THE GEOLOGY OF THE WILLIAM B. UMSTEAD STATE PARK

A semi-popular dissertation for use by the Park Naturalist for public information

This report is preliminary and has not been edited or reviewed for conformity with North Carolina Geological Survey standards and nomenclature.

by
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Plate I "Geologic time chart of events in the William B. Umstead Park Area." --Back of report

Plate II "Geologic map and structural cross section of the William B. Umstead Park Area." --Back of report
INTRODUCTION

The William B. Umstead State Park is located approximately five miles northwest of Raleigh, North Carolina, and is situated in the Piedmont province. The Park area is a good representative of the Piedmont, having the typical rolling topography. The hills rarely exceed 400 feet above sea level, and the maximum relief is less than 150 feet. Over 15 miles of permanent streams exist in the Park. Deep chemical weathering has destroyed most of the fresh bedrock outcrops, leaving a thick soil cover on the surface in most places. This is also typical of Piedmont geology. However, fresh bedrock, or its saprolite, is commonly exposed along steep hillsides, gulleys and stream-cuts, road-cuts, quarries, and in other man-made excavations. The smaller streams afford better exposures than the larger ones because of their higher gradient and negligible flood plains.
ROCK TYPES

General

All three classes of rocks exist in the Park: metamorphic, igneous, and sedimentary. The metamorphic rocks include gneissess, schists, and phyllites, and are the most abundant rocks in the area. The only notable igneous rock is quartz monzonite, with associated quartz veins. The sedimentary rocks are the youngest, being the Triassic fanglomerate and sandstone, and the stream-deposited alluvium.

Metamorphic Rocks

General

Nine metamorphic rock units have been separated on the Geologic Map (Plate II). They are: Quartz-disk gneiss, Hornblende gneiss, Mica gneiss, Quartzite, Hornblende-biotite schist, Conglomerate gneiss, Ilmenite-magnetite quartzite, Epidote metasiltstone, and Clastic phyllite. They are the oldest rocks in the Park, being late Pre-Cambrian to Early Paleozoic (see Plate I). With minor exceptions, they all strike to the northeast and dip to the northwest. The oldest units are believed to be in the southeastern part of the area, becoming progressively younger towards the northwest. They are all products of regional metamorphism of medium to high grade, the degree of metamorphism decreasing toward the northwest. Many of the units are intimately injected with irregularly shaped bodies of quartz monzonite.
Quartz-disk Gneiss

General Location and Extent

Quartz-disk gneiss, labeled "gdg" on the Geologic Map (Plate II), outcrops in the southeastern corner of the Park. The best local outcrop, labeled "01" on the map, is a dirt road-cut 600 yards southeast of the southeastern corner of the Park.

Petrography

The general appearance of the quartz-disk gneiss is a coarse-grained, slightly foliated to almost massive, white to pink colored rock, characterized by the presence of flat quartz disks up to 1 inch in length.

The mineral composition of the rock includes quartz, over 50 percent; feldspar, up to 45 percent; and mica (muscovite and biotite), less than 10 percent. The pink color of certain layers is due to a high percentage of feldspar.

Soils

The residual soil is a coarse-grained, mottled, grayish-orange to yellowish-brown colored material. The remains of foliation are often visible as alternating bands of the above colors. The quartz disks often stand out due to their greater resistance to weathering.

Origin

This unit was originally a series of coarse-grained sandstones which were deposited in a sea or large lake. The larger quartz grains were flattened during the regional
metamorphism which followed, thus acquiring their disk-like shape.

Hornblende Gneiss

General Location and Extent

Hornblende gneiss, labeled "hgn" on the map, is the next rock unit adjacent to the Quartz-disk gneiss. Its outcrop width ranges up to 1 mile across strike, and its thickness is estimated to be over 2,000 feet. Its general strike is about N 10° E, and dip is to the northwest at a rather steep angle. Good outcrops may be seen in the southeastern portion of the Park, especially at location "02" on the map.

Petrography

The general appearance of the rock is a rather medium-grained, dark green texture, whose characteristic feature is well oriented, elongated hornblende needles up to 0.5 inch long.

