Geology of the Williamsburg Peninsula

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by Joseph Kent Roberts

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Introduction

This brief report summarizes the more significant geological features of a region, which is known as the Williamsburg Peninsula, a region of intense interest to the public, since it may be said to be the "Cradle of the Republic". This region lives in history because on every hand, it bears evidences of the hardships undergone by the early English settlers and their struggle have been told in the classroom, in song, and in romance. All of this story is interesting for the birth of a state and nation is no better seen anywhere. Of this same region there are records to be read of its changes through vast periods of time with regard to land and water relations, of plants and animals, which lived upon the land, along the shores and in the ocean, of materials accumulated by natural agents or in brief, its geological history. The reader will probably wonder how this long buried past can be made to talk and unfold all the changes of organic and inorganic nature,

which have transpired during a long expanse of time. Some years ago a noted Scottish geologist, Sir Charles Lyell, called the attention of his contemporaries to the fact that the present must be used in our interpretation of the past. So, what we know of the present day conditions, we can apply these to the past and gradually work back to those more remote periods. It is true we do not know every detail of physical and other changes of these past periods & probably never will know, but in the main we can understand the broad changes which have taken place if we know how to recognize marks left as records or witnesses of the past.

Location of the Area. —

The Peninsula from Newport News to the "Fall line", or the contact of the Coastal Plain with the Piedmont, embraces the following counties: Elizabeth City, York, Warwick, James City, Charles City, New Kent, & portions of Henrico and Hanover. Only the four lowermost counties of the peninsula will be considered in this report, namely Elizabeth City, York, Warwick, and James City.

The major axis of the peninsula extends in a

County	Area (Sq. miles)	Date when formed
Elizabeth City	54	1634
York	136	1634
Warwick	69	1634
James City	164	1634
New Kent	191	1654
Charles City	188	1634
* Henrico	280	1643
* Hanover	512	1720

Scope of the Report:

This report has to do with the geology of Elizabeth City, York, Warwick, and James City Counties. The geology will be considered from the standpoints of the topography and its effect upon the civilization, the kinds of sediments exposed in the region, their composition, the remains of life or fosils, and whatever may be of economic worth in the way of mineral resources.

The earliest reference of any note on the geology of the lower peninsula is that of Benjamin Lincoln in 1783. There have been many short references to the geology of the region, but the first studies of any note were by William B. Rogers,

* western portion not in the Coastal Plain but the Piedmont.

The city of Richmond lies partly on the Coastal Plain & partly on the Piedmont. The Fall line may best be known in Virginia as the point where the tides stop thus giving the name, "Tidewater" to eastern Virginia. Navigation up the larger streams to the Fall line was very important for the first two hundred years of colonial life and it is only within the last quarter of a century that such transportation has shown a rapid decline.

Drainage of the Region: The drainage of the Peninsula is rather simple in pattern. The region is bordered by the York and James Rivers respectively on the north and south, which are the master streams of the country. The James River takes its source west of the Blue Ridge. In its course it receives numerous small tributaries and after passing over the Fall line at Richmond it is navigable from that point to its mouth. In former days a canal connected Lynchburg with Richmond along the James River. The James is a fine example of an antecedent stream; it cuts through the Blue Ridge at Balcony Falls as does the Potomac at Harpers Ferry. In its upper course it is most likely a pirate stream, while in its lower course it is a good example of a drowned stream to Richmond.

The amount of fall in the James River from Richmond to its mouth is very small, and salt water extends far up its course. It has developed many curves and floodplains of large sizes. Along the lower part of the Peninsula the approximate widths for the James River at certain points are as follows:

Mouth of the Chickahominy River	3.5 miles
Jamestown Island (Ferry line)	2.5 "
King's Mill (Old Wharf)	2.3 "
Carter's Grove	2.8 "
Fort Eustis Wharf	2.0 "
Burwell Bay	5.7 "
Mouth of Warwick River	3.7 "
Newport News	3.2 "

The York River is a very different kind of a stream compared to the James. Instead of being an antecedent stream, that is, having its source west of the Blue Ridge & cutting as fast as these mountains rose, it rises to the east, and is a fine example of a consequent stream in its upper course or two main tributaries & a drowned stream from near West Point to the Chesapeake Bay. It takes its source in the Piedmont and is formed by the confluence of the Mattipony and Pamunkey Rivers at West Point. Its water is clear and saline far up its source. It accommodates shipping as far as West Point.

This stream shows no meanders and not many floodplains. Neither the York nor the James Rivers have many abandoned bluffs and what few exist are not very far from the present river shores. The York is a narrow stream compared to the James as shown in the following cross sections:

New Kent - James City County line ---------- 1.8 miles
Mt. Folly ---------- 1.5 "
Skimmino Creek ---------- 2.0 "
Queen Creek ---------- 2.2 "
U.S. Navy Mine Depot (Sandy Point) ---- 1.3 "
Yorktown - Gloucester Point ---------- 0.5 "
At Chesapeake Bay ---------- 2.5 "

No better harbors are known in American waters than Hampton Roads, the Chesapeake Bay, and the York River. This was very well brought out in the late war and in the war between the states. The York River at Yorktown has a depth of something like 80 feet in its main channel, and the U.S. Navy has a Mine Depot one mile above Yorktown and a fueling station two miles southeast. The James River accommodates large war vessels far up the river and during the war between the states one of the main confederate navy yards was located at Richmond.

There are many small streams on the peninsula most of which are short and

of a swampy nature in most of their courses. The small streams flowing into the James River are Powhatan, Mill, College, Skiffs, Potash, Deep, and Watts Creeks and the Chickahominy and Warwick Rivers; into the York River are Ware, Taskinas, Scimmino, Carter, Queen, King, Felgates, Yarmley, Back, and Cheesman Creeks, and Poquoson and Back Rivers.

