Geologic Ancestry of the York-James Peninsula

ARTHUR BEVAN[1]
Churchville, Virginia

FOREWORD

The Peninsula was discovered and settled by the first Virginia colonists 350 years ago through the historic landing on Jamestown Island. That fortuitous event was the precursor of all the history of Virginia during the last three and a half centuries. Far back in time as 1607 seems to us in this eventful age, the elapsed centuries are not a second as measured against the geologic time recorded in the rocks, rivers, and landscapes of the Peninsula.

How old, then, is the Peninsula? How was it developed? What has been its geologic ancestry? What particular geologic events prepared the way for the landing at Jamestown?

READING GEOLOGIC RECORDS

To read meaning into the geologic manuscripts of the Peninsula, which contain the records of its earth history, and to interpret them validly, one should comprehend the elements of geologic field research. A geologist is no less a skilled detective than a versatile Sherlock Holmes. He studies clues in rocks and minerals, hills and valleys, and seacoasts and rivers instead of human personalities and aberrations. The geologist is always seeking clues to past natural events so as to reconstruct the history of the earth and its inhabitants. To do that logically, he should be proficient in the field observation of present geologic processes, for "the present is the key to the past." An active, logical imagination is almost indispensable, for the observing interpreter must envision agents, processes, and results on a grand scale throughout eons of time. Many geologic records present perplexing problems because of their antiquity, stupendousness of ultimate events, and partly because many of the processes and results cannot yet be duplicated in laboratories. This state of affairs is a challenge and a lure to geologic research. The records and problems of the geologic history of the Peninsula are, however, relatively simple.

The geologic ancestry of the Peninsula is derived from observable features: landscapes along the shores and inland; Chesapeake Bay and its tributary rivers; surface and subsurfaces rocks; and the fossils of former

[1] State Geologist of Virginia. 1929-1947.

indigenous organisms—plants, invertebrates, and vertebrates. All of these data must be critically studied, having constantly in mind the guiding axiom—the present is the key to the past.

As rivers now carry gravel, sand, silt, and mud toward the sea, so did they throughout geologic ages from the time rain fell on the young solid earth. As those sediments now accumulate in layers along river flood plains, in lakes, and in shoal waters along seacoasts, so did they during all past centuries and geologic periods. Calcareous sediments are now being produced chemically and biochemically in lacustrine and marine waters; they were no doubt formed under similar environmental conditions throughout geologic time.

Fragments of land plants become buried in sands and muds along river channels and flood plains and in estuaries. Shells and other hard parts of invertebrate animals are incorporated in some sediments, especially muds and calcareous oozes. Fresh-water clams and snails leave their shells in alluvial and lacustrine deposits. Marine invertebrate remains are characteristic of many sands and muds deposited in the sea. They are common in calcareous sediments, derived in part from their shells and other hard parts. Skeletal parts of land vertebrates are found in river, swamp, and lake deposits; of marine forms, *e.g.*, sharks, in marine sediments.

Each landscape feature, whether a river valley, a hill, or remnant of an upland plain records specific geologic history. Each has been fashioned by some geologic agent through long intervals of geologic time. The most common and ubiquitous sculpturing agent in humid climates is running water, as rills on slopes and streams in valleys. Waves and current along a seacoast erode the shore and transport sediments to depositional areas. Long-continued wave erosion at a stable sealevel reduces the adjacent land to a submarine plain, bordered landward by a cliff or escarpment. Winds transport sands from beaches and flats to construct dunes. Water percolating underground dissolves soluble mineral matter, chiefly calcareous, and carries it to other sites.[2]

The essential point to keep in mind in understanding geologic records in the Peninsula, or elsewhere, is that as geologic agents now erode and sculpture the land, transport and deposit sediments to build sedimentary rocks and certain land forms, so have they done since the earliest recorded geologic time. This principle of uniformitarianism, in general, is another guiding axiom in deciphering earth history.

---

[2] Details and examples of these common geologic processes cannot be given here; a textbook on geology should be consultud. Only those relevant to the interpretation of the geologic ancestry of the Peninsula are mentioned.