The minerals present are hornblende, about 50 percent; scattered silt sized quartz grains, about 30 percent; and small amounts of epidote, chlorite and feldspar. The zones containing large amounts of hornblende are the more foliated. In addition, the unit contains numerous small, irregularly shaped injection bodies of quartz monzonite, which are described later.

Soils

The soils are good indicators of their parent rock. The soil is generally a dark reddish-brown colored material, having
a rather crumbly, massive texture and even coloration. Weathered injection bodies of quartz monzonite readily show up on white areas.

**Origin**

Most hornblende gneisses and related rocks are believed to have been metamorphosed mafic igneous lava flows or sills. However, the presence of such large amounts of quartz seems to postulate a sedimentary origin. The type of sediment required would have to be a dolomite containing appreciable amounts of clay and silt. It would supply the necessary iron, calcium, magnesium, alumina, and silica needed for the growth of hornblende crystals with metamorphism.

**Mica Gneiss**

**General Location and Extent**

Mica gneiss, labeled "mgn" on the map, is the next adjacent unit on the northwest side of the hornblende gneiss. The contact between the two is gradational. There are, in fact, several small zones of hornblende gneiss within the mica gneiss unit, but they were too small to distinguish on the map. The strike and dip of the unit is similar to the adjacent rocks. The unit is rather wide, being over 2,500 feet thick. Good outcrops occur along Sycamore Creek, especially at location "03" on the map.

**Petrography**

This rock is essentially a rather coarse-grained mica gneiss, with minor zones which are rich in hornblende, or which
contain enough mica to become schists. The typical appearance of the rock is that of alternating layers of quartz and feldspar, with parallel oriented mica flakes. In addition, large amounts of quartz monzonite occur in the unit, both as injections and as larger bodies.

Soils

The soils are rather undependable guides for parent-rock identification due to their wide color range. They average reddish-orange in color.

Origin

The concept of a series of sedimentary rocks, varying in sand, silt, clay and carbonate content, seems to be the most applicable origin for the unit as a whole. The schistose zones are probably shales, and the coarser mica gneisses sandstones. The thin hornblende-rich layers were probably zones of dolomite, similar to that described for the origin of the Hornblende gneiss. The micas and hornblende "grew" with regional metamorphism from the clay and iron-rich carbonate.

Quartzite

General Location and Extent

Quartzite, labeled "qtz" on the map, is the next unit adjacent to the northwestern side of the Mica gneiss. It is a rather thin unit, trending along a rather consistent N 15° E direction and dipping steeply to the northwest. It is probably not over 500 feet thick. The best outcrops are
in an old quarry next to Sycamore Creek (labeled "04" on the map), located 0.25 mile south of High Rock Lake.

**Petrography**

This bluish-gray colored, slightly foliated quartzite appears very uniform in texture and composition. The typical mineral composition is quartz, 80 percent; feldspar, 15 percent; and the remainder is biotite, muscovite and pyrite.

**Soils**

The soil is generally a light gray to yellowish-orange colored material which preserves foliation streaks fairly well.

**Origin**

This unit was undoubtedly deposited originally as a fairly clean beach sand, rich in well worked quartz and feldspar grains. The small amount of mica indicates relatively little clay or other impurities were present in the original sediment.

**Hornblende-Biotite Schist**

**General Location and Extent**

Hornblend-biotite schist, labeled "hbs" on the map, is the next adjacent unit on the northwest side of the Quartzite. Its outcrop width ranges up to 0.7 mile in its southern extent, and thickness varies up to about 2,000 feet. Its strike varies locally, but in general is about N 15° E. It dips to the northwest. The best exposure of this unit is located at the High Rock Lake spillway, labeled "05" on the map.
Petrography

The typical appearance is a dusky blue-green, schistose rock with visible grains of hornblende and biotite, which together make up over 75 percent of the rock. The remaining minerals are quartz, feldspar, chlorite and epidote. Abundant bodies of quartz monzonite also occur in the unit.