<u>Relief and Terraces:</u> The Peninsula is well peneplained and nowhere is the elevation beyond 150 feet and the average is far under this figure. On the basis of elevation the Peninsula may be divided into a lower portion comprising Elizabeth City County, most of Warwick and about half of York Counties; the upper portion comprises parts of Warwick and York and all of James City County. The average elevation of the lower portion is around 25 feet & that of the upper portion from 60 to 75 feet.

This region of the state is widely known as Tidewater Virginia. There are many acres of marsh and mud flats in Elizabeth City County and to a less extent in Warwick and York Counties. These mud flats are covered by water at high tide and represent a third level, and one which will become land in time. Vegetation has taken hold on many of these flats and is converting

In the study of the geology of the Coastal Plain of Virginia we find that the Upper Cretaceous and Oligocene have no areal representation. Apparently sediments of Upper Cretaceous have been found in deep wells at Old Point Comfort and Norfolk but nowhere have outcrops been found. Nowhere in Virginia have deposits of Oligocene age been found either in outcrops or well records; this holds true for the Coastal Plain except Florida, and portions of the Gulf embayment.

Miocene Deposits:

In the four lower counties of the Peninsula the oldest sediments consist of sand, clay, marl, and coquina of Miocene age, most of which carry abundant fossils. The complete column is not shown in Virginia or in Maryland for the Miocene as is shown in the following table:

Chesapeake Group.
- Yorktown formation - exposed in southeastern Virginia + equivalent to Duplin formation of Coastal Plain of North Carolina.
- St. Mary's formation - occurs over much of the Coastal Plain of Virginia.
- Choptank formation - chiefly restricted to Maryland but known to occur in the northern portion of Virginia.
- Calvert formation - exposed as a belt near the Fall line.

St. Mary's Formation: This formation was named by Shattuck (1902) from exposures in St. Mary's County, Maryland. The St. Mary's is the oldest Miocene formation exposed in the lower counties of the Peninsula. It is reported to lie conformably upon the Calvert near the fall line where the contact is exposed. The basis for the recognition of the St. Mary's formation in Virginia is mainly the fossils contained in the beds, and subordinate reasons are the position and the composition of the beds.

The St. Mary's formation is very well exposed at Mt. Folly, James City County on the York River, nine miles southeast of West Point. The region around Jamestown Island is mapped as St. Mary's but there is nothing in that particular there to know it is of that formation.

The St. Mary's formation is composed of sand and clay and certain beds carry a greensand. As a general rule fossils are abundant but they are extremely scarce in the lower part of the Peninsula. The sand of this formation is usually gray but often stained by iron oxides. In some localities certain beds of sand are consolidated into a rock of considerable strength; the cementing agent is hydrated iron oxides,

examples of such consolidation may be seen a short distance southeast of Mt. Folly in James City County. The sand grains down to a certain size are well rounded. The texture is fairly uniform ranging from fine to coarse. Occassionally gravels occur scattered through the beds but not collected in layers. The sand runs high in the percentage of quartz, most of which is transparent, some milky. The only fossils found at Mt. Folly are the genera of Melina and Venus, near the bottom of the section. There is so much talus in this section that collecting is very poor.

The interbedded clay of the St. Mary's is a blue to gray and unconsolidated except in a few layers near sand-clay contacts. The texture is uniform and smooth except for a few fragments of molluscan shells. Water often flows out at the sand-clay contacts where the clay is the bottom member. The clay is well bedded & the beds range upwards of three feet in thickness. The clay weathers into small blocks and the iron oxides impart to it a yellow to yellowish brown color.

Another common sediment over the state is shell marl in the St. Mary's formation but this facies does not occur on the Williamsburg Peninsula in James City County or in any of the region east of this county.

This marl has been used in some sections for agricultural purposes. Nearly one hundred years ago William B. Rogers reported the occurrence of greensand in the vicinity of Williamsburg and Clark, Miller, and Berry in their report regarded it as being in the St. Mary's formation. A small thickness of green colored sand occurs one mile southwest of Williamsburg on the Jamestown Road but this exposure contains fossils of the Yorktown fossils.

Section at Mt. Folly, James City County

Soil, reworked sand, grayish color - - - - - - - - - 2-3 ft.

Sand (Pleistocene and Recent) yellowish brown, medium to coarse texture, no fossils, no apparent bedding, vertical fractures - - - - - - - - - - - - - - - - 18 ft.

St. Mary's formation

Sand with subordinate amounts of clay. Sand of fine to medium texture upper portion brown + lower portion light gray + spotted - - - - - - - - - - - - - - - - 45 ft.

Gray sand, fine to medium grained containing Melina and Venus, usually covered by talus - - - - - - - - - - - - 20 ft.

Yorktown formation: The name for this formation was proposed in 1906 by W. B. Clark and B. L. Miller from Yorktown where fosil beds of this formation are exposed. No more appropriate name could have been chosen because along the South bank of the York River above and below Yorktown and especially below the town, the best exposure of this formation is found. This point has been the favorite collecting ground for Tertiary geologist for the past one hundred years. Many students have taken trips here in past years. In the last five years the writer has taken over five hundred students and visitors to Yorktown for collecting and seeing the great river bluffs.

The Yorktown formation extends from Mathews County southward to the state line and into North Carolina where it becomes known as the Duplin formation. Of the four counties of the Peninsula under consideration this formations has exposures in York, Warwick, and James City Counties, and in Elizabeth City County the beds pass beneath those of later age. By far the best exposures occur along the York and James Rivers. There are very few outcrops

between these two rivers due to the younger deposits covering the Yorktown.

The sediments which make up the Yorktown beds consist of coquina, sand, clay, sandy clay, and marl, some of which in varying degrees of consolidation. The thickness of the entire formation does not exceed 150 feet, and the beds slope towards the east and strike about north and south. The main differences between the Yorktown and the older Miocene beds lying to the west is the occurrence of coquina, subordinate amounts of sand, and certain fossil faunas restricted to the Yorktown.

