The Geology of "The Cliffs of the Neuse State Park" and its surrounding area.

A semi-popular dissertation for
use by the Park Naturalist
for public information,
with Appendixes I. - V.

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Introduction.

"The Cliffs of the Neuse State Park" is situated in the southeastern corner of Wayne County, about 10-11 miles southeast of Goldsboro, North Carolina. It extends a short distance on the low lying, often flooded, left bank of the Neuse River and for a considerably longer distance along the relatively steep right bank of the river. The southwestern and southeastern boundary of the park lies almost on the divide between the Neuse River to the North and the Cape Fear River to the South. The whole area lies otherwise within the geographical-geological unit known as the North Carolina Coastal Plain.

Geography, Morphology.

Geographically and morphologically "The Cliffs of the Neuse" is situated at that point, where the watershed between the Neuse River and the Cape Fear River (more precisely the Northeast Cape Fear River) is the narrowest. A cursory glance at the drainage area map of the Neuse River, published some months ago in The News and Observer (see Appendix No. V.) will clearly show that a considerable inequality in the drainage area of the Neuse River Basin exists below Smithfield, North Carolina. This inequality is well expressed in N-S profiles of the drainage area. A flat, low-graded land rises from the Neuse River toward the North and it is drained by the relatively long runs of these branches of the Neuse River. On the opposite side, however, the creeks of the right bank show considerably shorter runs. In the vicinity of the park the southern divide is scarcely one mile from the Neuse River, and below the park the watershed draws off gradually from the Neuse River. A possible explanation of this morphological phenomenon will be given in a following chapter.

General Geology of the Coastal Plain.

The State of North Carolina is geographically and geologically divided into three zones:

1. The western-most belt, consisting of the Appalachian and Blue Ridge chains.

2. The middle belt, consisting of the Piedmont Peneplain with its general flat surface, dissected by a younger valley system.
3. The Coastal Plain, consisting of more or less rolling country in the western part, becoming gradually flatter and lower until it reaches sea level at the present coast line.

In order to more fully understand the following discussion, it may be helpful to refer occasionally to the Geologic Time Table appended to this report (Appendix No. I).

The two western belts were built up in geologically older times and are composed in general of originally sedimentary and igneous rocks of the Paleozoic and Proterozoic eras. These rocks are found now either in their original nature or metamorphosed to a greater or lesser degree. Essentially the two western belts differ only in the morphological appearance. The Appalachians, where the metamorphosed sedimentary rocks yet are prevailing, have retained their rugged character in spite of erosional action, whereas the Piedmont Peneplain has been beleveled and now is being dissected by rejuvenated erosional activity.

The eastern belt, starting generally at the "Fall Line" - a NE-SW line along which most of rivers leave the Piedmont Peneplain through small falls or rapids - was built up by sediments of younger geological times on the base of similar rocks we know on the Piedmont Peneplain. As we shall see, the oldest of these sediments are from the Upper Cretaceous epoch. The same rocks which composed the Piedmont Peneplain dip eastward beneath this younger sedimentary blanket, as the deep well data revealed the surface of these "basement rocks". Recently won data of new deep wells have proven that the subsurface shows undulations, there are places within the Coastal Plain, where such ridges outcrop, having been exposed by severe local erosion. Such outcrops are located near Princeton, North Carolina, and in the vicinity of Cox Mills, whereas a Goldsboro well disclosed the same material at a depth of 93 feet (= 13 feet below sea level).

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The sedimentary cover gives us evidence of the conditions of the area in much younger geological times and the events which led to the present situation. These events will be discussed in greater detail following a general description of the materials observable in the park and near vicinity. (Once again it will be helpful to refer to tables Appendix No. I and Appendix No. IV, the general geological time table and a time table ~~and a time table~~ especially of the sediments within the North Carolina Coastal Plain)*

There are three formations distinguished as representing the oldest known Coastal Plain sediments, those of the Upper Cretaceous epoch. The

* It is a copy of the Table, published by Brown (loc.cit.).

Cape Fear?

oldest, the Tuscaloosa formation is composed chiefly of loose sands which contain or which are interbedded with more or less kaolinic materials.

The second is called the Black Creek formation and is represented by two subdivisions. Its lower member, known generally as the Black Creek formation (recently named as Bladen member), is characterized by dark-gray or black, fissile, laminated shales, loose sands, and occasionally lignitic remnants of tree trunks, branches, or leaves, grains of amber. This lower member represents littoral and continental depositions. The upper member, known as Snow Hill member, shows an increase of lime content and the embedding of typical marine life which in places resulted in impure limestones.

The youngest Upper Cretaceous formation is known as Peedee formation, with a much more predominant marine character of shelf type sediments. It is composed of so-called "green-sands" (glauconitic beds), containing in places interbedded, impure, lenticular limestones, and indurated shell beds.

The members of the Black Creek formation outcrop within the extended area of the Cliffs of the Neuse State Park (see appended maps No. II and No. III). The older Tuscaloosa formation, outcropping along the "Fall Line", is in subsurface position below Goldsboro, Mt. Olive and Lagrange according to well records from those localities. The Peedee formation, on the other hand, is known in surface outcroppings east of a NE - SW line drawn through Kinston, North Carolina.

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The following Cenozoic era shows a more widely varied sequence in the deposition of the sedimentary cover on the North Carolina Coastal Plain. The oldest sequence of the Paleocene series, as well as the lower member of the Eocene series, are known only from subsurface studies of wells drilled in the eastern part of the Coastal Plain. The middle member of this series is represented by a few scattered outcrops, whereas the Castle Hayne limestone member, which represents the youngest part of the Eocene epoch, is known more widespread both from surface outcrops and subsurface data.

This youngest member of the Eocene series, showing outcrops also in the extended area of "The Cliffs of Neuse State Park", consists of predominatly sandy shell-limestones, calcareous sands and marls, having been in places silicified. The fossils, which can be collected from them, either preserved with shells or only as internal casts, molds, prove their marine character. The surface outcrops in the extended area of "The Cliffs of the Neuse State Park", which will be described in the proper chapter, supported by evidences from well records, indicate that the Castle Hayne limestone member is present west of the State Park only south of the Neuse River but farther eastward, below Kinston, it is known outcropping on both sides of the Neuse River.

