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Dan E. Stewart, *Director*

Division of Mineral Resources

Stephen G. Conrad, *State Geologist*

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GEOLOGY AND MINERAL RESOURCES OF ORANGE COUNTY, NORTH CAROLINA

by

Eldon P. Allen and William F. Wilson

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LETTER OF TRANSMITTAL

Raleigh, North Carolina
October 31, 1968

To His Excellency, HONORABLE DAN K. MOORE
Governor of North Carolina

Sir:

I have the honor to submit herewith manuscript for publication as Bulletin 81, "Geology and Mineral Resources of Orange County, North Carolina," by Eldon P. Allen and William F. Wilson.

This report was initiated at the request of the Research Triangle Regional Planning Commission and contains the results of detailed investigations of the geology and mineral resources of Orange County. There is an ever increasing demand for this type of geological information which plays a vital role in planning for the total development of areas on both a local and regional basis. This report should be of value to those interested in improving the general welfare of Orange County and North Carolina through a better understanding and wiser use of its geology and mineral resources.

Respectfully submitted,

DAN E. STEWART
Director

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GEOLOGY AND MINERAL RESOURCES OF ORANGE COUNTY, NORTH CAROLINA

by

Eldon P. Allen and William F. Wilson

ABSTRACT

Orange County is located in the northern Piedmont of North Carolina and covers an area of 398 square miles. The county contains a variety of rocks which collectively can be divided into three distinct types. These are metavolcanic-metasedimentary rocks of Ordovician (?) age, igneous intrusive rocks of Devonian (?) or later Paleozoic age and sedimentary rocks of Triassic age.

Stratigraphically and lithologically the metavolcanic rocks in Orange County, North Carolina, have been divided into four units. Units I through IV are metavolcanic rocks consisting of flows, pyroclastics and epiclastics which are products of both subaerial and subaqueous deposition. This metavolcanic sequence locally grades from Unit I, composed of amygdaloidal basalt flows, some of which exhibit pillow structure, and interlayered basaltic lithic tuffs and crystal lithic tuffs to the andesitic to dacitic pyroclastic rocks with minor basalt flows of Unit II. Unit III, which overlies Unit II, is predominantly composed of dacitic to rhyolitic lithic tuffs, crystal lithic tuffs and scattered spherulitic flows and flow tuffs which are rhyolitic in composition. The epiclastics of Unit IV overlie Unit III and consist of conglomerates with intercalated graywackes, overlain by graywackes with laminated argillite interbeds which are in turn overlain by laminated argillites. These metavolcanic rocks have been thightly folded into a series of northeast trending asymmetrical anticlines and synclines and are considered of Ordovician (?) age.

Intrusive into the metavolcanic rocks are the igneous plutonic rocks. These intrusive plutons and plutonic complexes of Devonian (?) or later Paleozoic age range in composition from granites, quartz monzonites, granodiorites, quartz diorites, diorites and gabbros to ultramafics. These intrusive rocks were apparently injected along zones of weaknesses such as shear fault and fracture zones in the older metavolcanic rocks.

Fine-grained aplite and highly-weathered lamprophyre dikes and stringers, primarily found in the vicinity of the igneous intrusive rocks, cut one another as well as all other pre-Triassic rocks in the county. These dikes and stringers were apparently a later phase of the Paleozoic igneous intrusive activity in the area.

The extreme southeastern corner of Orange County contains sedimentary rocks of Triassic age which occupy a downfaulted area known as the Durham basin. These rocks are considered to be Late Triassic age and are assigned to the Newark group. The Triassic sedimentary rocks are fine-grained clastics and interbedded conglomerates which were apparently derived from the older metavolcanic and intrusive igneous rocks that occur west of the Durham basin.

Intrusive into the Triassic sedimentary rocks and the pre-Triassic rocks are discordant diabase dikes of a basaltic composition that are of Late Triassic or Early Jurassic age and are considered the youngest rocks in the county.

Numerous abandoned mines and prospect sites exist in Orange County that have in the past been worked for gold, copper and iron. At present, pyrophyllite, crushed aggregate, building stone and gravel are being commercially mined in the county.