The coquina member is around fifty feet in thickness, and stratigraphically occurs well up in the formation and between abundantly fossiliferous members. The term, coquina, is of Spanish origin and means shell. It is made up of finely broken or worn marine molluscan shells, a few of which are preserved in surprisingly good detail. It is cemented together by calcareous material and colored by iron oxides, the latter taking some part as a cementing agent. At times it forms a very resistive rock,

Section 2 Miles southeast of Yorktown on the York River

Sand and loam, reworked, no fossils ---------- 6 ft.

Sand, medium grained, yellowish brown at top, contains numerous shell fragments and is between a sand and coquina in composition. Towards the base the sand becomes green and higher in quartz, + fossils better preserved. Sharp conformable contact below with the clay ---------- 10 ft.

Clay members:

a. Brown clay few fossils and a very uneven contact with underlying blue clay due to weathering + iron oxides ------- 2 ft.

b. Dark blue clay, Many Crepidula ----- 1½ - 3 ft.

c. Medium gray clay, abundant Crepidula ------ 2½ ft.

d. Pecten Zone ---------- 6 - 8 in.

e. Blue Clay, Very abundant Crepidulas ---- 1 - 4 ft.

f. Blue clay, very few fossils, weathers to a grayish brown at top + uneven ---- 1 - 4 ft

River Edge in which there is Recent sand covering older Yorktown beds.

In certain localities along the York River and one point 1/4 mile south of Yorktown there are beds made up of almost pure fossils with very little interstitial material. Probably the most typical of all these is the deposit near the junction of Felgate Creek with the York River on the U.S. Navy Mine Depot property. Thirty-five species easy to identify occur here in a thickness of ten feet. Shell marl from this pit has been used on the Navy property for roads and it makes a very good temporary surface. The marl is not consolidated and the shells may be picked out without difficulty. The principal fossils are mollusca with corals, shark and whale remains and numerous barnacles.

Pliocene Deposits

Certain deposits of sand and gravel have long been on the Coastal Plain and to a less extent on the Piedmont and these are found to have various sediment and rocks underlying them. In the Piedmont these unconsolidated deposits lie unconformably upon the crystallines of Pre-Cambrian age, and rocks of early Paleozoic and Triassic ages. At the "Fall Line" these gravels and sands rest in unconformable manner upon the Lower Cretaceous and towards the east upon the Aquia, Nanjemoy, Calvert, St. Marys, and lastly the Yorktown formations. About three miles southeast of Yorktown these deposits pass under sediments of Pleistocene and Recent age and the same relations can be seen along the James River in the vicinity of Carter's Grove. From their position upon the youngest of the Miocene formations, it is quite certain their age is later than that of the Yorktown formation or post-Miocene. This was the reason for assigning these deposits to the Pliocene. There is always a sharp and

distinct break between these deposits and their sub-jacent formations. However, there is no sharp break at the top compared to the base and in some places there is a gradation into the Pleistocene. Hence these sands and gravels may be Plio-Pleistocene in age.

These deposits are found over most of the four counties but there are no known outcrops in Elizabeth City County. To this variable thickness of reddish brown sand and gravel the name, Lafayette, was applied by E. W. Hilgard in 1891 from what he considered the type section in Lafayette County, Mississippi. At the present time the name, Lafayette, is abandoned also several other names, and the name, Brandywine, is used by some.

On the Peninsula these deposits are mostly sand with subordinate amounts of gravel. The sand is coarse and always well rounded and usually coated with iron oxide. Bedding is not well developed but occassional cross-bedding is to be observed. Quartz is high with varying amounts of feldspar and other Piedmont minerals. Iron oxides occur as a very thin coating, and

being opaque, the percentage seems to be highly. It probably never exceeds six per cent. There is not a trace of fossils in any of the sand. Thin layers may be indurated by iron oxide as a cementing agent.

The best exposures occur east of Williamsburg and also one mile to the west on the Jamestown road. A good exposure occurs at Mt. Folly on the York River, and one at Carter's Grove on the James. All of these exposures show little or no gravel, and so far observed the gravels are never over a foot thick. They are always rounded and of about the same composition as the sand. In size they range up to as much as two and three inches and cobbles are common. The average is probably under an inch & some are flattened. Like the sand they contain no fossils of the age when they were accumulated. Some on being broken open show Paleozoic bryozoan brachiopod, and coral fragments. From the standpoint of origin these deposits are most likely due terrace conditions and are not marine.

Pleistocene and Recent Deposits

The Pleistocene deposits, commonly known as the Columbia group, on the Peninsula comprise bedded sands, clays, and loam though elsewhere on the Coastal Plain gravels occur. Earlier geologists divided the Columbia group into the Sunderland, Nicomico, and Talbot, the latter two of which occur on the Peninsula. It is impossible to separate them except lithologically as no fossils have been found in any of them.

The Pleistocene deposits are best exposed southeast of Carter's Grove on the James River in bluffs from five to twenty-five feet high consisting of interbedded sand and clay, and above Kings Mill wharf on the same river. One other good exposure is at old Bellefield on the Navy Mine Depot property where the entire thickness is a clay and sandy clay.

The Pleistocene sand is a light gray + very high in quartz. It carries small amounts of rounded grains of magnetite, concentrates of which occur in large amounts along the bottoms of the bluff at water edge.

The sand is of medium to fine texture & contains considerable clay. The clay is light to medium gray when dry & quite plastic when wet. It contain abundant plant fragments but in such a comminuted condition they could not be determined. All observed are carbonized.

The deposits of Recent age are largely limited to Elizabeth City County, to a smaller extent Warwick and York Counties, and the many swamps and small streams between the two large rivers. These deposits consist of gravels, sands, and muds formed under three sets of conditions, namely, marine, swampy, and fresh water. Under conditions marine the numerous mud flats are being formed and along the York and James rivers. Along the smaller streams muds are being deposited and in the swamps vegetation is accumulating.

