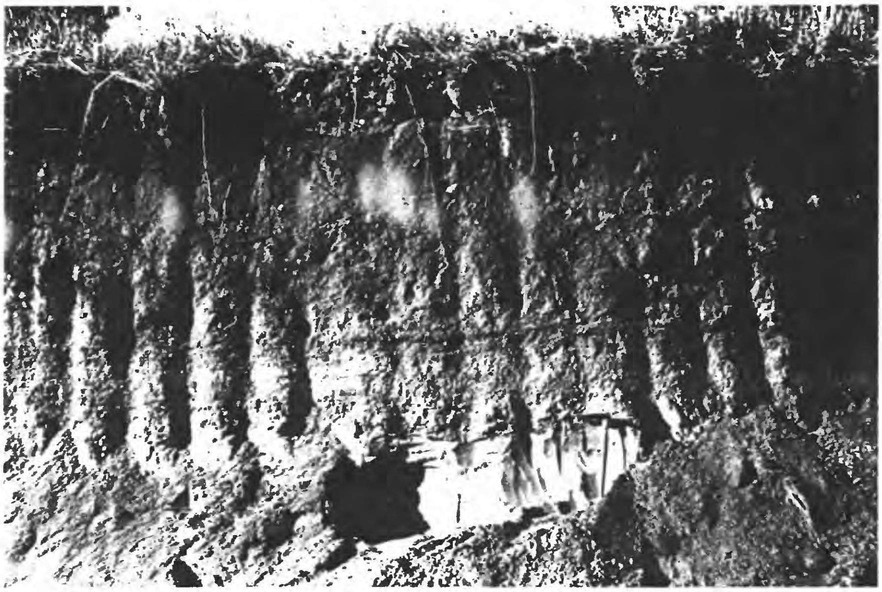


Figure 9
Schematic diagram showing deposits and location of photographs

Photo 22, Stop 9. Midway down slope, note colluvial stone line over deeply eroded weathered Cohansey Formation. The Cohansey consists of burrowed sands and gravels deposited in intertidal channels with flasers and laminated clay beds. Overlying stone line is .3m of windblown sand with a very young soil profile developed on it.

Photo 23, Stop 9. Congeliturbated sediments showing flame structures and shearing in colluvium at the toe of scarp. Colluvium was derived from both Bridgeton Formation Cohansey Formation.



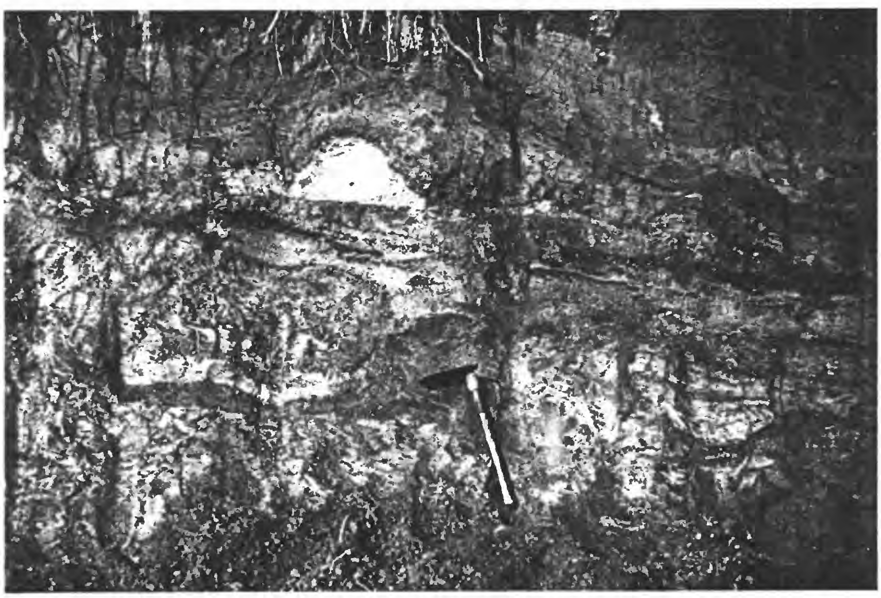


Photo 24, Stop 9. Involutions in estuarine terrace sediments of Cape May III inset in the underlying Cohansey Formation.