FIELD OBSERVATIONS

Surface features. – The Peninsula is a part of the Coastal Plain of Virginia, popularly known as Tidewater Virginia. In a board view, as from an airplane at high altitude, the region appears to be a plain with a gentle eastward slope. The inner margin is at the somewhat irregular eastern edge of the Piedmont province, along the Fall Zone where rivers, such as the James, descend over rapids and low waterfalls. Early Richmond, for instance, was located at the Fall Zone – the head of tidewater navigation. The outer border of the Coastal Plain is deeply indented by bays and estuaries, of which Chesapeake Bay is the most prominent and, for this account, the most significant. The eastern part of the Coastal Plain is now submerged; the surface slopes gently under the ocean.

The lower part of the Peninsula lies between two broad and beautiful tidal rivers, the James on the southwest and the York on the northeast. Northwest of the confluence of the Pamunkey and Mataponi rivers to form the York, the valley of the former may be taken as the northern boundary of the Peninsula. The Peninsula thus has within its borders one large, long river, the Chickahominy. It has a remarkably tortuous course, as has the James to a less extent in its upper Tidewater reaches. The Pamunkey is similar, flowing seaward in broad sweeping curves.

Because the lower part of the Peninsula is bounded on three sides by deep valleys, including Chesapeake Bay, its borders are digitate. Along the Bay the land is deeply indented by estuaries of Back and Poquoson rivers and their short tributaries. The bay borderland consists of "necks," smaller bays, marshes, islands, and shoals. A long coastal bar or beach extends northward from Old Point Comfort into the Back Bay estuary.

Valleys tributary to the James are partly submerged, or "drowned." Low riverside islands, such as Jamestown, have been separated from the mainland of the Peninsula by the relatively high waters in the James. Marginal swamps are rather common. A few necks of land. *e. g.*, Curles Neck, are almost enclosed by the broad meandering curves of the river. Similar drowned tributaries, swamps, and islands are marginal features of the Pamunkey and Chickahominy rivers. The York River is almost straight. Its short tributaries are also drowned. Steep cliffs border the York in the vicinity of Yorktown.

The surface of the Peninsula rises gradually northeastward from slightly below sealevel to an altitude of about 200 feet on the flattish upland near Richmond. The outer part is submerged. The Peninsula is a low, broad plain in most of York, Warwick, and Elizabeth City counties. Here it is only slightly dissected by streams except for the bayside indentations. The surface rises imperceptibly to a maximum general altitude of about 50 feet southeast of Lee Hall and Yorktown. Extensive stream dissection has destroyed most of the original plain northwest of these points. Intervalley uplands are remnants of the gently sloping plain. The uniform continuity of the seaward slope is interrupted by low escarpments—the landward "risers" of broad, approximately north-south trending terraces.

Observable rocks. – The outcropping rocks are much more ancient manuscripts of its geologic history than are the surface features of the Peninsula. They are exposed in cuts along streams, roads and railroads, and in excavations of all kinds.

The visible rocks of the Peninsula are sedimentary, *i. e.*, their constituent particles were laid down as sediment – pebbles, sand, silt, mud, and shell fragments. Most of the sediments are still unconsolidated or loosely consolidated. Rainwater and snow-water percolating downward from the surface have dissolved soluble material and redeposited some of it as cement to bind together some of the sediments: pebbles into conglomerate, sand grains into sandstone, and shells and shell fragments into marl. Mud flakes and clayey particles formed layers of clay. The particles of these sedimentary rocks have been more or less sorted according to size and shape into layers or beds.

Some of the strata contain plant remains, particularly those near the Fall Zone and in surficial deposits. Fossil shells occur here and there; however, they are abundant in bluffs along the York above and below Yorktown and in a few outcrops along the James. Most of the forms are pelecypods and gastropods. More than 100 species have been collected by the School of Geology at the University of Virginia. Vertebrate fossils consist of vertebrae and other parts of whales and teeth and vertebrae of sharks.