In addition, a "greenstone" layer occurs along part of the northwestern side of the unit. Good stream-cut exposures occur at point "06" on the map. This layer appears similar to the Epidote metasiltstone, being a fine-grained, massive, light green rock. However, it differs in that it contains larger irregularly shaped grains which are more resistant to weathering than the remainder of the rock. These range up to 1 inch in diameter and appear to have been amygdules. These amygdules characteristically stand out from the surface of the rock and are easily recognizable.

Soils

The soils appear somewhat similar to those of the Hornblende gneiss. Foliation is fairly well preserved as alternating yellowish-brown and reddish-brown streaks. The usual irregularly shaped patches of white soil indicate the presence of weathered quartz-monzonite injection bodies.

Origin

The origin of this unit is believed to have been similar to that of the Hornblende gneiss; that is, an impure dolomite. The biotite could have been an original product of regional
metamorphism, or it could have been derived from the hornblende at a later stage.

**Conglomerate Gneiss**

**General Location and Extent**

Conglomerate gneiss, labeled "cgg" on the map, occurs as the next unit adjacent to the northwestern side of the Hornblende-biotite schist. It strikes from due north to N 30° E. Its width is approximately 0.4 mile across strike in its widest part. It thins toward the southwest. The best outcrops are stream-cuts such as at point "07" on the map.

**Petrography**

In many respects this gneiss is similar to the Quartz-disk gneiss, except that its larger grains are more rounded and less disk-like, and it contains a higher percentage of mica. Varied sized quartz and feldspar grains make up about 75 percent of the rock, the remainder being mostly muscovite, biotite, epidote, clinozoicite and zircon. The rock is white to light yellow-green in color.

**Soils**

The presence of quartz grains in the soil could cause confusion between the Quartz-disk gneiss soil. However, the color of the soil is generally grayish-yellow to light orange.

**Origin**

The unit was originally a pebbly sandstone. Since it contains less than 10 percent mica, the original sediment was
relatively free of clay. Many of the quartz grains still retain much of their original roundness, and many grains appear to be sorted into zones. This unit represents a slightly lower metamorphic rank than do those southeast of it.

Ilmenite-Magnetite Quartzite

General Location and Extent

This small, very thin unit, labeled "imq" on the map, occurs within the eastern band of the Clastic phyllite. It appears to pinch out approximately 0.3 mile north of High Rock Lake. It trends about N 20° E. None of this rock has been seen actually in place. Float, made up of fragments averaging the size of a brick, occurs on the topsoil in areas along strike. Good samples of this float may be found 100 yards north of the Park entrance on U.S. Highway 70, shown as "09" on the map. Apparently the unit is rather thin, probably at most not over 10 or 20 feet in thickness and perhaps much less. If it were thicker it could undoubtedly be seen in place at the surface due to its resistance to weathering.

Petrography

The float fragments are massive, light bluish-gray rocks containing fine-grained quartz with ilmenite and magnetite all in various ratios, but averaging 75 percent quartz and 25 percent for the iron-bearing minerals. Trace amount of small unoriented muscovite occurs in some areas. Some pieces of float are almost entirely grains of ilmenite and magnetite in various ratios, averaging 75 percent quartz and
25 percent for the iron-bearing minerals. Trace amounts of small unoriented muscovite occur in some areas. Some pieces of float are almost entirely grains of ilmenite and magnetite. Much of the float is magnetic enough to attract a compass needle held nearby.

Soils

The pieces of float are highly resistant to weathering, but the iron-rich varieties readily oxidize to a rusty brown color. The soil is a light colored sand.

Origin

There seems to be little doubt that this rock originated as a beach or channel-deposited sand rich in ilmenite and magnetite detritus. Zones of concentrated iron-bearing minerals appear to be original bedding planes. Many of the quartz grains have retained much of their detrital roundness.

Epidote Metasiltstone

General Location and Extent

Epidote metasiltstone, labeled "ems" on the map, is the next unit adjacent to the northwestern side of the band of Clastic phyllite. In effect, this unit separates the two Clastic phyllite units, and might be considered a quartz-rich and mica-poor facies of them. Its general trend is about N 20° E, and it dips to the northwest. It ranges in places over 0.5 mile wide. Its thickness is estimated at about 1,300 feet. Good outcrops are not as common for this unit as for most of the others. The best fresh outcrops are along
Sycamore Creek about 0.5 mile northwest of High Rock Lake, at point "010" on the map.