The detailed time table of the North Carolina Coastal Plain sediments (Appendix No. IV) notes in a footnote that the sediments of the Oligocene epoch and the lower formation of the Miocene series are entirely missing from the North Carolina Coastal Plain. The unnamed Middle Miocene formation is not known to occur in outcropping sections, but its subsurface distribution is known locally from some of the north-eastern counties of the State.

Sediments of the youngest section of the Miocene epoch occur more frequently on the surface. They were separated into two formations:

1. The lower, the Yorktown formation, consisting of blue-gray marls and interbedded lenticular sands, usually containing abundant remnants of marine life of somewhat deeper waters, often with whale bones, phosphatic pebbles, concretions.
2. The upper, the Duplin formation, composed of light colored sandy shell beds, which is considered to have been deposited in a littoral or sublittoral environment.

These Miocene sediments may once have occurred as more or less continuous sheets. Today they are known only in relatively small areas, where they were protected from subsequent erosion. Although the Yorktown formation is known north of the Neuse River both from surface and subsurface data and in Northeastern North Carolina it reaches a thickness of about 300 feet, its only known occurrence south of the Neuse River is a single small area in the southwestern corner of Wayne County. The Duplin formation covers in considerably thinner sheet the Cape Fear River drainage area and extends to the South.

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At the present time, very little authenticated information exists concerning Pliocene and Pleistocene formations in this area. The sediments of the younger times were possibly deposited in this area, but to date their presence in type of marine character has been established only in the extreme coastal region. If that time sediments were present in the vicinity of "The Cliffs", they should consist mainly of materials of continental origin, local accumulations of stream gravels, pebbles, clays, and weathering products.

Sediments believed to be of Pliocene age have been described from the coast and perhaps from the southern parts of North Carolina. All of these, however, are still subjects of controversy. They are undoubtedly younger deposits than those of the Miocene series, often representing, however, reworked sediments of former marine life.

Likewise, the sediments of continental origin are still not precisely known. These are represented by seven (or two, depending on author) terraces, cut either by sea action or former rivers. One thing seems certain, and that is that after the withdrawal of the Miocene seas, no or only a relatively small area got a cover of marine sedimentation in North Carolina Coastal Plain, and that if any such deposition occurred, it has since been more or less removed through erosion.

The Geology of "The Cliffs of the Neuse State Park" and its surrounding area.

The geological formations which can be studied within the State Park and the surrounding area are shown on Geologic Maps (Appendix No. II and Appendix No. III). Both maps show only the factual surface outcrops of the formations as they are revealed in the river banks, road cuts, etc. Some well data establish the presence of this or that older formation beneath the younger overburden,* but also these data are partly too limited in number to allow conclusions concerning the possible extent of these older formations. However, these data do give evidence of deeply-carving erosional activity at places, resulting in the destruction of the older formations where they should logically be present.

The Geologic Map of "The Cliffs of the Neuse State Park and Vicinity" in scale of 3/8". 1 mile approximately (Appendix No. III) contains also such locations as were first described by Stephenson (1912),** although some of them were not personally observed. Likewise, there are included other outcrops about which I was friendly informed by Richard D. Pusey, Division of Water Resources, U. S. Geological Survey, Raleigh, North Carolina, who is presently making a new survey of Wayne and Johnston Counties.

A superficial glance at the geological map of the Park area seemingly indicates a very simple geological situation. Besides "The Cliffs", in which the sediments of the Snow Hill member of the Upper Cretaceous Black Creek formation are evident, sediments of that member were observed in two other small outcrops clear of their overburden. Also the nature in the most part of the Park area undifferentiated overburden can be seen only in a very few places, f.e. in the wall of "The Cliffs", on top of the Snow Hill sediments, where they overlie the older material on an irregularly formed surface (an unconformity). Apart from those very few locations, where the older sediments are outcropping, the sandy, pebbly parts of the "undifferentiated overburden" can be observed only in the soil and even this meager evidence is usually hidden by the dense vegetation, which conceals not only the nature and extent of the "undifferentiated overburden", but also of the formations which may be present beneath it.

Because of the relative stepness of the creek beds in the Park area - due to their short run and the relatively great relief of the watershed - I was expecting clean creek beds with an abundance of outcrops. I was surprised, therefore, at the extreme depth of the "undifferentiated overburden" and the paucity of outcrops (most of which are a result of man's disturbance).

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*The word: overburden is used here in the sense No. 2 of the "Glossary of Geology and related Sciences, AGI, 1957, p. 208: "overburden designates only loose soil, sand, gravel etc., that lies above the bedrock".

**Complete reference in bibliography.

The section exposed in "The Cliffs" is well described by Stephenson (loc. cit., pp. 134-135,-1912). I quote his description as follows:

Pleistocene:

Sunderland formation (?): Feet

Light-yellow sand....................................12

Band of small pebbles with sand matrix.................1.5

(Unconformity).

Cretaceous:

Black Creek formation:

Light greenish-gray sand, mottled with yellow..........5

Dark to black clay, chocolate-colored where weathered, with seams of fine sand and seams of peaty material in which occur small amber grains, the whole mottled with yellow....................................4

Chocolate-colored, sandy clay, mottled with sulphur and iron stain....................................1.5

Pale greenish-yellow, fine grained, cross-bedded sand with a large percentage of brown, partially weathered, glauconite grains..............................4

Chocolate-colored, sandy clay, with laminae of sand at base, mottled with sulphur and iron stain........2.5

Pale greenish-yellow, glauconitic, cross-bedded sand, with some clay laminae. The glauconite grains are weathered brown....................................1.5

Chocolate-colored, glauconitic, coarse, sandy clay, becoming more sandy at base........................3

Chocolate-colored clay interlaminated with green and yellow glauconitic sand............................2.5

Light argillaceous sand, mottled with chocolate tints..3.5

Dark, chocolate-colored, slightly indurated argillaceous sand..4

Pale greenish yellow, and darker chocolate-colored sands, more or less argillaceous in different layers, mottled with iron and sulphur stain, and containing some indeterminable shell casts....................25

Yellow and purple, coarse, ferruginous, cross-bedded sand, for the most part indurated to sandstone.....11

As it is shown, Stephenson differentiated below the 13.5 feet of "Pleistocene, Sunderland formation (?)", a 56.5 feet thick sequence of the "Black Creek formation". The "Black Creek" material continued downward another 11 feet, being visible at its lowest point as yellow and purple, coarse, ferruginous, cross-bedded, for the most part indurated, sandstone.