Geologic formations. – Geologists classify sedimentary rocks into formations, each having distinctive physical characteristics and, perhaps, a diagnostic fossil flora or fauna. Each formation was deposited during a particular stage of geologic time. Such an orderly classification is essential to depict the distribution of contemporaneous strata upon a geologic map as well as to arrange the episodes of geologic history in a proper and understandable sequence. As in a stack of books, the topmost formation is the last one that was laid down; each lower stratum was placed earlier and thus is increasingly older. This natural order of superposition is of critical importance in arranging the manifold events of earth history in a true succession. When the natural vertical succession of strata has been determined, fossils in the beds can be used to identify more or less contemporaneous formations, even at widely separated localities.

The geologic succession of plants, invertebrates, and vertebrates has in general been worked out for much of the entire sequence of sedimentary rocks, from the oldest fossil-bearing beds to the youngest. Hence the twin principles of superposition and of the geologic evolution of organisms enable stratigraphers and paleontologists to correlate, or match approximately in time, formations that cannot be traced at the surface because of the scarcity of outcrops. The same method is used to identify strata penetrated in deep well borings, often many miles apart. In this manner formations that are meagerly exposed on the Peninsula can be shown on a geologic map according to their geologic ages and extent.

Thickness. – The sedimentary rocks on the Peninsula range in thickness from a feather edge near the Fall Zone to a measured maximum of about 2,250 feet in the deep well at Fort Monroe. They have been traced seaward in a geophysical traverse: their thickness is calculated to be more than 12,000 feet below the submerged plain about 60 miles east of Cape Henry.

Structure. – The attitude, or structure, of the formations on the Peninsula is not immediately obvious, for the stratification is commonly poor or indistinct. The structure, however, is simple. Recognizable beds in restricted exposures appear to be horizontal; notwithstanding, it has been found that over extensive areas the upper strata dip seaward at about 10 feet per mile. Data from well borings indicate that the deeper beds have somewhat steeper seaward dip; also, that in places they may be broken and displaced by faults.

Foundation rocks. – The sedimentary formations of the Peninsula rest upon a foundation of much older rocks which are of two main types. Very old crystalline rocks – "basement rocks" – crop out along the Fall Zone and underlie much of the Piedmont region. They consist of igneous rocks, and highly altered sedimentary and igneous rocks. The other type is exposed in the Richmond coal basin, comprising sedimentary "red beds," other strata, and coal. Some igneous rock was intruded, in a molten state, into these formations. These rocks are very much younger than the ancient crystalline rocks of the Piedmont but are much older than the sediments that comprise the upper crust of the Peninsula.

It is a logical and safe inference that both groups of rocks underlie the Peninsula, at increasing depths seaward. The red beds were penetrated by a well in another part of the Coastal Plain. A well drilled in 1902 at Fort Monroe struck crystalline rock at a depth of 2,240 feet. A boring made in 1929 at Mathews Court House reached granite at 2,300 feet below sea level. A later geophysical traverse determined the depth to basement rock at Cape Henry to be about 2,900 feet.

These foundation rocks afford considerable information about the early stages in the geologic development of the Peninsula. Its early history can be soundly inferred only from an intensive study of the rocks in the Piedmont province of Virginia. Even the great pile of sedimentary formations in the Valley of Virginia, which probably lies upon similar foundation rocks, affords numerous clues to ancestral conditions and events in the area of the Peninsula before its mantle of sedimentary rocks was deposited.

GEOLOGIC TIME

Just as the significant events of human history have been chronicled in terms of ancient, medieval, and modern history, so the known important events of earth history have been arranged in time categories. Virginia's physical ancestry, in which the peninsular area inevitably participated, progressed through four great eras of geologic time. Each of those eras was characterized by some distinctive combination of events and the approximate end of each one was marked by some particularly significant series of events.

Eras have been divided into major units of time, called periods, each with more or less characteristic records. This classification of geologic time is rather similar in general nature to the division of human history into periods and epochs. It is a natural division of geologic history; it is also essential for a clear and world-wide interpretation and comprehension of the succession of geologic events. The classification is based in part upon major physical changes on the continents and in part upon changes in contemporary floras and faunas, whose remains have been entombed in the strata.