**Petrography**

The typical appearance is a green, fine-grained, poorly foliated rock. It is composed of about 40 percent very fine-grained quartz, with the remainder of the rock being various ratios of epidote, chlorite and sericite.

**Soils**

The soil resembles those of other, more mafic rocks in the Park. The colors range from olive brown to dark brown.

**Origin**

Such a fine-grained epidote-chlorite-rich rock was probably originally a siltstone rich in clay at about a 50:50 ratio. The clay material produced the chlorite, epidote and sericite with metamorphism.

**Clastic Phyllite**

**General Location and Extent**

Clastic phyllite, labeled "cph" on the map, occurs as two zones adjacent to each side of the Epidote metasiltstone respectively. The eastern band, containing the narrow lens of Ilmenite-magnetite quartzite, is adjacent to the northwest side of the Conglomerate gneiss. It trends from N 10° E in its thinner southern parts to N 23° E in its northern parts. Its outcrop width ranges up to 0.25 mile. Good outcrops occur at
point "O8" on the map in the parking area. The trend of the western band is a more consistent N 15° E. Fresh outcrops of this zone are hard to find, except at point "Oil" on the map. A very good outcrop occurs at its intersection with U.S. Highway 70 just outside the Park area going north.

Petrography

The clastic phyllite units contain several types of rocks. Some, especially in the eastern zone, are dusky yellow colored rocks which are rather sheared parallel to foliation. These range to other mottled blue-gray types. In the western zone, dusky yellow-green to light blue-gray types persist. The green color is usually caused by the presence of chlorite. The light colored types often contain readily visible quartz pebbles. Most of these rocks are too fine-grained to be called schists. The rock contains fine grains of parallel-oriented sericite and chlorite which make up about 80 percent. Quartz, feldspar, epidote and leucoxene make up the remainder of the rock.

Soils

The soils are rather good indicators of their parent rock, because they tend to present foliation as streaks of characteristic colors. The colors range from pale orange to yellow to very pale blue, and even grayish-pink.

Origin

These fine-grained rocks probably had an origin as shales or other fine-grained sediments mixed with volcanis
ashfalls and other land waste, including larger grains of quartz.

**Igneous Rocks**

**General**

There is one main kind of igneous rock in the Park area: Quartz monzonite. It is believed to be middle or late Paleozoic in age (see Plate I). In addition, veins of quartz—which strictly speaking are not igneous rocks—are often intimately associated with the bodies of quartz monzonite as well as commonly occurring as joint fillings.

**Quartz Monzonite**

**General Location and Extent**

Quartz monzonite, labeled "qm" on the map, occurs as bodies of large variety of sizes and shapes, not being confined to regular igneous forms such as dikes or sills. Generally it is restricted within three metamorphic units: Hornblende gneiss, Mica gneiss, and Hornblende-biotite schist. The larger bodies are shown on the map. The smaller injection bodies are too small to be shown, ranging from less than 1 inch to several feet in width and generally being elongated semi-parallel to the foliation of the gneisses which contain them. Exposures of the larger bodies are at points "014" and "015", while a good example of a smaller unmapped injection body is located at point "05" on the map.
Petrography

The Quartz monzonite is a moderately foliated to massive, fine to coarse-grained, light colored granitic-looking rock usually containing visible grains of white and/or pink feldspar, quartz and lesser amounts of biotite and/or muscovite, epidote, chlorite, and apatite. The foliated zones are made prominent by the presence of semi-parallel micas. The fine-grained types are rather restricted to the smaller bodies. In general, if the bodies are located within hornblende or hornblende-biotite gneisses or schists they contain slightly less quartz and more mafic minerals, such as biotite, epidote and chloride, while those associated with the mica gneisses are more foliated and contain more muscovite and quartz.

Soils

Fresh residual soils are often mottlings of white and pale grayish-orange to yellow-orange. Some of the smaller injected bodies weather to pure white soil, due to the high percentage of feldspars which weather to white kaolin minerals.