New measurements, made from the small monument near the parking area, where the top of "The Cliffs" is 4 feet below the 121-122 feet elevation of the monument, showed a thickness of 16.7 feet for the so-called "Pleistocene, Sunderland formation (?)". Downward from the uneven top of the Snow Hill member of the Black Creek formation, a thickness of 59.2 feet was measured to the top of the indurated sandstones. The exact thickness of the sandstone beds could not be determined, at it was not determined by Stephenson, because these beds continue below the surface of the Neuse River.

The small difference between the two series of measurements is due perhaps to differences in the exact points at which they were measured, and probably also to small undulations along the strata or to lithologic changes in the sequence.

In addition to Stephenson's descriptions, I want to mention that the lowest visible, ferruginous, mostly indurated, sandstones are also observable in the bed of Still Creek, just above its junction with Mill Creek. The water there falls over small cascades, but all other cascades along this creek are caused by roots, fallen trees, etc.

Small pieces of a ferruginous sandstone can also be found along the trail which leads from the monument toward the Bird Trail and Galax Trail. These are at a higher elevation than the sandstone of "The Cliffs" and may belong to Stephenson's "Pleistocene, Sunderland formation (?)".

Within the sandstones outcropping near the Neuse-level are previously undescribed tube-like, sometimes branched fillings of the same material and color, which usually may be removed from the matrix. These may be fillings of worm tracks in the originally loose sands.

Stephenson mentioned in his section a 25 feet thick sequence, sedimented over the lowest ferruginous sandstones, which contained "some indeterminable shell casts". In the present condition of the outcrops, it was possible to obtain from the upper part of these yellowish brown loose sands (about 52-53 feet below the level of the monument), more or less preserved, very breakable, partly leached, shell bearing fossils, which could be collected and saved for determination. Above these loose sands a 2.7 feet thick horizon of the same material contains smaller to larger, more or less cemented concretions and loose sandstone lenses, containing a good number of casts, sometimes imprints and also shell bearing fossils. Although in most cases only generic determination was possible, some specimens were well enough preserved to afford specific determination. This small fauna assemblage, which needs further comparative study, is composed of Isognomon (tree oyster*), Ostrea (common oyster), Gryphaea (Cretaceous relative of oysters), Pecten (scallop), Trachycardium (cockle), Tellina (tellin), Etea (a distant Cretaceous relative of the "oceanquahog"), Nucula (nut clam), Anomia (jingle shell), Cymbophora (Cretaceous type of surf-clam), and different Arca species (arks) in great number. A small Seminola specimen (a relative of the buccinums), some Ataphrus (top shell), similarly several specimens of the genus Trichotropis (a relative of the hairy shells of the today Arctic Ocean) are representatives of the snails in the assemblage besides many tubes of the Vermetus genus (worms), and other, indeterminable casts of shells. Finally some shark types also are represented by teeth, such the genera Galeocerdo and Scapanorhynchus, collected on "The Cliffs" and the genus Odontaspis, gained from the concretionary layer near the spillway of the Park Lake. This small fauna assemblage establishes the correct position of these beds as being within the Snow Hill member of the Upper Cretaceous Black Creek formation, representing an encroachment of the sea upon the mainland (transgression, or onlap), forming an environment along the shoreline like the oyster-banks of today. The nearshore: littoral, sublittoral or even paludal environment, which characterizes the older (=Bladen) member of the Black Creek formation, with its lignitized wood fragments, returned, nevertheless, at least once more. This reverse movement in the oscillation of the shoreline (regression, or offlap) is well established by the dark colored lignitic beds in the upper part of "The Cliffs" above the concretionary horizon, which contains already marine life remnants.

Such concretions, containing marine shells, were also found in a small area on the east side of the spillway below the Park Lake, as mentioned above. Furthermore I have been informed by Dr. Phil M. Brown, geologist, U. S. Geological Survey, Division of Water Resources, Raleigh, North Carolina, that he and Richard D. Pusey have found the same type of rock also downstream from "The Cliffs" along the Neuse River. These three localities may represent a certain horizon, which, following the general dip of these sedimentary groups, slowly dips toward the East, or they may have been formed in different levels of the advancing Snow Hill sea. Just how they fit into the general geology of the Snow Hill member of the Black Creek formation may be proven only by exact determination of their elevations and by further investigation of similar type outcrops within the Snow Hill member. Some additional specimens of the same material, collected at "The Cliffs" are in the collection of the North Carolina State Museum of Natural History.

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*The English name of these fossils are mentioned according to the names used by Tucker R. Abbott in his book: "American Seashells".

In the upper part of "The Cliffs", as was mentioned in the discussion of the detailed section, there is also a younger group of sediments. Stephenson determined this to be "Pleistocene, Sunderland formation (?)", and measured its thickness as 13.5 feet (loc. cit., p. 134). In the course of the present investigations, this uppermost sedimentary ~~sedimentary~~ sequence was found in a thickness of 16.7 feet. The uneven surface on which these younger sediments cover the Cretaceous group lies at an elevation of about 101-102 feet above sea level.

The lower 3.2 feet of these strata is composed of fine sand containing abundant pebbles, while the upper part is composed of white to orange, fine to coarse sands. The pebble-containing layer is cemented in places by calcium carbonate, forming short lenses of conglomerate, which might be also blocks of some older basal conglomerate. This material is visible also on the small promontory southeast of the main cliff.

Somewhat similar, but more ferruginous, looser, semi-consolidated sandstone, locally with small clayey nests, was recently observed at a little bit higher elevation along the west side and near the spillway of the Park Lake, on the northeast end of the lake. However, the absence of more or less continuous outcrops made it impossible to determine whether these partly indurated, loose sandstones are contemporaneous with the conglomeratic horizon near the top of "The Cliffs", or they represent a later deposition. Perhaps the ferruginous sandstone fragments along the trail leading from the monument to Mill Creek may be correlated with those, known now along the lake, but the distances between these localities are too long to permit exact determination of this relationship.