Selected Bibliography

Brown, P.M., Miller, J.A., Swain, F.M., 1972, Structural and stratigraphic framework and spatial distribution of permeability of the Atlantic Coastal Plain, North Carolina to New York: U.S. Geological Survey Professional Paper 796, pp. 1-79.

Carter, C.H., 1978, A regressive and barrier protected depositional environments and geographic setting of the Late Tertiary Cohansey Sand: Journal of Sedimentary Petrology, v. 48, pp. 933-950.

Clifton, H.E., 1976, Wave-formed sedimentary structures- a conceptual model. In Beach and Nearshore Sedimentation (Ed. by R.A. Davis Jr. and R. L. Ethington), Special Publication Society of Economic Paleontologist and Mineralogists, 24, Tulsa 7.2.3., pp. 126-148.

Flint, R.F., 1971, Glacial and Quaternary Geology: John Wiley and Sons, New York, pp. 892.

Isphording, W.C., 1970, Petrology, stratigraphy and redefinition of the Kirkwood Formation (Miocene) of New Jersey: Journal of Sedimentary Petrologists, v. 40, n. 3, pp. 986-997.

Johnson, M.E. 1950, Revision of Lewis, J.V., and Kummel, H.B., 1912, Geologic Map of New Jersey: New Jersey Department of Conservation and Development, Atlas sheet 40.

Kummel, H.B., and Knapp, G.N., 1904, Part II, The stratigraphy of the New Jersey Clays: New Jersey Geological Survey Final Report, v. 6, pp. 117-204.

MacClintock, P., and Richards, H.C., 1936, Correlation of late Pleistocene marine and glacial deposits of New Jersey and New York: Geological Society of America Bulletin, v. 47, n. 3, pp. 289-338.

MacClintock, P., 1943, Marine topography of the Cape May Formation: Journal of Geology, v. 51, no. 7, pp. 458-472.

Maher, John C., Applin, Esther, R., 1971, Geologic framework and petroleum potential of the Atlantic Coastal Plain and Continental Shelf: U. S. Geological Survey Professional Paper 654, pp. 1-98.

Mixon, R.B., 1985, Stratigraphic and geomorphic framework of the uppermost Cenozoic deposits of the southern Delmarva Peninsula, Virginia, and Maryland: U.S. Geological Survey Professional Paper 1067-6, pp. 1-53.

Owens, J.P., and Denny, C.S., 1979, Upper Cenozoic deposits of the Central Delmarva Peninsula, Maryland, and Delmarva: U.S. Geological Survey Professional Paper. 1067A, pp. 1-28.

Owens, J.P., and Minard, J.P., 1979, Cenozoic sediments of the lower Delmarva Valley and northern Delmarva Peninsula: U.S. Geological Survey Professional Paper 1067D, pp. 1-47.

Owens, J.P., Gonzalez, V., Sugarman, P., Paulachok, G., and Ager, T., Bybell, L., Poore, R., (in press) Stratigraphy of the sediments in a 945 foot corehole near Mays Landing in the southern New Jersey Coastal Plain: U.S. Geological Survey Professional Paper.

Richards, H.G., 1944, Notes on the geology and paleontology of the Cape May Canal, New Jersey: Notulae Naturae, no. 134, Academy of Natural Sciences Philadelphia, pp. 1-12.

Salisbury, R.D., 1898, Report on surface geology, in: John Smock , State Geologist Annual Report of the new Jersey Geological Survey, Trenton, New Jersey, pp. 1-41.

Salisbury, R.D., and Knapp. G.N., 1917, The Quaternary Formation of southern New Jersey: v. 8 of the final report series of the state geologist, New Jersey Department of Conservation and Development, pp. 1-218.

Soil Survey, 1969, Soil Survey of Salem County, New Jersey, U.S. Department of Agriculture and New Jersey Agricultural Experiment Station, pp. 1-80.

Stuiver, M. and Daddario, J.J., 1963, Submergence of the New Jersey Coast, Science, v. 142, pp. 951.

U. S. Geological Survey, 1983, Water Resources data for New Jersey, vol. J, Atlantic Slope Basins, Hudson River to Cape May: U.S.G.S. Water-Data Report, NJ-79-1, pp. 152.

Wolfe, J.A., and Poore, R.Z., 1982, Tertiary marine and non marine climatic trends In J. C. Crowell and W. Burger, eds., Climate in Earth History, Studies in geophysics: National Research Council, Washington, D.C., pp. 154-158.