Origin

The exact origin of the quartz monzonite is still rather speculative, pending further investigation on a larger and more detailed scale. The evidence seems to indicate that it was formed during one orogenic period, rather than as a series of emplacements covering a wide span of time. There appear to be two alternative origins: igneous intrusion or some kind
of granitization process. If they were igneous intrusions, they were probably injected during a major orogenic period, such as during the Taconic orogeny (see Plate I). Their relations to the enclosing rocks seem to indicate this age. This is the age of many other granitic rocks in the Piedmont areas. The concept of granitization is relatively new, but is being rapidly accepted as an explanation for the origin of many granitic rocks. Under this theory, the elements which later combined to form the minerals making up the quartz monzonite migrated through the local rocks by a process called soil diffusion. This could have happened during the Taconic orogeny, because heat is one of the prime causes of granitization processes.

Sedimentary Rocks

General

Included in this group are the Fanglomerate and Sandstone of Triassic age, and the Alluvium of post-Pleistocene (?) age (see Plate I). They are all relatively unconsolidated, "continental" type sediments, not having been deposited in a sea.

Fanglomerate

General Location and Extent

Fanglomerate, labeled "Trf" on the map, occurs as a fairly narrow belt adjacent to the northwestern side of the Jonesboro fault contact along the western side of the Park. The unit trends about N 15° E. Good exposures are located at point "012" at Sycamore Creek on the map.
Petrography

The fanglomerate is an unsorted rubble made up of a large size-range of material from clay to boulder size. In places rude, irregular stratification results from alternation of beds having fewer pebbles and more clay material. Its color is typically a dark reddish-brown. The typical assemblage is large angular to subrounded chunks of igneous and metamorphic rocks several inches or feet in diameter, surrounded by a matrix of sand, silt and clay. The largest boulders are usually granite. The sand and silt-sized grains are rich in quartz and feldspar. The clay is of indefinite argillaceous composition, but containing large amounts of reddish-brown iron oxides, which stains and cements other grains.

Soils

The soils are stained the characteristic dark reddish-brown color. The individual detrital members weather to their normal results, as described for each of them in their respective sections.

Origin

This coarse, rudely deposited rock appears to have had a combination of continental landslide origins, combined with west-facing stream alluvial fan deposition, all under highly oxidizing conditions. This occurred during the Triassic disturbances when block-faulting occurred (see Plate I).
Sandstone

General Location and Extent

Sandstone, labeled "Trs" on the map, grades into the fanglomerate on the east. It occurs only in the northwest corner of the Park. It is exposed at point "013" on the map.

Petrography

This unit is composed of loosely consolidated sands and silts, with varying admixtures of pebbles and argillaceous material. The minerals present are mostly quartz, feldspar, and mica grains of sand and silt size. No fossils occur, but traces of bedding dip locally to the southeast.

Soils

The sands weather to a buff to light red color, depending on the quantity of iron oxide present.

Origin

These sands are believed to have had their origin contemporaneously with the Fanglomerate, except that they were river deltas, channel and floodplain deposits.

Alluvium

Alluvium, shown as "Qal" on the map, constitutes mapable floodplains along many streams in the Park. It ranges up to 200 yards in width and up to several feet deep. Generally, however, it is a rather thin deposit, allowing the outcrops of bedrock to be exposed in or beside stream beds. This is especially true of the smaller streams. Typical alluvium is
sand-sized grains of quartz, feldspar, mica, clay and other minerals. The age of the material is speculative, but is probably post-Pleistocene (see Plate I).
ROCK STRUCTURES

Folds

The three major types of structures seen in the Park are folds, faults and joints. Generally the folds are small undulations in the rocks which are readily visible at many locations. However, the regional picture should also be considered. From the Structural cross section (Plate II) it can be seen that the Park as a whole is made up of a series of homoclinically dipping rocks which represent the west side of a very large anticlinal structure. This folding occurred during the uplift of middle to late Paleozoic time (see Plate I).