On the before-mentioned promontory toward the southeast edge of "The Cliffs", the lower, pebbly, conglomeratic part of the sequence also contains fossils. In addition to several shark teeth, which represent the Isurus, Odontaspis and Scapanorhynchus genera, a Crocodilian tooth, in all probability of the genus Polydectes, an undeterminable bone fragment, a tiny, thin-shelled Brachiopod, (Terebratulina lachryma) and several small oysters have been found. These fossils, with the exception of the small Brachiopod, are not exact indicators of the age of this horizon, they are present in both Cretaceous and Eocene sediments. The Brachiopod species, Terebratulina lachryma originally was reported from "Cretaceous" beds of South Carolina, but later the age of beds which contained this fossil, was rectified as Eocene and the species was found also in the Eocene beds of North Carolina around Wilmington, North Carolina. The present condition of this tiny Brachiopod containing conglomeratic blocks, which in all probability may be remnants of the Eocene basal conglomerate on the top of

"The Cliffs", is proof of local reworking of those sediments, which action might have occurred at any time later, or, at least a very short transportation of the material from nearby areas. Such Post-Eocene reworking as mentioned, could have taken place during the Oligocene, during the Upper Miocene, when the area north of the present Neuse River was newly covered by a progressing sea. It is also possible - though I personally doubt it - that a reworking of the Cretaceous and Eocene surface was done by rivers during Pliocene, or even Early Pleistocene time. As stated earlier, the present state of the fossil material, collected from these blocks, indicates rather a local disintegration of the rocks containing them than a longer transportation by rivers.

Determination of the age of the uppermost, fine to coarser sand sequence on the top of "The Cliffs" is much more difficult because of the total lack to date, of any fossil material. This sequence might have been deposited at any time after the Cretaceous period - or rather after the Eocene Epoch. This latter theory is more credible because the top strata of "The Cliffs" differ completely in character from known Cretaceous and Eocene sediments in the vicinity.

It is regrettable that no very definite conclusions could be drawn from the study of the three wells now existing in the Park (shown on the map, Appendix No. II). Well No. II was drilled by the Heater Well Company. The only available information concerning it is its depth (87 feet), and its elevation above sea level (113 feet).

A second well (No. I on the map) was drilled by the now non-existent Hickory Well Company. Its elevation is 129 feet and its depth 134 feet. A drillers' log is available for this well.

The third (No. III on the map) was drilled late October and early November 1958, by the Poole Brothers Well Company, Raleigh, North Carolina. A series of samples were taken from this well (elevation about 150 feet, depth 126 feet).

Data from the Hickory-well indicates that the in all probability Post-Miocene overburden (composed of sands and occasional clays) was penetrated at the depth of 42 feet (87 feet above sea level). Between 42 and 100 feet (87 and 29 feet above sea level, respectively) the drillers' log mentions a similar sandy sequence, which, however, contained "small black grains". It cannot now be determined whether these grains were small fragments of carbonized wood material, phosphatic materials, or any other minerals. The first assumption seems to conflict with the fact that the log emphasizes the presence of "carbonized wood fragments" in addition to the "black grains" in the following entry. If the "black grains" should indeed be carbonized wood fragments, the Black Creek formation (called here in general sense) begins in this well at the depth of 42 feet (87 feet above sea level). There is, however, no indication of the presence of fossil-containing lenses, concretions of the Snow Hill member of that formation, known in the nearby sequence of "The Cliffs". If these grains were phosphatic material, this sequence might have been sedimented either in Eocene or Miocene times, or, through any later reworking, even in Pliocene or Pleistocene.

In the Hickory-well (No. I), definite proof of the Black Creek formation was encountered at a depth of 100 feet (29 feet above sea level). Also in this section is no evidence of the younger, Snow Hill member of the formation, but the log notes the presence of the "carbonized wood fragments" associated with the Bladen member of the Black Creek formation. (Since the verified presence of the Black Creek formation in this well as mentioned, encountered at the depth of 100 feet (29 feet above seas level), I indicated the subsurface of this formation in the cross-section (Appendix No. II) at this depth and the formerly mentioned possibility that the formation was encountered at the depth of 42 feet (87 feet above sea level), I marked with a question mark.

The deepest part of the well is represented in the drillers' log as sands, containing both "black grains" and "carbonized wood fragments". This zone between 120 and 134 feet depth (9 feet above and 9 feet below sea level) differs from the next shallower zone between 100 feet and 120 feet depth (29 to 9 feet above sea level), only in the grain size of the sands. In the upper zone, the sand is finer grained, while in the lower zone it is medium grained. As mentioned, the presence of carbonized wood fragments in both of them is definite proof of their being part of the Black Creek formation.

I was expecting that the recently drilled Poole-well (No. III) would provide some fossil material which would give an indication of the sequence overlying the Black Creek sediments. Unfortunately, the sequence penetrated in this latter well showed a similar lithological character to that of the Hickory-well, and also did not furnish any fossil material. This condition, however, resulted in new problems.

In the Poole-well, the Black Creek formation was first encountered at a depth of 96 feet (54 feet above sea level), when the bailer carried up some fragmentary carbonized wood pieces and dark gray mud. The same material continued to a depth of 109 feet (41 feet above sea level. This 13 feet thick sequence was characterized by a low percent of glauconite grains and mica lamellae, which were missing both in the overlying and underlying sections of the well. The carbonized wood fragments composed about 15% of the 96-foot sample, decreasing to 5% at the lower depths. The clay and sand ratio in these partially washed samples was 50-60%

Well drilled in [illegible]

0-20' undivided Holocene-Pleistocene
20-107 "B" } Cretaceous Black Creek Fm.
107-255 "C" }
255-330 "D" Cretaceous Cape Fear Fm
330-363 "F" unnamed
363 + Basement

clay, 30% sand (determined by Richard D. Pusey, U. S. Geological Survey, Division of Water Resources, Raleigh, North Carolina).