The clays or muds are extensive in the floodplains though not very thick. They are usually light colored and quite plastic. The chief coloring agent is organic matter and some iron oxides. The sands are gray and fairly clean. Recent sediments occur in all the Counties, more along the rivers and towards the end of the Peninsula.

Types of Fossils: As above stated, the majority of fossils of the Yorktown formation are molluscan, but there are others, representatives of most all the invertebrate and some of the vertebrate groups. Clark and Miller in their study of the fossil faunas followed closely the Maryland work, which is necessarily close to the Virginia faunas. They determined and arranged the species by phyla to some extent, and others have been entered by the writer. There are many micro-faunas which the collector passes over in the field; these are abundant in some zones.

	No. of Species
Vertebrata:	
Mammalia	2
*Pisces	1
Arthropoda:	
Malacostraca	1
Cirrepedia	1
*Ostracoda (at least)	5
Mollusca:	
Pelecypoda	92
Gastropoda	60
Scaphopoda	2
Molluscoidea:	
Brachiopoda	1
*Bryozoa (at least)	2

Polynices heros — Plate II, Fig. 10.

1 - Opening about semi-circular and white on inside.
2 - Deep conical opening (umbilicus) at side of the opening.
3 - Spire low but distinct + height slightly exceeds the diameter.

Septastrea marylandicus — Plate II, Fig. 15.

1 - Individuals (corallites) measure 4 to 8 m.m. + are closely packed together & not separate as in Astraugia.
2 - The individuals are five or six sided.
3 - Individuals form large colonies some as much as two feet in length.

Serpula fistula — Plate I, Fig. 9.

1 - Tube-form, slightly curved but never coiled.
2 - Walls up to 3 m.m. thick + internal diameter up to 8 m.m.; length of tube at times 4 inches.
3 - Tubes usually soft and easily broken, + white colored.

Turritella variabilis — Plate I, Fig. 13.

1 - High and graceful spire + very sharp.
2 - Each revolution (whorl) enlarged towards base and shows two or three ridges + flattened in middle.
3 - Opening about circular and no depression near the mouth.

Kinds of Mineral Resources — Mineral Resources

The mineral resources always command first line interest in the eyes of the people of any region. The people of this portion of the state were interested in the mineral resources long before the days of Rogers. Before the days of the revolution the settlers of the peninsula country were operating crude smelters. Shortly after the settlement we read of their sending a considerable quantity of the yellowish ferruginous clay to England thinking it contained gold. It may be stated in the beginning that there is little of metallic resources even in the entire Coastal Plain of Virginia. The main resources are sand, gravel, clay, and marl, with small occurrences of limonite, magnetite and other minerals of scientific interest among the sediments.

Sand: There is probably not a square mile on the peninsula which does not contain sand, as this is the most widespread of any one kind of sediment. Comparatively small amounts of sand occur in the exposures of Yorktown age. Most of the St. Marys formation in James City County is composed of sand. The next younger deposits, the old "Lafayette," is largely sand with occassional gravel. The Pleistocene carries an abundance of sand

while the Recent shows large amounts.
Sand has many uses in industry but the sand on the peninsula is limited on account of certain impurities and other features. The Miocene sand is difficult to reach except in its exposures along the James & York rivers. It usually is thin bedded & contains shell fragments. Its texture is fairly uniform and very few gravels are found in it. Sand of this age has never been used to any large extent. It could be used apparently for building, engine, and molding purpose and some of the very light gray layers might be used for cheaper grades of glass. In some of the beds of the light colored sands there is very little clay.

The Pliocene (Lafayette) sands are all colored by hydrated oxides to rather a deep brownish to yellowish red. These offer little possibilities other than molding sand. These sands are found over most of James City, York, and Warwick Counties and are exposed in practically every excavation for roads, railroads, and buildings.

The Pleistocene sand is interbedded with clay and is a fine texture. Certain layers contain considerable magnetite but not enough to make the color very dark. Usually the color is very light. at present there is no use being made of these sands. They occur along the James River in James City County & along the York River in the same County & in York County.

Gravel: This very necessary modern building & road constituent is found over much of the Coastal Plain. It is found in all four lower counties of the peninsula. At present the gravel is used for road building and construction and in the past some has been used for railroad ballast. Regardless of the age of the gravel, it is largely composed of quartz, all constituents of which are rounded.

The Miocene deposits contain no commercial gravel though a few good size pebbles occur scattered through the beds. The source of the best gravels is the Pliocene and Pleistocene. In James City County several small pits have been opened from time to time for gravel. At present a pit is operated to the west of Williamsburg for road gravel, and this is from the Pliocene deposits. Sand is the dominant type of sediment in the Pliocene deposits but accasional lenses of gravel occur. Mixed with these gravels is considerable sand & the two are generally used together on roads. As pointed out by Nelson Clay with the gravel makes a very firm surface as the clay serves as a cement for the gravels.

Gravels of Pleistocene age occur in a few places and these are probably reworked from the older beds. The only difference between the Pleistocene and older gravels is the absence of the iron oxides from the younger ones. No gravels of this age are being recovered at present. Along some of the streams gravels of Recent age are to be found.

All the gravels dredged from the streams are of Recent age and some have been recovered by this means.

Clay: Clay is found over all the four counties and is the most plentiful of all the mineral resources. In age it may be Yorktown, Pliocene, and Pleistocene. All of the clay is low grade and at present it is used mostly in the manufacture of brick. It probably would make very good drain tile and low grade pottery. It was from this clay that the early settlers made their bricks for their fortifications, their churches, their homes, their capitols at Jamestown and Williamsburg and for whatever other buildings they may have had. Clay is found in all four of the counties and over the entire Williamsburg peninsula.