Faults

The major fault, as can be seen from the Structural cross section, is the so-called Jonesboro fault, which was produced in Triassic time. This fault actually extends for several hundred miles northeast and southwest. The northwest block dropped down with respect to the southeast side, and has filled with the Triassic sediments (see Plate I). Its estimated vertical displacement is on the order of 10,000 feet. Although the fault zone cannot actually be seen because of weathering effects, it makes a rather distinct boundary between the clastic phyllite and the Fanglomerate. Other minor displacements occur in the metamorphic rocks, which could be considered small faults.
Joints

Most of the rocks in the Park are jointed to varying degrees. This is caused by a release of forces acting on the rocks. Therefore, the joints occurred after the major disturbances in the area. One prominent set of joints is rather consistently oriented about N 70° W and dips nearly vertical. This orientation is close to being perpendicular to the foliation trends. Many open joints are filled with quartz.
REGIONAL HISTORY

Original Deposition

Most of the present metamorphic rocks were members of a sedimentary series deposited under either marine or non-marine conditions. Some appear to be mixed with igneous ash-falls and lava flows. They were probably deposited in late Pre-Cambrian or Early Paleozoic time (see Plate I). It is assumed that the Quartz-disk gneiss was deposited first. It was represented by layers of cleanly washed sands and gravels. The Hornblende gneiss was produced from silty, muddy dolomites rather than lava flows because of the high percentage of quartz silt. Likewise thin, alternating beds of sand, mud, clay and carbonate, followed by cleanly washed sands, produced the present Mica gneiss and the Quartzite. The Hornblende-biotite schist is believed to have been a mixture of dirty carbonate and andesitic or basaltic lava. The Conglomerate gneiss and Epidote metasiltstone represent a series of rapidly deposited gravels, sands and silt mixed with a high percentage of argillaceous matrix material. These alternated with layers of clay and volcanic ashfalls which became the Clastic phyllite units. These poorly sorted series strongly contrast the well worked sands rich in iron oxide detritus which produced the Ilmenite-magnetite quartzite. These sands were probably deposited in a local or temporary beach, bar or channel near shore.
Regional Metamorphism

The major period of diastrophism for the area probably occurred in Ordovician or Silurian time (see Plate I) after the original deposition of the sediments and volcanics. This was the major period of folding and metamorphism, and was also the time in which the Quartz monzonite was injected into the rocks. This was the so-called Taconic orogeny, which had its effects in the Central and Southern Appalachians.

Triassic Disturbances

The Triassic events which followed (see Plate I) represent the last major disturbances in the area. Block faulting, of which the Jonesboro fault is an example, occurred; and the down-faulted basin produced was then filled with sediments, including the Fanglomerate and Sandstone.

Subsequent History

From the Jurassic until the present time (see Plate I), the area has been subjected to cycles of profound weathering and erosion. These processes had leveled the area considerably by Cretaceous time. The post-Cretaceous history has been continued weathering and erosion, with minor local uplifts, which produced the present topography and alluvium deposits.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>alluvial fan</td>
<td>a fan-shaped deposit of alluvium deposited by streams, generally at points where the slope decreases sharply.</td>
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<tr>
<td>anticline</td>
<td>a fold in which the dip away from each other.</td>
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<tr>
<td>argillaceous</td>
<td>rock composition in which clay-sized minerals (those less than 0.005 mm in diameter) constitute an appreciable proportion.</td>
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<tr>
<td>diastrophism</td>
<td>the processes by which the crust of the earth is deformed due to the application of internal and external forces. Mountain ranges and ocean basins, folds, faults, etc., are typical effects.</td>
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<tr>
<td>dip</td>
<td>the direction and angle of inclination from the horizontal of a surface measured at right angles to the strike of the surface.</td>
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<tr>
<td>float</td>
<td>pieces of weathered rock or minerals which have &quot;risen&quot; to the soil surface from the parent bedrock below.</td>
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<tr>
<td>foliation</td>
<td>the presence of parallel-oriented inequidimensional mineral grains in a rock. A typical metamorphic texture.</td>
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<tr>
<td>mafic</td>
<td>a rock composition in which minerals high in iron and magnesium (such as hornblende and biotite) compose an appreciable quantity. Often called &quot;basic.&quot;</td>
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<tr>
<td>massive</td>
<td>a homogeneous texture in rocks, lacking in any preferred orientation of grains. The opposite of foliation.</td>
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<tr>
<td>matrix</td>
<td>the smaller grains located in between the larger grains of a rock.</td>
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<tr>
<td>orogeny</td>
<td>the process of deformation or diastrophism in which an area is subjected to extensive uplifting, folding, faulting, etc.</td>
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<tr>
<td>physiography</td>
<td>as applied to geology, the study of land forms and arrangements.</td>
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</tbody>
</table>
I have enjoyed doing this project, Dave, and hope it will be a worthwhile contribution to the Division of State Parks and to the public.