Beneath the Black Creek section, the well crossed to its total depth of 126 feet (24 feet above sea level) a generally tan, pebbly sand sequence in which the quartz-content rises to 90%. The last 5% is made up of small pyritic aggregates and a few per cents of feldspar and black opaque grains. The presence of the pyrite, usually indicating stagnant conditions on the sea bottom, might favor the assumption that this lowest sequence also belongs to the Black Creek formation. However, the sandy, pebbly character of the material seems contradictory to the above conclusion. There is good possibility, therefore, that this lowest section belongs either to the deeper Tuscaloosa formation, or that it at least represents a transition between the Tuscaloosa and Black Creek formations. The fact that the Tuscaloosa formation immediately underlies the 13-foot thick undifferentiated, Post-Miocene overburden in the nearby Goldsboro well (Phil M. Brown, well record, loc. cit. p. 53) and there covers the "basement rocks" to a depth of about 80 feet, somewhat confirms this hypothesis. Assuming that the Tuscaloosa sediments may show an uneven surface, it seems possible that this material may lie closer to the surface in the Park area than might normally be expected. Moreover, it would not be surprising me, if the Tuscaloosa formation were encountered only a short distance below "The Cliffs" and that there also the "basement rocks" should bulge upward beneath their sedimentary dover.

Absolutely no positive evidence of the age of the 0 -96 feet section was recovered from the Poole-well. Although the clay content nearer the surface was more or less considerable (rising to 70% at the depths of 23 and 75 feet, quartz was the dominant component. Some samples contained 95-98% quartz, consisting of bluish or yellowish grains and pebbles and partly covered by a thin coat of iron stain. Iron concretions were rare, but feldspars and black opaque grains were found throughout this section, stated by Richard D. Pusey. It seems probable that this first 96-foot section of the Poole-well represents at least Post-Eocene, or more likely Post-Miocene sedimentation, as did the first 100-foot section of the Hickory-well. Perhaps new data will someday provide bases for a closer age determination.

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In summary of all these mostly negative results, it may be stated that the (probably) Tuscaloosa formation (pebbly, gravely, deepest section of the Poole well) underlies the along-shore, sublittoral or even paludal sediments of the Black Creek formation within the Park. These sediments form an outcrop in "The Cliffs" where also their younger member is present, but the subsurface slopes slowly toward the Hickory-well and again rises toward the Poole-well. The presence of this shallow, eroded trough (shown in the cross-section on the Appendix No. II) may explain why no evidence of the Snow Hill member of the Black Creek formation with its fossiliferous concretions was found in the wells even though they are present in the same elevation in "The Cliffs". If such marine deposition was once present in the interior of the Park area, it was later removed by erosion that formed the trough. The surface of the Black Creek formation throughout this area no doubt shows other topographic features (hills, holes etc.). In such hilly parts, which remained preserved from the erosional activities, remained also small concretionary nests, where also the younger Snow Hill member remained preserved, e.g. on the side of the spillway.

No. sure evidence of Eocene limestone or marl was found in the Park area (either in well samples or on the surface), although they are present nearby. However, despite any definite evidence fixing the age of the pebbly layer which overlies unconformably the Snow Hill sediments in "The Cliffs", its fossil content, which may represent both Cretaceous and Eocene life) and its calcareous cementing mate.ial yet may indicate Eocene origin, especially if the Eocene age of the small Brachiopod _Terebratulina lachryma_ is accepted as a decisive factor. Even if later erosion reworked this, in all probability Eocene basal conglomerate, its blocks remained at the place of their destruction and certainly prove that Eocene sedimentation took place in this area.

After the retreat of the Eocene seas, the area was subjected to a certain amount of erosional activity, resulting on the other hand also in accumulation of loose sediments. Such erosional activity could have been in progress during the Oligocene epoch or the earlier part of the Miocene epoch, when the sea retreated from the entire Coastal Plain of North Carolina. To date, no evidence of material from the period between the Upper Eocene epoch, which sedimented the Castle Hayne limestone and the deposition of the Middle Miocene phosphatic sands has been found in North Carolina, and the latter formation is known only from subsurface data from northeastern North Carolina. It seems, moreover, that the Upper Miocene sea, which deposited the Yorktown formation north of the Neuse River, did not cover the area of the Park (despite a small area west of the Park near Grantham, Wayne County, North Carolina). Furthermore, it seems probable that the likewise Upper Miocene Duplin sea, which covered a larger part of the Coastal Plain south of the Neuse River with more marly and sandy sediments, did not extend ~~to the State Park.~~ It seems to me that this part of the Neuse - Cape Fear River watershed, stretching from west of Mount Olive to the State Park, which was built up of

Cretaceous and Eocene sediments, as a long, narrow peninsula divided the sedimentation areas of the Yorktown and Duplin seas. If this premise is not correct, the only other explanation for the complete absence of the Upper Miocene sediments in the State Park area would be their total destruction by a new erosion cycle, after the retreat of the Upper Miocene sea from the North Carolina Coastal Plain. This last period, which continues also today, began in the early Pliocene. It is definitely responsible for the present relief and recent surface deposits, and was influenced by the changes in drainage patterns and an abundance of flowing water.

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The oldest Upper Cretaceous Tuscaloosa formation is located in submerged position at Goldsboro. The overlying older, nearly along-shore Bladen member of the Black Creek formation outcrops at many places in the vicinity of the State Park, first of all along the Neuse River, depending on the water level. Such localities were found and described by Stephenson (loc. cit., p. 133-136) below the Highway 117 bridge, south of Goldsboro, at mileposts 93 and 92, 1/8 mile above the Arrington Bridge and at several point between that bridge and the bluffs formed by the Sarpony Hills at their junction with the Neuse River (milepost 83 1/4). Along this section the normal Black Creek (Bladen member) material is exposed, which contains lignitic material, grains of amber, and pyritic aggregates. In addition, plant fossils representing ancestors of the genera Araucaria (today a South American and Australian conifer), Sequoia (Red Wood), Ficus (Fig), etc., were found at these sites. Stephenson found the first evidence of the landward progress of an oscillating sea - poor casts of cockles together with leaf remains - at a point 87 5/8 miles aboue New Bern. Downstream from the bluff of the Sarpony Hills the Bladen member submerges beneath the river, but emerges again for a shorth distance at milepost 83 (above Broadhurst Bridge), and again at mile post 82 (a short distance below the bridge). I saw a somewhat better exposure of the same material, with glauconitic interbeddings, along the western part of the northward turning bend of the Neuse River below the Broadhurst Bridge. On the eastern part of this big bend, nearer "The Cliffs", at milepost 79 1/4, Stephenson found the first definite evidence of the Snow Hill member of the Black Creek formation. Here the sediments contained determinable casts of different clams. Shortly below milepost 77, but now on the left bank, pyritic casts of "tree oysters" were found by Stephenson ("The Cliffs" are located at milepost 76 1/2). Several localities in the vicinity of Seven Springs (milepost 75) were also mentioned as containing some fossils. One, at the "Ninth Spring", consisted of dark green marine clay, yielded 18 types of pelecypods and 2 of gastropods. From the bed of the Neuse River, a well preserved internal cast was dredged among others at Seven Springs. The best of those far relatives of the today pearly Nautilus (ammonites) is partly covered with its original pearly shell remains, and clearly shows the sutures (partitions between the gradually abandoned living chambers). It is currently exhibited in the State Museum of Natural History, Raleigh, N. C.