The Miocene clay outcrops principally N.W., & Southeast of Yorktown. It is so sandy and even the less sandy varieties are so full of fosil remains that none of them could be used. There is no record of the Miocene ever having been used. The clay is a blue to gray & most of the coloring matter is organic.

The Pleistocene clay and loam have been used quite extensively and it grades into the Recent clay to such an extent that no one would be very particular about the choice of them for brick. The Pleistocene clay makes a brick of very light color with very little red and often no red at all. The best exposures of

such clay are along the James River south east of Carter's Grove, & northwest of King's Mill, and along the York River on the U.S. Navy Mine Depot property.

The Recent clay may be found over most of the region along the smaller streams & along the floodplains of the James & York Rivers. This clay has been the main source of the bricks from the early days. This clay has been used together with Pleistocene clay in brick manufacture at Hampton, Newport News, Morrison and everywhere over the peninsula where native clay has been burned.

All of the bricks were hand-made which went into the early buildings. Most of the bricks were of larger dimension used in the old buildings. At the present there are two companies making bricks to be used in the reconstruction of old Williamsburg. The actual sites of the first brick kilns and clay pits are not known but we know that the poor means of transportation in early days prohibited hauling either the clay of clay products any great distance. It is a common story that the older brick structures of the region were made from bricks brought over from England. Probably some few bricks were imported but most of them were made in small kilns near the building sites.

There are several brick plants either operating or temporarily closed at the present time at Hampton, Newport News, & some of the smaller towns. One of the more interesting plants is that of the Pinedale Clay Products Company located about 2 miles east of the junction of the Chickahominy & James Rivers. At the present time this plant is making bricks for the Restoration of the old Masonic building at Williamsburg. All the bricks are hand made.

The clay used by the Pinedale Company is most likely of Recent age, though the lower part may be Pleistocene. It is a very plastic clay of light gray color when dry. It burns to a light red, sometimes a dull gray & the color varies with the iron content & temperature of the kilns. The clay is a floodplain deposit which was formed in a cut off arm of the river. It is quite free of grit and gravels.

The clay is taken from the shallow pit, and ground with water to a desired condition. It is then placed into hand molds, one box holding six bricks. These bricks measure when placed in the pan for drying 9 x 4½ x 2½ inches. After being air dried they are packed into the kilns for burning. The kiln capacity is 50 million bricks. The kilns are burned for one week at 2200 degrees Fahr., and allowed

to cool for one week. The loss in shrinkage is approximately 16%. This clay makes a very good brick for building and resembles the bricks of three hundred years ago. On one side the bricks are stamped in the molds, "Jamestown Collony". The amount of clay for bricks manufacture is unlimited on the peninsula. The Pinedale Company is doing some beautiful work in pottery & ceramic experiments.

<u>Marl</u>: The marl occurring at Yorktown and other places in York, Warwick, and James City Counties is of two types. One type is a very finely divided mass of shells with quite a few large shells & animal remains cemented by calcium carbonate & colored by iron oxides, which is a coquina. The other type is the more perfectly preserved shells closely packed together. Both types run high in lime though the clay and sand are quite variable.

The coquina type is used for road metal locally and to a small extent for agricultural purposes since it is high in lime. The Yorktown deposit of Coquina has been used in early days for building. Grace Church at Yorktown is built of this material and plastered outside, & inside. The marl makes a very good road though it does not wear

any great length of time. It has been used on the Navy Mine Depot grounds and the marl pit located on the York River at Wormley Creek is the largest one open at the present time.

The large bluff southeast of Yorktown was sampled and tested about 20 years ago with a view to manufacturing Portland Cement. Two plants were chartered on the Peninsula some twenty years ago, the Jamestown Portland Cement Corporation at Yorktown, & the Colonial Portland Cement Corporation at Grove. The Yorktown plant drilled a well, & made quite a few investigations preliminary to starting their factory. It was found that the alumina (Al_2O_3) was too low and the iron oxides were too high. No production was realized, and no use other than for roads has been made of the coquina. A small pit of the shell marl was opened about ten years ago one-half mile south of Yorktown. Marl from this pit was used on the land as fertilizer to a small extent.

The fortifications of Cornwallis at Yorktown were made in the coquina; the deep trenches were sunken into the coquina & the material made into the high ridges. However, on the western edge of Yorktown the fortifications were constructed out of the sand overlying the Miocene.

Artesian Water: It has been known for some eighty years that artesian conditions existed on the coastal plain of Virginia. The deep wells at Old Point Comfort, Lambert's Point and other places were the first practical ones on the Coastal Plain. At Fort Monroe a well was drilled in 1902 to a depth of 2251 feet penetrating the entire thickness of Tertiary & Cretaceous sediments and about 8 feet into the crystalline rocks. The Chamberlain Hotel well at Old Point Comfort was put down in 1896 to a depth of 945 feet, but it is too saline for use except for flushing.

There are many ordinary non-flowing wells on the peninsula. The older ones are dug wells, while the younger ones are mostly drilled. Their depths vary from fifteen to forty feet. Usually the well water is high in lime and very noticeable to the taste. Nowhere is the ground water level very far beneath the surface. Springs and seeps are fairly abundant but there are no large springs compared to those of Florida. None of the wells inland give any salt water but this is not the case nearer the Chesapeake Bay in Elizabeth City County.

Certain conditions must be present for artesian water. There must be porous sediments or rocks to receive, store, and furnish passage for the water falling upon the surface. There must be impervious material such as clay or shale above and below the porous layer in order to prevent the escape of the water upwards or downwards. The source or the point of intake of the surface water must be considerably higher than the mouth of the well, made possible by a structure sloping in one direction. Then finally precipitation must be sufficient to keep the ground water level from falling too much. The distance the well is from the source of the water, the number of artesian wells, & some other factors have effects upon the strength of water flow & the number of wells.