INTRODUCTION

Location and description of area

Orange County is located in the northern Piedmont of North Carolina (see figure 1) between 35 degrees 51 minutes and 36 degrees 15 minutes north latitude, and 78 degrees 57 minutes and 79 degrees 16 minutes west longitude. The county is approximately rectangular in shape with an average width of 14 miles and a length of 28 miles from north to south. It encompasses an area of 398 square miles or approximately 254,720 acres and ranks 65th in size among the 100 counties in the State. On the north it is bounded by Caswell and Person counties; on the east by Durham County; on the south by Chatham County and on the west by Alamance County.

Purpose and scope of investigation

The Division of Mineral Resources of the North Carolina Department of Conservation and Development at the request of the Research Triangle Regional Planning Commission initiated in the summer of 1962, a detailed geologic mapping project and mineral investigation of Orange County, North Carolina. The objectives of the project were threefold: (1) map the geology of the area in detail and determine the local stratigraphic sequence; (2) interpret the structure of the sequence and (3) investigate known mines, quarries and mineral prospects in the area and through detailed mapping, locate and evaluate new areas of possible mineral potential, their relationship with the surrounding country rock and their probable mode of emplacement.

Four U.S. Geological Survey topographic quadrangle sheets were available as base maps. These maps are the Chapel Hill 7½-minute quadrangle, the Durham North 15-minute quadrangle, the Durham South 15-minute quadrangle and the Farrington 7½-minute quadrangle. Of the aforementioned maps, only the Chapel Hill 7½-minute quadrangle located in the southeastern section of the county was of significant aid in mapping. The Durham North and Durham South 15-minute quadrangles cover the eastern edge of Orange County and the Farrington 7½-minute quadrangle covers only the extreme southeastern edge of the county. Consequently, eleven 7½-minute planimetric maps acquired from the Research Triangle Regional Planning Commission were traced and were used as base maps to plot the geology. The contacts in turn, were transferred to the permanent base map on a scale of one inch to one mile.

A soils map of Orange County published in 1918 by the U.S. Department of Agriculture, Bureau of Soils, in addition to helping with the identification of soils, was particularly useful in locating now unmarked or abandoned roads and trails which provided access to many isolated areas.

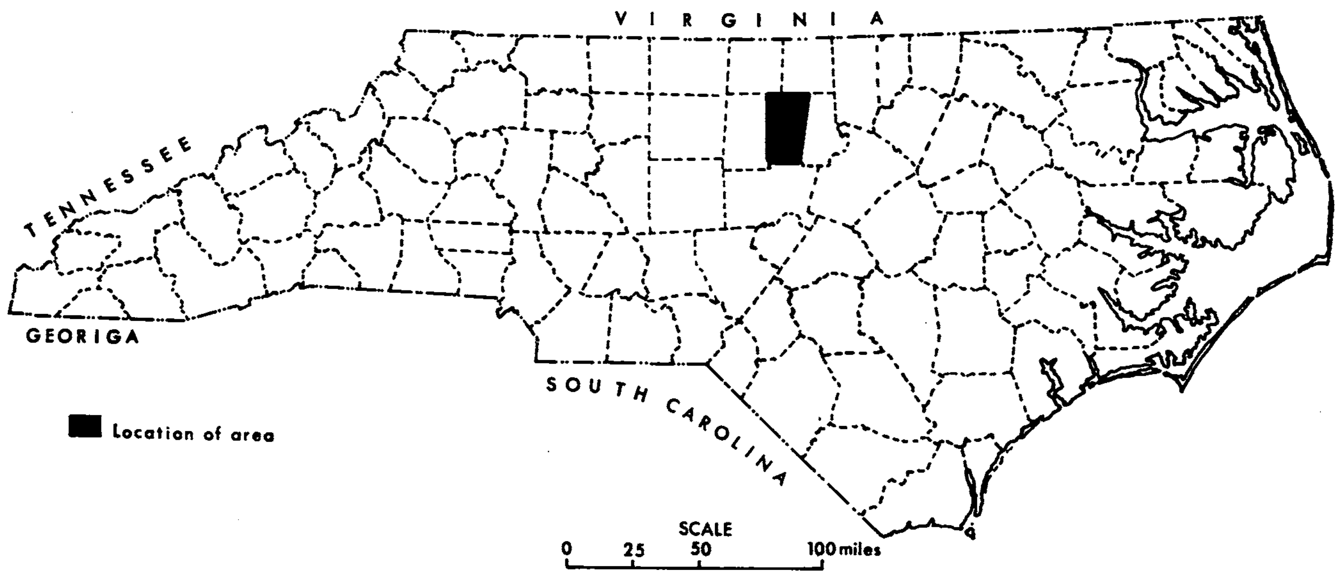


Figure 1. Index map showing location of Orange County, N.C.