The evidence presented by sporadic outcrops definitely prove that the western part of the Neuse - Cape Fear River watershed between Mount Olive and Seven Springs is built up by the Bladen member. It is probable that under the eastern part of this watershed-section these more along-shore deposits change to the nearshore Snow Hill member of the Black Creek formation. Additional evidence tending to corroborate this theory came from the well at Mount Olive. Here, beneath 17 feet of undifferentiated overburden, the Bladen member was found resting on Tuscaloosa material. However, the only possible evidence of the presence of the Show Hill member already in this area were a few broken and abraded shell fragments from a depth of 71-91 feet (Brown, loc. cit., p.53). This may be an indication that the transition between the two members also took place here.

It was mentioned earlier that the continuity of the Black Creek outcrops along the Neuse River occasionally seems interrupted. This apparent interruption is caused by the presence of Upper Eocene, Castle Hayne marly limestone at those localities. The limestone appears to fill more or less deep depressions on the eroded (faulted?) Cretaceous surface. A rather long area of this material is observable on an almost 100 feet high bluff, where the Sarpony Hills contact the Neuse River, 83 1/4 miles above New Bern, mentioned already by Olmsted in 1827 (loc. cit., p. 96). Downstream from this locality the Black Creek sediments again come into view, but a second depression (at the mouth of a small creek just above Broadhurst Bridge, and a third (about 1/2 mile below the Bridge) shown again the Eocene limestone outcropping. If the limy basal conglomerate in the upper part of "The Cliffs" is not an Eocene outcrop, or at least the remains of one, the next known downstream Eocene outcrops are south-east of Kinston, N. C.

Other surface data and well records establish the presence of Eocene sediments along the southern strip of Wayne County and Northern Duplin County, where it exists as fillings and a more or less thick covering on the surface of the Cretaceous formations. These materials are known from the Sarpony Hills, themselves, southeast of Genoa; along the Buck

Swamp and its tributaries, northwest of Mount Olive; and along a small creek west of Mount Olive and also southwest of that town. Finally, the record of a well drilled in the town of Mount Clive indicated that Eocene limestone was present as a thin cover also in that area (Brown, loc. cit., p. 53). These data imply that the Eocene limestone is present in at least a thin sheet over much of the Black Creek formation, that it probable was thicker that it is today, but has been greatly reduced through later erosion.

Concerning the next younger sediments of the Upper Miocene, specifically of the Yorktown formation, I mention again the greenish sandy clays, containing typical mollusks, which were dredged from a small pond northeast of Grantham, North Carolina. The presence of the same sediments was determined, through the use of augerholes, in a somewhat larger area between Cox Mill and Grantham (Richard D. Pusey, personal communication). This small area is the single known location of the Yorktown formation south of the Neuse River.

Geological History of the State Park Area.

Although some events of the geological history of "The Cliffs of the Neuse State Park" area have been mentioned in the previous chapters, I am sure it will be helpful to make a synthetized sketch of this history in chronological order.

Some data concerning the "basement rocks", the oldest rocks underlying the Coastal Plain, are available for this region. Although they are now cevered by younger sediments, they have been encountered in many deep wells within the Coastal Plain. These well data revealed the fact that "the basement rocks" are the same type that occur on the surface of the Piedmont peneplain. Therefore, in deciphering the oldest chapter of the history of the area discussed in this report, we may make conclusions from the data already compiled through studies of the Piedmont. This similarity or even identity of materials informs us that the "basement rocks" are of Proterozoic and Paleozoic origin, making up part of an old shield, called Appalachia. During the formation of this old shield there were times of submergences, when different types of sediments accumulated, and times of more or less intensive igneous activity. The igneous material, influenced also by crustal movements, was forced into the previously existed rocks, forming granite, monzonite etc., masses - visible at William B. Umstead State Park - and, through contact metamorphism, transformed portions of the former rocks or even themselves into gneisses, schists, phyllites, and slates, etc.

All these events are believed to have taken place during the Proterozoic era, perhaps contemporaneously with the formation of the same type old mass, the Canadian Shield. Recent studies revealed that such deep-seated igneous intrusions also occurred in the Ordovician period of the Paleozoic era in connection with the so-called Taconic disturbance. It is also assumed that some formation of the "basement rocks" took place during the period of strong mountain building crustal activity toward the end of the Paleozoic era, which eventually gave rise to the present Appalachian Mountains during the Permian period. The extent to which the "basement rocks" of the Coastal Plain area participated in these movements is still not nearly understood.

It is known that, following the crustal movements, which originally built up the Appalachian Mountains, this and the surrounding area got no sea cover for a long geological interval. Within the first period of the Mesozoic era, the Triassic period, troughs were formed in the area of the present Piedmont peneplain and Coastal Plain, which were subsequently filled during the later Triassic period by continental sediments. Red sandstones, conglomerates, clays and coal were formed in various localities. It is not understood to date whether such Triassic continental sedimentation took place on the North Carolina Coastal Plain. Some sediments, believed to represent them, have been taken from deep wells in the northernmost part of the State, but their identity is not well established. It seems more probable that, in general, the whole area was subjected to erosion, which carried away a great mass of the rock material, contributing to the formation of am almost even, gently eastward sloping surface - the Piedmont peneplain.

It is an interesting negative fact that neither marine nor continental sediments representing this long erosional period have been found on the Piedmont peneplain or on the surface of the "basement rocks" beneath the Coastal Plain in North Carolina. It is certain that this erosional activity finally planned off also all of the continental sediments accumulated in the Triassic troughs. Therefore, it must have occurred mostly after the Triassic period.