The names of eras and periods may seem odd to a layman, but they mean more than mere convenience in classification. Each name of an era is based upon the stage of evolution of the whole organic realm including the dominant types then living. Most period names have been derived from a geographic unit in which formations of that age were first described. A few names designate sedimentary deposits that were peculiarly characteristic of that time.

The geologic ancestry of the Peninsula can be most clearly and concisely presented by reference to the geologic time scale. It is given below in abbreviated form, with the major events on the Peninsula indicated.

GEOLOGIC CHRONOLOGY OF THE PENINSULA

Era	Life stage	Period	Typical animals	Peninsula record
Cenozoic	Recent	Quaternary	Mammals	Present landscapes Surficial sediments
		Tertiary		Principal sediments
Mesozoic	Medieval	Cretaceous	Reptiles	Oldest sediments (?)
		Jurassic		Probably erosion
		Triassic		Local sediments (?)
Paleozoic	Ancient	Permian	Invertebrates	Probably erosion throughout era, of landmass supplying sediments westward
		Carboniferous		
		Devonian		
		Silurian		
		Ordovician		
		Cambrian		
Precambrian				Basement rocks akin to Piedmont rocks

GEOLOGIC ANCESTRY

It is evident that the Peninsula was affected by most of the major geologic events whereby was constructed the physical framework of Virginia and adjacents parts of the continent. The oldest accessible records of its geologic ancestry are those in the basement crystalline rocks that crop out extensively in the Piedmont region and form the foundation of the Peninsula. Those rocks record events of Precambrian time and also some during the following Paleozoic era.

Precambrian history. — The principal events to be deduced from the great body of most ancient rocks are these: widespread deposition of thick masses of clastic sediment; intrusion of large masses of molten rock into pre-existing rocks; the rise of other bodies of molten rock to the surface where they became lava flows; very widespread and intense deformation of most of the Precambrian rocks; and alteration of the sedimentary formations and some of the igneous rock into completely crystalline metamorphic rocks.

Because of their thorough alteration, the original sediments are now scarcely recognizable. Nevertheless, the ancestry of the present rocks can be interpreted from some of their characteristics, such as constituent minerals, internal structure, and chemical composition. The source and depositional environments of the ancient sediments are unknown: the events were too remote and the obscuring later changes too great for confident interpretations. It is surmised that those sediments were derived from a landmass that may have included the site of the Peninsula; or it may have been situated east of the present seacoast. In the latter geographic relationship, the Peninsula may have been partly occupied by one or more of the troughs that received the land waste.

Throughout the decipherable history of the earth, rocks have melted in the deep interior and have risen toward the surface as large molten masses. Many of these magmas came to rest at considerable depths where they cooled slowly and crystallized to form intrusions of granite and other igneous rocks. Some of those within the basement rocks of the Piedmont and the Coastal Plain were injected during Precambrian time. It was formerly thought that most of them were of that age. Research in recent years upon the characteristics and environmental relations of the Piedmont intrusive masses indicates that some of them were associated with the profound crustal movements that occurred in eastern North America during the closing epochs of the Paleozoic era.

Some of the magmas were sufficiently fluid and were subjected to strong propulsive forces that brought them onto Precambrian land surfaces. There they spread over the land like lava flows do today. They have been found at several places in the Piedmont and the Blue Ridge. None has yet been encountered in deep borings in the Tidewater section.

The severe deformation and intense metamorphism of most of the Precambrian rocks denote that they were subjected to great compressive stresses. It may be that mountain ranges were produced, perhaps also far out in the Atlantic basin of today. Upwarping and folding of the late Precambrian land no doubt accelerated the processes of rock disintegration and stimulated the streams to transport rock waste to various basins. Reduction of the uplands and deposition on the lowlands may have produced a broad undulatory plain with local hills and ridges.

Paleozoic history. – The geologic history of the Peninsula and the Coastal Plain in Virginia during the few hundred million years of the Paleozoic era must be inferred. Indubitable clues to some of the conditions and events are found, however, in the great mass of Cambrian to Carboniferous sedimentary rocks that underlies the Valley of Virginia and composes the mountain ridges and valleys to the west.