The artesian well drilled by the Jamestown Cement Company about 20 years ago at Yorktown was located on the floodplain of the York River about 1/2 mile south east of the Yorktown Monument. This well was something over 400 feet deep according to the best information. It flowed about five feet above the surface and a constant stream of approximately one

inch in diameter. This well continued to flow until a development company put down another one sometime about 1920. The first well stopped flowing then; now the last well flows a stream of about 3 inches in diameter. The depth of the last well is over 400 feet. During the past summer the U. S. Government Sesquicentennial authorities have put down an artesian well to a depth of something over 700 feet in order to get water for the celebration in October 1931. A more detailed account of this well will be given in a more extensive report sometime later.

In addition to the above resources there might be mentioned small deposits of low grade limonite. Thin seams of this are found in the Yorktown formation usually at the sand-clay contacts. This occurrence is merely of scientific interest. It is possible some of this may have been used by the earliest smelters. There are several minerals occurring in the sands which are of scientific interest such as magnetite and others.

Vermes ---------- 1
Echinoderma:
*Echinoidea ---------- 1
Coelenterata:
*Anthozoa --- (at least) ------ 2
Protozoa:
†Foraminifera ---------- 37

The mammalian fossils consist of vertebrae, ribs and ear bones of whales all of which are fragmentary. Only on a few are the spines or processes preserved. The size of the vertebrae varies from about an inch up to five to six inches. In some cases the length greatly exceeds the diameter; in some the reverse is true, and some are about equidimensional. The ear bones are arcuate and have a deep groove. They resemble to some extent a hand grenade. The fish remains consist of shark teeth and a few vertebrae. The teeth are mostly small of one-fourth an inch in length but at times they may be two inches long. The vertebrae show conical depression at each end, and are never over an inch long.

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*Not named by Clark and Miller.
†Determined by Fred Andregg in M.S. Thesis, University of Virginia, 1950.

The arthropod remains common to all the exposures is a barnacle technically known as Balanus concavus. It is found attached to most any kind of a shell or object as well as to each other. They may attain as much as an inch in diameter at the base and the height of about the same dimension. In a few places tips of Crustacean claws are found but no part of the carapace has been observed. A few astracods occur in the sandy clay; the writer has identified five species and there are others. All of these are microscopic.

The Molluscan forms exceed all others in number of species, and the collector at first will think there is little else. In general the Pelecypods are in a ratio of 3 to 2 to the Gastropods. Many of these are unique and are easily recognized in the field. Many species offer difficulty in determining; for example the Pectens as a genus are easy but as species are very difficult, and the same is true for Venus, Turritella, Astarte, Fulgur, and many others.

Certain Pelecypods are so odd that never become confused; Teredo or the Shipworm is of this character. Teredo

resembles a worm more than any other organism and the student fails to see any resemblance of this calcareous tube to a bivalve or even a spiral gastropod. Ecphora is one of the gastropods so out standing in all its marks that is the oddest of all its allies; its ugliness, as one has said, renders it attractive. The visitor never forgets the shape + size of Pecten + Fulgurs, the shape and thickness of Venus, the very graceful spire of Turritella + the relative abundance of the Chamas and Crepidulas. The only large Scaphopod is the slightly curved and striated one, Dentalium and it is widespread in the Peninsula.

The brachiopods are represented by one species. It has two small, conically shaped valves of very black color. In none of the exposures is it abundant. In length it rarely exceeds three-fourths of an inch + its width and thickness are smaller.
At least two species of Bryozoa occur; one is a dendritic form, the colony becoming as much as three inches long, the other a veil-like colony found upon many of the molluscan valves + other objects. There are several other species which the specialist on Bryozoa would recognize.

Yorktown, and the Septastrea at Bellefield and along the James River from Carters Grove to King's Mill.

The Protozoa are represented by both foraminifera and radiolaria, all of which are microscopic. Thirty-seven species have been determined and described from the Yorktown formation and this does not complete the collections. No study has been made of the radiolaria and this field is promising along with the microscopic plants, the diatoms. These micro-organisms occur in the very fine sands and clays of a sandy nature. They are very well preserved.

Preservation of Fossils: In all except a very few cases the fossils are preserved in the original form. The outer of the three layers is always absent as this epidermal layer is organic and disappears during the initial stages of fossilization. The inner or nacreous layer has disappeared in nearly every fossil except Nucula, which retains its shiny inner surface. The middle or prismatic layer in most instances is well preserved. Molds are frequently found in

the bands and coquina of Venus, Pecten, Turritella and a few others; these are usually consolidated mud & rarely calcite.

The internal features of the pelecypods are well preserved in detail showing the size, & positions of the muscles, sinuses, and pallial lines. The spines of such forms as Crepidula are generally lost either through the soluble effects of ground water or erosion at the time of accumulation took place or it may be a combination of these two. The thin margins and fine spines of many forms are broken. Some very large molluscs are thin valved, as Scaphella, Pecten clintonius, Dosinia, Crepidula plana, and Cardium and these are often broken especially the last named genus.

In many of the forms, particularly the pelecypods, a round hole will be found near the beak or the vital point of the valve where the soft body was encased. This hole is conical in shape the widest portion on the outer surface. This was caused by a carniverous gastropod genus, Drillia, so named from its habits of drilling the forms for food. Even the spiral shells of Drillia show such perforations. Thick valves in the adult stage of Venus tridacnoides do not show any effects of Drillia.

Certain values of pelecypods as Pecten, Venus, Ostrea, etc., show very uneven and modified external surface, one with a network of depressions and occassional perforations. These may be due to soluble effects of water attacking the more soluble portions and making depression & leaving the less soluble portions as ridges. But it seems that there is not so much variation in composition of the valves as to cause the uneven surface. It has been suggested by Dr. Donald W. Davis of the College of William and Mary that these uneven surfaces and occassional perforations may be due to a boring sponge. At any rate, despite all the many hazards existing at the time of fossilization and since that time, the fossils are quite well preserved. Conditions must have been well near ideal to have brought to the present time such large numbers and varieties of fossils as are found in the Yorktown & associated formation.