The other limit of that erosional period in the North Carolina Coastal Plain is evidenced by the first appearance of the continental deposits of the Upper Cretaceous epoch (= Tuscaloosa formation). Then, with the gradual submergence of the present Coastal Plain, there follow along-shore sediments (=Bladen member of the Black Creek formation), shallow marine deposits (= Snow Hill member of the same formation), and shallow water, shelf-type material (= Pee-dee formation), all representing successively younger phases of the Upper Cretaceous deposition.

During the period of the development of the Piedmont peneplain there were also crustal movements of a minor scale, resulting in the Triassic sediments being split into blocks and the intrusion of diabase dykes into all types of older rocks. These intrusions resulted in, for example, the production of natural coke from Triassic coal beds adjacent to the dikes.

With the initiation of this relatively slow sinking of the present Coastal Plain in the Upper Cretaceous epoch, that part of the history of our area which may be more easily deciphered begins. The slow subsidence caused level differences, and the rejuvenated erosion began a new destruction of the peneplained surface. This resulted also in sedimentation over this area, building up here the so-called arkosic sands, disintegrated products of granitic rocks on the site of weathering, and into bedded clays and gravels which we know today as the Tuscaloosa formation. With progressive sinking, still within the Upper Cretaceous epoch, the formerly on-shore and continental depositions became overlain by alongshore, gradually more frequently occurring marine interbeddings containing sediments and much lignitic materials (Bladen member of the Black Creek formation). This likewise received, through the progressive sinking of the environment, a new cover of shallow marine sediments - much as occur on our present oyster banks (Snow Hill member of the Black Creek formation). The deposition of the shelf-type shallow marine sediments (Peedee formation) represent the final result of this general sinking period.

While these Upper Cretaceous formations occur on the surface in successive coastward belts, and underlie younger formations throughout the North Carolina Coastal Plain, the sediments of the following younger, Paleocene epoch of the Tertiary period are not known at all from surface outcrops. Their presence has been determined in a restricted area in some of the northeastern counties from subsurface data. South and west of Pitt County no traces of these sediments have been found to date. This restricted occurrence of Paleocene sediments proves that at least a part of the Upper Cretaceous sea bottom rose above sea level during the last part of the Cretaceous period or toward the beginning of the Paleocene epoch of the Tertiary period. While this new land-surface was being attacked by erosion, the still-submerged northeastern part of the State continued to receive sediments during the Paleocene epoch.

The same general history also pertains to the earliest section of the Eocene epoch, but this time the sedimentation occurred a little farther south. The greatest concentration of these sediments is in Craven, Jones and Onslow counties. Their sporadic occurrence also on that area and their variability in thickness suggest that they were once probably more widespread, but have been reduced through erosion.

This rather local emergence after the deposition of the Lower Eocene sequence was followed again by a submergence, which also did not extend all over the North Carolina Coastal Plain, as it can be concluded from the well data, showed by P. M. Brown in his cross=sections (loc. cit., figs. 2-9). No outcrops of Middle and Upper Eocene (Castle Hayne limestone) sediments are known north of the Neuse River, and their subsurface distribution is limited to the area south and east of Washington, Martin, Pitt and Lenoir counties. It seems probable, therefore, that the region north of the Neuse River and west of a line drawn through the eastern boundaries of Martin, Pitt and Lenoir counties was not covered by the Castle Hayne Sea.

As was mentioned earlier, no sediments representing the entire Oligocene epoch and the earlier part of the Miocene epoch have been found in the North Carolina Coastal Plain. This negative date, nevertheless, is definite proof that the area was above sea level during this time interval and was being attacked by erosional forces. By Middle Miocene time, the previously elevated area north of the Neuse River had either been peneplained, or had sunk down along fault zones. It remained still above water throughout the Middle Miocene, for Middle Miocene phosphatic sands are found only in Beaufort, Washington, Gates and Hyde counties and are absent from Martin, Pitt and Lenoir counties. During Upper Miocene time, this emergent area was finally covered by a new sea invasion, and received a cover of sediments representing a littoral and sublittoral environment (= Yorktown formation). During this time, or perhaps a little later, a thin blanket of the light-colored sandy beds of the Duplin formation were deposited south of the Neuse River. Because neither of the above Upper Miocene formation is found along along a narrow strip on the present site of the watershed between the Neuse River and Cape Fear River, (including "The Cliffs of the Neuse State Park"), it seems probable that a peninsula existed here, separating in this part the Upper Miocene seas.

This concludes that part of the geological history of the North Carolina Coastal Plain which may be determined with relative certainty. The history of the following 12 million years - from the end of the Miocene epoch until the present - is still a subject of controversial opinions. One fact is certain: after the deposition of the Upper Miocene

Yorktown and Duplin formations, the sea sedimentation became restricted to a belt near the present shore line, rarely exceeding 100 feet elevation. Landward parts of the Coastal Plain in North Carolina were being subjected to new erosion which carved river valleys to their present topography and filled other areas with gravel, sand, clay, etc. Behind the "Fall Line" the so-called High Level Gravels cover large areas in considerable thickness. To date, there is no evidence of the time of their origin. They may be reworked masses of erosion products left behind during the beleveling of the Piedmont Peneplain.

Eastward of the "Fall Line", these and other gravels form terraces at progressively lower levels toward the coast. Just how these 7 (or 2, depending on the author) terraces were formed is still another unsolved question. They may by of marine origin (?), having been carved out by various levels of an oscillating sea; they may be river deposits, or they may be the results of a combination of these two factors. The difficulty in arriving at a conclusion arises from the lack of fossils, particularly in the older, higher lying deposits beginning with the Pliocene. Even when fossils are present, as in the case of the more coastal, younger sediments, great care must be exercised in determining which fossils are representative of the age of the deposition, and which have been reworked and even transported from older sediments. A good example of such difficulties was mentioned in the previous chapter concerning the interpretation of the pebbly layer which covers the Cretaceous sequence toward the top of "The Cliffs".

Structural features. Conclusions.

Although the crustal movements which resulted in structural features of the Coastal Plain have been mentioned in previous paragraphs, it might be well to summarize the data concerning them and the effect they have had upon the present topography.