The topography of the Virginia area during the Paleozoic era was extremely unlike the present surface. A prominent landmass at the east was bordered by a broad sea to the west. A succession of invasive seas flooded the sites of the Blue Ridge, the Valley, and the mountains far west of Virginia, from Cambrian time at least through the early part of the Carboniferous. Some of those seas joined the north Atlantic with the Gulf of Mexico or its Paleozoic counterpart. The eastern shores of those seas is unknown; some of the eastern Piedmont was covered during the Ordovician period by marine waters.

An extensive landmass lay between the interior seas and the open Atlantic. Geologists long ago named it "Appalachia." Its actual extent and character can never be known, for it disappeared before late Mesozoic time. How is it known, then, that it ever existed? That interpretation is attested by the Paleozoic sedimentary rocks in and west of the Blue Ridge. The enormous volume of sand and mud that now makes up the sandstones and shales of that region was swept into the interior seas by streams that flowed down the western slopes of Appalachia. Much of the clastic sediment could have had no other source. That Paleozoic land mass may have been at times a bold mountain range. It may have occupied part of the Tidewater area or it may have been situated entirely east of the present coast.

Late Paleozoic cataclysm. – Before the end of the Paleozoic era, cataclysmic disturbances disrupted the eastern border of the continent. Irrestible forces impelled from the southeast buckled the Paleozoic strata into a broad series of huge corrugations. They trended northeast and southwest. The lateral pressure toward the interior of the continent ultimately became so intense that many of the overturned folds were broken and thick slices of the earth's crust were gradually propelled for many miles to the northwest. These long-continued convulsions in the outer shell of the earth produced the ancestral Appalachian mountains– a high mountain chain that may have had the grandeur of the present Rocky Mountains.

That late Paleozoic-early Mesozoic mountain system also eventually disappeared. Proof of its existence, nevertheless, is direct and obvious because the great folds in the strata are cogently evident in every crossing of the present Appalachian Mountains.

The effect of the birth of the old Appalachian mountains upon the coastal part of Virginia is unknown. Any inference is mere conjecture. The old landmass of Appalachia may have been slowly engulfed by the Atlantic. Perhaps it had another fate.

Mesozoic history. – As soon as the ancestral Appalachian mountains began to rise above the common level of the land, the forces of rock decay and disintegration attacked them, especially running water. Streams on all slopes transported rock debris to lower levels, always toward the sea. During the 130 million years of the Mesozoic era the uplands were gradually worn down to a vast plain. It covered all of Virginia and the eastern part of the continent. It sloped toward the Atlantic across the Peninsula, where it is buried under a mantle of younger sediments. Hills and ridges on more resistant rock or farther removed from main drainage courses stood in places above the plain. The geologic age of its completion is uncertain; perhaps in the Cretaceous period.

During the Triassic period large, elongate basins were developed in the Piedmont region. Thick bodies of sand and mud were deposited in them. Parts of the basins were at times occupied by swamps in and beside which lush vegetation grew. Vegetal debris which accumulated in the swamp waters eventually became coal beds. Molten rock at intervals invaded the strata. Some of these basins may have been formed in the Coastal Plain, possibly in the northwestern part of the Peninsula.

The Jurassic period was a time of widespread erosion in the eastern part of the continent. No sediments of that age are known in Virginia. The vast erosional plain mentioned above may have been in its penultimate stages. If Appalachia were destroyed by long-continued erosion during the Mesozoic era, the final phases were completed during this time of general planation of the land.

During the Cretaceous period the geologic record in the Peninsula became more definite and clearer, for sediments of that age have been preserved. It is from the rocks formed during a geologic period that the contemporary geography and geologic activities can be deduced with a fair degree of certitude.

Early Cretaceous sediments are chiefly gravels, sands, and clays, locally with considerable lignitic material, which lie upon the basement crystalline rocks. Most of the sediments are unconsolidated although some of the gravel has been cemented into conglomerate and some of the sand into sandstone. Abundant plant remains include ferns, cycads, and conifers. True flowering plants had not yet become numerous or abundant.