Sincerely,

Charles W. Fortson

CWF: mh

Enclosures
Mr. David A. Adams  
Chief Naturalist  
Division of State Parks  
Raleigh, North Carolina

Dear Dave:

Included here are copies of the manuscript, maps and rock samples which constitute the geology of the William B. Umstead State Park as stated in our Agreement of May 13, 1958. I trust that you will find this project suitably fulfilled in terms of the Agreement.

There are 4 main things included:

1. The manuscript, entitled "The Geology of the William B. Umstead State Park Area," which includes three copies of:
   (a) The report itself
   (b) Appendix
   (c) Geologic time chart

2. Three copies of the geologic map and structural cross-section of the William B. Umstead Park Area.

3. Thirteen (13) labeled samples of each rock type separated on the map (except Alluvium Fanglomerate and Sandstone which are unconsolidated) which were taken from a good accessible outcrop of that rock as labeled on the geologic map.

4. Other material which I trust will be helpful to you:
   (a) Two (2) Sepia prints of the maps of the William B. Umstead Park from which other prints can be made by a blueprinter for a nominal fee.
   (b) Several other rough draft and Sepia prints of the Reedy Creek State Park from which a draftsman could make suitable copies. The rock types separated on these maps correspond to those in the adjacent William B. Umstead Park.
regional metamorphism  large-scale metamorphism as that which occurs under diastrophism. It involves both static and shear forces with the attendant heat involved. Crustal movements, igneous intrusion and the growth of new minerals are usually aspects of the process.

retrogressive metamorphism  the process by which lower grade metamorphic minerals are produced from higher grade metamorphic rocks.

saprolite  residually weathered rock which, although decomposed, still retains much of the original rock texture. It has not been transported.

strike  the direction (usually from north) of the line formed by the intersection of an inclined surface with the horizontal.
<table>
<thead>
<tr>
<th>Era</th>
<th>Period or System</th>
<th>Epoch or Series</th>
<th>Approx. length</th>
<th>Approx. length</th>
<th>Geologic events in the William B. Umstead Park Area</th>
</tr>
</thead>
<tbody>
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<td>in millions</td>
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<tr>
<td>Cenozoic</td>
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<tr>
<td>Quarternary</td>
<td>Recent</td>
<td>Pleistocene</td>
<td>0-1</td>
<td>1</td>
<td>Deposition of alluvium.</td>
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<tr>
<td></td>
<td></td>
<td>Pliocene</td>
<td>1-12</td>
<td>11</td>
<td></td>
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<td></td>
<td></td>
<td>Miocene</td>
<td>12-28</td>
<td>16</td>
<td>Weathering, erosion and minor uplifts.</td>
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<td></td>
<td></td>
<td>Oligocene</td>
<td>28-40</td>
<td>12</td>
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<td></td>
<td></td>
<td>Eocene</td>
<td>40-60</td>
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<td>Mesozoic</td>
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<td></td>
<td>Cretaceous</td>
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<td></td>
<td>Jurassic</td>
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<td>Triassic</td>
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<td>Paleozoic</td>
<td>Permian</td>
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<td></td>
<td>Pennsylvanian</td>
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<td></td>
<td>Mississippian</td>
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<td></td>
<td>Devonian</td>
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<td>Silurian</td>
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<td></td>
<td>Ordovician</td>
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<td>Cambrian</td>
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<td></td>
<td>Pre-Cambrian</td>
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<td></td>
<td>520-2100</td>
<td></td>
<td>1600</td>
<td></td>
<td>Original deposition of the present metamorphic rocks as a sedimentary series.</td>
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</tbody>
</table>