There must have been extensive wave action during Yorktown time as shown by the thick beds of fragmental shells or coquina. And yet in this cross-bedded material with all the evidence of vigorous wave action,

delicate shells are fairly well preserved. The clay contains the most poorly preserved fossils in many respects; they are not broken but very fragile. The clay holds the water more than the sand and keeps the fossils continually wet. Probably organic acids seeping through the clay help in the solution of the shells. The fossils in the sand are easily removed without breaking and they are not kept continually as in the clay. The sandy clay contains better preserved forms than the purer clay. The high cliffs on the York and James Rivers bear evidence of the tremendous amount of erosion during post-Miocene time. Consolidation and crustal movement have not been instrumental in the destruction of fossils

Leading Yorktown fossils: It is very difficult to name the ten or the fifteen most significant fossils of the Yorktown formation. Much has been asked by many people. Whatever list might be named others might not agree with it. The list below contains thirty of what the writer considers the most significant and abundant fossils to be collected on the Yorktown beach and bluff.

at any rate most any one would choose from this list fifteen of the outstanding fossils.

LIST OF THIRTY SIGNIFICANT FOSSILS

	Arca centenaria	Pelecypod
	Arca incile	Pelecypod
	Asaphis centenaria	Pelecypod
	Astarte thomasii	Pelecypod
5	Astrangia lineata	Coral
	Balanus concavus	Arthropod
	Calliostoma philanthropus	Gastropod
	Cardita protracta	Pelecypod
	Crassatellites marylandicus	Pelecypod
10	Crepidula aculeata	Gastropod
	Crepidula fornicata	Gastropod
	Crucibulum costatum	Gastropod
	Dentalium attenuatum	Scaphopod
	Dosinia acetabulum	Pelecypod
15	Ecphora quadricostata	Gastropod
	Fissuridea redimicula	Gastropod
	Glycymeris parallela	Pelecypod
	Glycymeris subovata	Pelecypod
	Oliva litterata	Gastropod
20	Ostrea sculpturata	Pelecypod
	Pecten jeffersonius edgecombensis	Pelecypod
	Pecten madisonius	Pelecypod
	Plicatula densata	Pelecypod
	Polynices heros	Gastropod
25	Septastrea marylandica	Coral
	Teredo fistula	Pelecypod
	Turritella variabilis	Gastropod
	Venericardia granulata	Pelecypod
	Venus tridacnoides	Pelecypod
30	Vermetus virginica	Gastropod

EXPLANATION OF PLATE I

Fig. 1 - Cretaceous Pterosaurs: Pteranodon ingens; external view.

2 - Vertebrae, Nilssonia; external and internal views.

3 - Siliceous sponges; internal, bottom, & external view.

4 - Cretaceous coral Burnatia; external and internal views.

5 - Glycymeris perplicata; internal and external views.

6 - Pecten quinquenarius; external and internal views.

7 - Area centenaria; external view showing a Dyllita boring; and an internal view.

8 - Pteropsellipes cunjiandiensis; external and internal views.

9 - Taeniodontia fistula; showing different shapes of tubes.

10 - Area lapilla; external and internal views.

11 - Cretaceous Unionella; external and internal views.

12 - Venus lamella Gardnerian; external & internal views.

13 - Turritella vertabrata; a Dyllita boring in one.

14 - Cretaceous Fornicata; showing spines, a smooth exterior, and an internal view.

15 - Ostrea conservus; one showing a top view; one large form with several attached to it.

Plate I

15 figures of fossils

To be

placed

here

Explanation on opposite page

EXPLANATION OF PLATE II

Fig. 1 - Glycymeris subovata; external and internal views.

2 - Dosinia acetabulum; external and internal view.

3 - Cardita protracta; external and internal views.

4 - Asaphis centenaria; internal and external views.

5 - Crepidula aculeata; external and internal views.

6 - Galliostoma philanthropus; three views: aperture & spire, top view, and side.

7 - Euphora quadricostata, showing spire and ribs.

8 - Oliva litterata; Aperture, back view and spire.

9 - Crucibulum costatum; top, bottom and side views.

10 - Polynices heros; top view with aperture and umbilicus, side view with Drillia boring and aperture, and side view showing spire.

11 - Vermetus virginica; showing the coils.

12 - Fissurides redimicula; top and side views.

13 - Dentalium attenuatum; one cross section and four side views.

14 - Astrangia lineata; a branching coral; one colony attached to a crepidula valve, and this valve shows the effects either of a boring sponge or of solution.

15 - Septastrea marylandica; a compact coralline colony.

Plate II

15 figures of fossils

to be

placed

here

Explanation on opposite page

Brief Descriptions of Fifteen Outstanding Yorktown Fossils

In the following brief descriptions nothing in the way of technical terms will be used except as necessary. For detailed descriptions and figures of the fossils the reader is referred to the Maryland Miocene, Dall's Tertiary and other references found in these two just cited. The student often asks for two or three of the most outstanding marks of the various forms and this way of giving the descriptions may serve to answer the needs of many. The reader can refer to the photograph of the fossil in question. In case of the pelecypods, photographs of the both the interior and exterior of the valves are given, showing as nearly as possible the main features. It is difficult to get a clear focus on the forms with a great range of relief.

Arca centenaria Plate I Fig. 1

1 - Exterior shows many fine ribs radiating from beak, and concentric growth lines.

2 - Front and rear portions rounded & muscle scars show well.

3 - Many transverse teeth and triangular area between the teeth and beak.

Balanus concavus Plate I, Fig. 15

1- Individuals, truncated cones, made up of several plates almost triangular in shape.