These data show that late in the Jurassic or early in the Cretaceous period, perhaps during both, the vast erosional plain was tilted – up toward the west and down toward the sea. This gradual uplift rejuvenated the streams that flowed toward the Atlantic so that they began to scour off the thick mantle of decayed rock upon the plain. The lignitized wood – incipient coal – and fossil land plants, together with the absence of marine fossils, suggest that the rivers emptied into marshes and estuaries on a broad coastward flat. Topographic conditions were perhaps similar to those along the eastern side of the present Coastal Plain.

The sea may have submerged the eastern part of the Early Cretaceous coastal plain, which inclined seaward, but because marine fossils have not been found in deep well borings its shore is unknown. A pronounced thickening of the strata from the Fall Zone to the deep well at Fort Monroe indicates that the land was tilting seaward during Early Cretaceous time.

The sea encroached upon the eastern Coastal Plain during Late Cretaceous time, for sediments with marine fossils of that age were penetrated in deep wells near Norfolk and at Old Point Comfort. How far the sea spread inland or whether it submerged much of the Peninsula will be unknown until more deep wells have been drilled in that area. A low coastal plain sloping gently seaward would have favored marine invasion.

Tertiary history. – The Tertiary is the earlier period in the era in which we live. It began approximately 60 million years ago. Sediments were deposited over much of the Coastal Plain during that period; hence the Tertiary history of the Peninsula is more completely evident than at any previous time.

During the early part of the period (Eocene) the sea slowly crept over the Peninsula at least as far west as the Fall Zone. This may have been one of the most extensive submergences of the Tidewater Virginia region which throughout most of prior geologic time had been land. Streams had eroded this land into an irregular surface before the sea submerged it, as is shown by the uneven lower surface of the Eocene deposits. Some of the sediments appear to have been deposited in basins where they are much thicker than elsewhere.

Most of the time during the Eocene epoch rivers carried fine sand and clay to the incoming sea. Much greensand (glauconite) was formed in offshore waters. Marine invertebrates abounded: the strata contain many shells of many species of pelecypods and gastropods. Some of the beds are shell marl. Well cuttings from deep borings in 1941-42 at the Navy Mine Depot at Yorktown contained many tests of numerous species of Foraminifera.

The second epoch (Oligocene) of the Tertiary period seems to have been a time of relatively static conditions on the Peninsula. The Eocene sea had withdrawn into the Atlantic basin, possibly because of a slight upward tilt of the land. Erosion was slight upon the Peninsula and deposition was virtually nil; at least there is no clear record of either process having been active. The area probably was a stable, low, flat coastal plain. Toward the Fall Zone, however, an eroded surface lies beneath the oldest Miocene sediments. That area was land, crossed by eroding streams.

During the next epoch (Miocene) the sea advanced again toward the Fall Zone, in places flooding beyond it. This was the last extensive marine submergence of the region. In the early part of the Miocene, rivers carried much fine sand to the sea, where it was reworked and distributed by the waves and littoral currents. Some greensand was produced off shore. That sea harbored an abundant and varied fauna, as is shown by the many species of fossil gastropod and pelecypod shells as well as numerous other forms of invertebrates. It contained some vertebrates, *viz.*, fish, reptiles, and mammals, some of the remains of which have been fossilized. Peculiar marine conditions for a long stage permitted billions of diatoms to flourish: microscopic plants that extracted silica from the sea water to form their remarkable and, in some species, beautifully ornate tests. Leaves from land plants floated down the rivers to become imbedded in the estuarine and littoral sediments.

After the initial Miocene formation was deposited, the sea appears to have withdrawn, for sediments deposited farther north are lacking on the Peninsula. The area was submerged again during the Middle Miocene. Rivers contributed large quantities of clay and less quartz sand to this sea than to the Early Miocene sea. These sediments indicate that the Piedmont source areas were mantled deeply with the products of long-continued rock decay. The turbid waters prevented the growth of the large colonies of diatoms which had been so characteristic of the Early Miocene sea. Considerable shell marl and the abundance of fossils denote the richness of the marine invertebrate fauna.