In order to understand the structural features of this region, it is necessary to turn once again to the "basement rocks". It was once believed that the surface of those rocks sloped uniformly beneath its younger sedimentary cover, but with the increasing amount of data from deep wells, certain irregularities of that surface became apparent. In the central part of the Coastal Plain the northwest-southeast slope was found about 14 feet per mile, calculation based on the Havelock-well data (Craven Co.) But new data from the Morehead City-well showed that toward the coastline the surface steepens to about 122 feet per mile. Even at this latter section, the slope amounts slightly over 1 degree.

Additional data revealed that, in addition to this general slope toward the Atlantic Basin, there are also undulations along the northeast--southwest direction, which have had a profound influence upon the development of the Coastal Plain. The crustal movements, resulting in the formation broad ridges and troughs determined areas of emergence and submergence, and thusly areas of erosion and deposition during different periods of geologic time. In summary, the general dip to Southeast of the "basement rocks" beneath the Coastal Plain resulted in a progressively thicker accumulation of sediments toward the present coastline while the undulations in this surface produced areas of greater or lesser deposition along the NE - SW direction.

One such ridge was described by Glenn (loc. cit., p. 375 - 379) as the "Hatteras axis", which should have influenced sedimentation during the Triassic and Miocene times. Although the position of this "axis" has not been delineated, it was also thought by Glenn to have influenced the distribution of the faunal elements of the Upper Miocene formations along the North Carolina Coastal Plain.

A second such deviation in the slope of the "basement rocks" is known as the "Cape Fear Arch" or the "Great Carolina Ridge" (Stephenson). The surface of the "basement rocks" lies at a relatively shallow depth throughout the whole area of the North Carolina Coastal Plain along the "Cape Fear Arch".

These subsurface undulations on the top of the "basement rocks", with their main direction roughly perpendicular to the axis of the Appalachian chains, may be interpreted simply as flat slopes, caused by erosion. Furthermore, they may be interpreted as the loci of structural movements - fault zones, zones of warpings. The thinning or even the total absence of sedimentary units as they approach these fault zones, zones of the weakness, is a proof that these unstable areas influenced the sedimentation in parts of the North Carolina Coastal Plain. The "Hatteras axis", in all probability a NW-SE zone of weakness, influenced the deposition of the Triassic sediments, for example. North of it, toward Virginia, the "basement rocks" are covered initially concerning the deep well data by sediments of the Triassic period. South of the "Hatteras axis" no sedimentation took place on the North Carolina Coastal Plain until south of the "Cape Fear Arch", where they are known in subsurface through the deep well of Florence, South Carolina. North of the "Hatteras Axis" the Cretaceous and Eocene formations are relatively thick, while between the Hatteras axis" and the "Cape Fear Arch", they are somewhat thinner. The members of the Middle Eocene formations, which occur on the surface in Virginia and northeastward, are found only as phosphatic sands in a trough near the "Hatteras axis", and wedge out toward the "Cape Fear Arch".

To return to our local area, in my opinion "The Cliffs of the Neuse

State Park" lies on the northeast wing of the "Cape Fear Arch". However, this part of the region between the ridge of the "Cape Fear Arch" and the deepest part along the "Hatteras axis" is divided by an intermediate structural feature, which I would like to call the "Cape Lookout - Neuse fault zone". This zone runs along the Neuse River in a NW-SE direction. During the Middle and Upper Eocene (of?) a land area along this zone limited the northeastward progress of the Eocene seas, resulting in the deposition of Eocene limestone only south of the Neuse River-line and in complete absence of those sediments north of that line. Again, during the Upper Miocene period, this zone limited the deposition of the Yorktown type sediments, which are covering the Coastal Plain north of the Neuse River.

This fault zone must also have been active during the Oligocene and Lower Miocene times, perhaps in connection with some geyser activity. I am sure that such geysers caused the silification of the Eocene sediments along the fault zone in the following localities: in the railway cut, Garner; at the boundary of Wake and Johnston counties on the old U. S. 70 Highway, Auburn; southwest of Dudley, Wayne Co., with silicified Bryozoan stocks; southeast of Kinston, Lenoir Co., mentioned by J. L. Stuckey (loc. cit., p. 22.23). Perhaps the silification of the Eocene Castle Hayne limestone, formerly described and distinguished as the Trent formation, may also be considered a result of such geyser activity. Undoubtedly, the greatest intensity of geyser activity took place where the "Cape Lookout-Neuse fault zone" crossed another similar zone of weakness: the previously mentioned western boundary of the Lower, Middle and also Upper Eocene seas, along the eastern borders of Martin, Pitt, and Lenoir counties. It seems certain, too, that activity along this fault zone resulted in the present level differences in the surface of the "basement rocks", as shown by well data. In Craven County, the "basement rocks" lie at depth of about 2500 feet, while in Pamlico and Carteret counties they are at least around 4000 feet below the surface. Additional proof of this zone of weakness is seen in the asymmetry of the Neuse River drainage area below Smithfield, where the fault zone greatly restricts the southern portion of the drainage area. A similar morphology has been caused and influenced by the "Cape Fear Arch" in the run of the Cape Fear River on the Coastal Plain portion. Although the "Hatteras axis" no doubt has had an effect upon the course of the Roanoke River, its past influence is not as evident today as that of the "Cape Fear arch" and the "Cape Lookout - Neuse fault zone" upon their respective rivers.

Just as the location of the "Cape Fear arch" and the "Hatteras axis" predestined the location of Cape Fear and Cape Hatteras, respectively, the location of the "Cape Lookout - Neuse fault zone" predestined the location of Cape Lookout*.

In addition, I am convinced that this fault zone played at least some role in the formation of "The Cliffs of the Neuse" and also of the bluffs of the Sarpony Hills. On the other hand, the presence of the somewhat more resistant ferrugineous sandstone at the present bottom of "The Cliffs" and the concretions, which contain there the Snow Hill fossils, finally the former Eocene limestone cap on the top of "The Cliffs", have preserved the scarp to the present day. The active force which was most instrumental in finally forming "The Cliffs" as they exist today was a gradual carving of the Neuse River, which in its southward trending, as it is ruled on the Northern Hemisphere, carrying away the formerly existing sediments from the north side of the river, working in this direction in all probability since the Pliocene time through the Pleistocene and Recent time.

* Such a relation between the site of the Cape Canaveral, Fla. and a structural line was recently determined by William A. White, of Chapel Hill, N. C. (loc. cit., p. 8).