2- Individuals always attached to other shells, or objects, or to each other.

3- Opening at top usually very small and usual height to the diameter about 2:3.

Calliostoma philanthropus Plate II, Fig. 6

1- Low spire very pointed and conical.

2- Each spiral or whorl angular near the base.

3- Spiral line showing development of beads.

4- Large opening, very smooth interior usually with bright surface.

Cardita protracta Plate II Fig. 3

1- About 15 coarse radiating ribs from the beak, and resembles Arca in this respect.

2- Shell margin at top + bottom parallel, sides sloping at about same angle.

3- Beak far to the front + teeth immediately beneath + very unlike those of Arca.

4- Lower margin notched in pronounced manner by the ribs.

Arca incile Plate I Fig. 2

1- Coarse ribs, about 27 in number radiating from the beak, and few concentric growth lines.
2- Inner lower margin notched by ribs, upper margin marked by many transverse teeth.
3- Front rounded, rear vertial & angular, beak far to front with wide triangular area between teeth and beak.

Asaphis centenaria Plate I Fig. 3

1- Oblong valves, many ribs and concentric growth lines with beak a little nearer the front.
2- Three teeth in one valve and two in other, and muscle scars show only fairly well.
3- Smooth margins.

Astarte thomasii Plate I Fig. 4

1- Shell triangular in shape lower portion rounded.
2- Exterior marked by concentric lines.
3- Inner lower margin shows ridges (crenulations).
4- Pointed beak, three teeth in one valve in one valve, two in the other & depressed area in front of the beak.

Astraegia lineata Plate I, Fig. 5

1- Individuals or corallites branching, cylindrical and conical in shape & not fused or grown together except at base.
2- Partitions (septa) numerous, radiating from a point, and very thin.
3- Always attached and many individuals grow together.

Crassatellites marylandica Plate I Fig. 8.

1 - Valve widely rounded in front & narrowly rounded in the rear.
2 - Valve rather thick & heavy with very small inner cavity.
3 - Deep muscle scars becoming deeper towards the center, & pronounced line (pallial line) connecting the scars.
4 - Beaks little to front, high teeth & deep sockets.
5 - Exterior shows many growth lines and an elevation at rear extending from beak to rear.

Crepidula aculeata Plate II Fig. 5.

1 - Smooth exterior with a few concentric growth lines.
2 - Partial septum or partition interior.
3 - Exterior rather shallow compared to C. fornicata.

Crepidula fornicata Plate I Fig. 14.

1 - Shell deep and thick compared to C. aculeata.
2 - Shell shows a development of thick partition.
3 - Has a short spiral and occasional spines.

Dentalium attenuatum Plate II Fig. 13.

1 - Form slightly curved and open at end of cone.
2 - Twelve to sixteen ribs and numerous growth lines
3 - Diameter gradually increases and form may attain 1 3/4 inches.

(Put before Dentalium)

Crucibulum costatum Plate II, fig 9.

1 - Low cone point of which is pointed to one side.
2 - Development of ridges or costae radiating from near the point.
3 - An internal attached valve to one side of shell.

Dosinia acetabulum Plate II fig. 2

1 - Valves almost round and rather thin.
2 - Exterior shows excellent concentric growth lines.
3 - Muscle scars high in shell, three teeth in one valve and four in other.

Euphora quadricostata Plate II, fig. 7

1 - Four large revolving ridges (costae) T-shaped in larger forms.
2 - High spire in the small forms & lower in large ones.
3 - Opening almost round and groove from the opening deep but short.

Fissuridea redimicula Plate II, fig. 12.

1 - Cap-shaped or low cone with many ribs radiating from the top, & shows growth lines
2 - Small opening (foramen) at top towards the front.
3 - Shape of base is oval, length to the width is about 3:2, and height less than the width.

Glycymeris parilis Plate I, Fig. 5.

1 - Valves almost round, and about bilaterally symmetrical

2 - Teeth + muscle scars very distinct, and double ridges on lower inner margins.

3 - Heavy ribs radiating from fairly prominent beak, and faint concentric lines.

Glycymeris subovata Plate II, Fig. 1

1 - Valves depressed at top, & almost bilaterally symmetrical.

2 - Teeth, Muscle scars, and marginal area very distinct with large ridges on lower inner margin

3 - Small ribs radiating from beak, and more distinct concentric growth lines.

Oliva litterata Plate II, Fig. 8.

1 - Shell cylindrical, largest above the middle, and usually brilliant surface.

2 - Spire low + shows only on only one end.

3 - Opening long, outer lip thicker towards lower end + several small ridges on inner lip.

Ostrea sculpturata? Plate I, Fig. 4

1 - One flat valve showing concentric growth lines, and one deep with numerous ribs & growth lines.

2 - Hing area narrow.

3 - Muscle scar crescent shaped on to one side of the middle.

Pecten jeffersonius edgecombensis Plate I, Fig. 1

1 – Length slightly exceeds height, ribs 16 to 17 in number well raised.

2 – Ribs have 4 or 5 – ridges with small spines, and the intervening spaces show about three ridges.

3 – Ears well developed & valves are almost bilaterally symmetrical.

4 – One large muscle scar high in valve, one central triangular pit in hinge & ribs show in the interior.

Pecten madisonius Plate I, Fig. 6.

1 – Valves slightly higher than wide & one valve nearly flat.

2 – Ribs about 16 in number with about three ridges on each.

3 – Ears about equal making the valves about bilaterally symmetrical.

4 – Muscle scar high in valve & ribs show well on interior.

Plicatula densata Plate I, Fig. 3

1 – Valves show from 5 to 6 high ribs & growth lines.

2 – Closely resembles Ostrea; valves are pointed at hinge & at base are rounded.

3 – One muscle scar, smooth margin, teeth usually show very little but are curved.

4 – Valves are higher than long.