It is uncertain whether this sea withdrew from the Peninsula and advanced again over the area in the Late Miocene or whther the supply of terrigenous sediment was depleted. In either case the marine waters were at times clearer; hence the uppermost Tertiary formation in many places consists chiefly of shell marl or coquina. Excellent exposures are in the cliffs up and down the south side of York River near Yorktown.

This section of Miocene strata was named the Yorktown formation from these typical sediments. These outcrops and beaches have long been noted places for collecting fossils – among the best Tertiary ones on the Atlantic Coastal Plain. Professor Joseph K. Roberts of the School of Geology at the University of Virginia reported two decades ago that he had collected "110 of the reported 123 species". That fossils are predominantly shells of gastropods and pelecypods, but most of the invertebrate phyla are represented. Some outcrops yield shark teeth and the vertebrae of whales.

Toward the close of the Miocene epoch the sea withdrew from the Peninsula and the rest of the Coastal Plain in Virginia, never to flood the region extensively again. A long period of emergent land ensued during which streams from the Piedmont and western parts of Virginia brought gravel and sand and deposited them on flood plains in the Peninsula. These Late Tertiary or Early Pleistocene sediments have been preserved at several places, *e.g.*, east of Williamsburg. Some of the pebbles of limestone were derived from outcrops west of the Blue Ridge, as is proved by the Paleozoic fossils in them.

Pleistocene history. – The Quaternary period is divisible, chiefly for convenience of reference, into an earlier or Pleistocene epoch and the present or Recent epoch.

The Pleistocene epoch is also called the "Great Ice Age," because expansive sheets of ice – continental glaciers – spread over much of Canada and the northern United States. South of the southern limit of glaciation other geologic processes were normally active, except as they were affected by changes in climate and precipitation. One effect was pronounced on the Peninsula and other parts of the Coastal Plain – the fall and rise of sea level causing lands to emerge far east of the present shore and then to be flooded a considerable distance west of the present coast. This slow cyclic fluctuation of sea level was in response to the locking up of large amounts of evaporated sea water in the huge ice sheets, followed by its slow return to the ocean as those glaciers melted during the warmer interglacial stages.

Four distinct Pleistocene glacial stages have been recognized from geologic records in the glaciated region; likewise, four interglacial stages if the present stage is counted as one of them. (It may, however, be a post-glacial stage, in which case the term "Recent epoch" may be somewhat appropriate.) Responses of sea level to the variable supply of water are recorded on the Coastal Plain, though in general not so well on the Peninsula. The invading seas smoothed their new floors, partly by wave and current erosion and partly by sediments eroded from the coasts and contributed by tributary rivers. This mantle of recent sediment constitutes some of the surficial formations on the Peninsula. Large rivers dropped parts of their loads of gravel, sand, and silt along their lower courses before they reached the seas. As successive seas withdrew from the present land surface, James and York rivers of necessity extended their courses across the newly emergent sea floors, as they had done in each prior cycle of emergence since the Cretaceous sea invaded the Coastal Plain.

An index to the climate in Virginia during the glacial stages is afforded by striated cobbles and boulders in some of the fluvial and estuarine sediments. In this part of the state these erratics occur mainly south of the James. They have the earmarks of ice transport and scoring. Because they occur far south of the terminii of the continental glaciers it seems most probable that they were ice-borne in rivers from the colder regions of the upper Piedmont and the Blue Ridge; perhaps even from the upper valley of the James in the distant mountains.

The shore of each invading Pleistocene sea is marked by a moderately steep upward slope or subdued sea-cliff. The present surface of the region consequently is composed of a series of broad plains, or "treads," and north-south trending scarps, or "risers." These are the coastal plain terraces. The most recently exposed submarine plain, or sea floor, is the broad, low surface in the southeastern counties of the Peninsula. That gently sloping plain in late Pleistocene time was exposed land far east of the present coast. The mouths of the York and James were east of their present positions. These interpretations are clearly evident from the deep channels that lead into the ocean. The lower part of the James – the magnificent harbor of Hampton Roads – is approximately 100 feet deep. The lower York is about 80 feet deep. These stream-scoured valleys could have been cut mainly in a land surface only, at considerable height above the sea, even though sediment-laden submarine currents may have partially scoured them. The extreme eastern edge of the coastal plain during its maximum emergence is unknown.