Previous work in Orange County, North Carolina

Orange County, because of its location and variety of rock types has been of geological interest for many years. Significant geological contributions written on the county have appeared in the literature and have been helpful to the authors in their study of the area.

Eaton (1908) described the "flint-like slates" near Chapel Hill, North Carolina, as sedimentary in origin and intercalated with sandstones and conglomerates. In 1909, Eaton again published on the petrography of the granites around Chapel Hill describing hand specimens and thin sections.

Fry (1911) authored a paper on the plutonic rocks of Chapel Hill, noting their areal extent with detailed descriptions of outcrops, hand specimens and thin sections. During the same year, Fry published on the important minerals known to occur in the Chapel Hill area with emphasis on locations and their descriptions.

Smith (1916) described the diorites occurring north of Chapel Hill on Bolin Creek. Based on field evidence, he stated that the amount of quartz in the diorites decreases outwardly from the center of the intrusives. He also stated that near the contact zone between the diorite and granite intrusives, inclusions of the diorite occur frequently in the granite showing the greater age of the diorite. During 1917, Smith published two papers on the geology of Orange County. The first published in November described his interpretation of the structure of the rock types in Orange County and their order of sequence from the southeast to the northwest. In his second paper, Smith described terrace deposits in the plateau and Triassic sections of the county and stated his belief that they were of Pliocene age.

Harrington (1951) in the article, "Structural Analysis of the West Border of the Durham Triassic Basin," stated that through reconnaissance mapping, linears in the Triassic-crystalline contact are buried fault scarps. Harrington used the term crystalline to denote not only granitic type intrusions, but also rocks of volcanic origin

During the summer of 1954 and 1955, Kirstein mapped the northern half of the Chapel Hill quadrangle. The southern half of the quadrangle was mapped by Clarke in 1956 and 1957. A petrographic study and map revision of the quadrangle was completed by Hayes in 1962. The entire project was supervised by Virgil I. Mann, Chairman of the Department of Geology of the University of North Carolina at Chapel Hill, North Carolina. This compilation of data was published in 1965 by the Department of Conservation and Development, Division of Mineral Resources as Special Publication number one.

The authors' reconnaissance field mapping in the Chapel Hill quadrangle leaves the contacts as shown by Mann, et. al., essentially the same with the exception of a few changes.

Wilson and Allen (1963) described a northeast trending rhyolite ridge approximately one mile northwest of the Cross Roads Baptist Church on Secondary Road 1134, as a new locality of Ebenezer Emmons "*Palaeotrochis major*" and "*Palaeotrochis minor*." Emmons thought them to be siliceous coralline fossils that were the "oldest representatives of the animal kingdom." The Palaeotrochis, which are actually spherulites (Diller, 1899) form grayish-white, concentrically arranged aggregations of several minerals radiating outward from a common center or nucleus which is usually composed of quartz and epidote. The spherulites range in size from less than one-tenth of an inch to four inches in diameter.

Butler (1963) stated that the rocks in Orange County have a pronounced cleavage that strikes approximately northeast, is vertical and appears to be parallel to the axial planes of major folds. He also noted that mineral assemblages typical of the chlorite zone of metamorphism are present in the area. In 1964, he again published on the area and stated that the chemical compositions of the greenstones in the county are similar to Nockold's average "Central" basalts.

Allen and Wilson (1965) described amygdaloidal basalt flows in Orange County, North Carolina, and stated that the flows have been located in at least seven mappable bodies in the central portion of the county. The basalts are massive, show no apparent layering or cleavage and due to their greater resistance to weathering than the adjacent rocks, the flows are ridge formers and waterfalls often occur where the basalts are crossed by streams.