At this relatively recent geologic stage in the ancestry of the Peninsula its seaward portion was a low swampy plain. Its inland portion was higher above the sea than now. This altitude provided stream gradients and velocities that caused the James and the York to deepen their channels. The erosive power of their tributaries was accentuated; hence they dissected the western upland into the present pattern of ridges and valleys. Chesapeake Bay in its present form did not exist. Its area was occupied by the drainage system of the lower part of the great Susquehanna River. The York and the James were major tributaries.

Recent geologic events. – An immense volume of evaporated sea water was temporarily locked in the million or more cubic miles of ice that constituted the last great continental glaciers. As the cold Pleistocene climate moderated, large quantities of melt waters from the wasting ice sheets flooded rivers which poured the water back into the Atlantic and other oceanic basins. Those basins, therefore, became filled to overflow and the sea again gradually inundated the coastal plain. The seaward portions of the James, York, and similar rivers became estuaries and tidal channels; in the James today even to Richmond. A major part of the large, ancestral Susquehanna Valley and its major tributaries were slowly drowned to make Chesapeake Bay. As the sea crept farther inland, sluggish tributaries of the James and the York also were drowned, and the adjacent lowlands became swamps. With their gradients and velocities decreased, the rivers wandered from side to side across their low floodplains in broad meandering curves. Shallow depressions across some of the riverside peninsulas became short straits and the "necks" of land became islands. Jamestown Island is typical.

The long coastal bar or barrier beach that extends northward from Old Point Comfort into the Back Bay estuary has been built recently by waves and wind-driven shore currents which swept sand northward along the shallow sea floor. Winds have heaped up dry sand locally into dunes, as at Cape Henry. Flooded rivers have carried silt and clay into the estuaries, gradually converting them into mud flats on which vegetation slowly gains an anchorage.

Through its long and diversified geologic ancestry the Peninsula was gradually developed to its present form and constitution. It was the setting of the stage, so to speak, for the chance landing of the first colonists on Jamestown Island. Their activities and those of successors were henceforth influenced in part by environmental conditions inherited from that geologic ancestry.

Age of the Peninsula. – The foundations of the Peninsula were constructed a half billion and more years ago. This deduction is based upon the age determination of certain minerals in analagous crystalline rocks in the upper Piedmont and elsewhere, by study of the isotopes of elements involved in radioactive disintegrations. A characteristic mineral in Amherst County, for example, has been determined to be of the order of 800 million years old. The superstructure of sedimentary formations which was built up from Early Cretaceous time to the latest Pleistocene encompasses approximately 110 million years. The last Pleistocene sea retreated into the Atlantic basin a few tens of thousands of years ago. The present inundation of the Coastal Plain and the lower Peninsula has been in progress, perhaps, for 10,000 years, though possibly for even less time.

REFERENCES

CEDERSTROM, D. J. 1954. Geology and Ground-Water Resources of the Coastal Plain of Southeastern Virginia. *Virginia Geol. Survey Bull.* 63.

————— 1945. Selected Well Logs in the Virginia Coastal Plain North of James River. *Ibid. Circ.* 3.

CLARK, W. B. AND B. L. MILLER 1912. Physiography and Geology of the Coastal Plain Province of Virginia. *Ibid. Bull.* 4.

COOKE, C. W. 1391. Seven Coastal Terraces in the Southeastern States. *Jour. Wash. Acad. Sci.,* 21: 503-513.

CUSHMAN, J. R. AND D. J. CEDERSTROM 1945. An Upper Eocene Foraminiferal Fauna from Deep Wells in York County, Virginia. *Virginia Geol. Survey Bull* 67.

ROBERTS, J. K. 1932. The Lower York-James Peninsula. *Ibid. Bull.* 37.

WENTWORTH, C. K. 1930. Sand and Gravel Resources of the Coastal Plain of Virginia. *Ibid. Bull.* 32.

Acknowledgment. – This interpretation of the geologic history of the Peninsula has been made possible by the geologists who have done intensive field work in the area, as listed in the "References."