Bain (1966) stated that the rocks within the "so-called Carolina Slate Belt" in Orange County consist of metavolcanic and metasedimentary rocks. He further stated that the volcanic and sedimentary rocks are tightly to openly folded, have been faulted and intruded by igneous plutons.

Acknowledgements

This report was authorized and initiated under the direction of Jasper L. Stuckey, State Geologist, who is now retired from that position. Stuckey furnished the authors with some background material and helpful suggestions.

Stephen G. Conrad, who was appointed Stuckey's successor in July 1964, assumed responsibility for the successful completion of the Orange County project. While in the capacity of Assistant State Geologist, Conrad spent many weeks in the field with the authors as senior project advisor. Upon his appointment as State Geologist, he relinquished his active field participation to assume the responsibilities of his new position. The authors are grateful to him for his generous efforts on behalf of the project.

James R. Butler, Assistant Professor of geology at the University of North Carolina at Chapel Hill, North Carolina, was not only generous with his knowledge of the geology of the area through personal communication, but also furnished the authors with fifty-one thin sections and hand specimens collected during his field projects conducted in Orange County.

W. R. Hahman of the staff of the Division of Mineral Resources spent several days in the field with the authors collecting samples and examining abandoned mines and prospects. His knowledge of metallization was of significant aid to the authors and was a valuable contribution to the report.

Appreciation is extended to John M. Parker, III, for his critical review of the manuscript and his helpful suggestions.

The friendly cooperation of the residents of Orange County during the field mapping phase of the project bears acknowledgement. With their help, valuable time was saved in locating some of the abandoned mines and prospects which otherwise would have been a time consuming task.

GEOGRAPHY

Culture

Orange County was formed in 1752 from western portions of Granville, Johnston and Bladen Counties and was named for William of Orange from William, III's dynasty in England. The area was settled primarily by German Protestant families.

The University of North Carolina, located in the southeastern section of Orange County at Chapel Hill, North Carolina, was the first state chartered university in the United States. The university was chartered on December 11, 1789 by the General Assembly meeting in Fayetteville, North Carolina, but it was not until six years later in 1795 that students were accepted for enrollment.

Hillsborough, the county seat, located in central Orange County was platted in 1754 by William Churton on 400 acres from his land grant. Hillsborough, North Carolina, has an exciting and illustrious early history, much of which can be reviewed in the Orange County Historical Museum located in the old Hillsborough courthouse. Other principal towns in the county include Carrboro and Efland.

The county is made readily accessible by a network of state and federal highways. Major highways that traverse the area are Interstate Highway 85, U.S. 70 and N.C. 86, 54, 57 and 49. The Southern Railway serves the area and passes through or near the towns of Efland, Hillsborough, Chapel Hill and Carrboro. The Horace Williams Airport located approximately two miles north of the center of the town of Chapel Hill and just west of Highway N.C. 86 serves private aircraft flying to and from the area.

Orange County with an estimated 1967 population of 47,506 has a well diversified economy based primarily on retail and wholesale outlets, agriculture, textiles, income from the University of North Carolina and mining.

Climate and vegetation

Orange County falls within the section of the state denoted as the northern Piedmont. The mean temperature for the area is a comfortable 61 degrees with a monthly mean fluctuation of 43.3 degrees in January to 79 degrees in July.

Total annual precipitation for the county is 45.99 inches with extremes of 2.79 inches in October to 5.71 inches in July. The remaining months average between 3 and 4 inches of precipitation yearly.

Forestation in the county is predominantly loblolly pines with lesser amounts of short leaf and Virginia pines and cedars. Miscellaneous hardwoods such as red oak, white oak, maples, yellow poplar, hickory, dogwood and beech trees were noted in some abundance in certain areas throughout the county. Laurel and wild azaleas occur along several stream banks with laurel being the dominant of the two.

Topography

The topography in Orange County is typical of the Piedmont region with gently rolling upland, rounded hills and V-shaped valleys. Elevations within the area range from 859 feet above sea level in the Occoneechee Mountains to approximately 600 feet above sea level over the greater part of the county, with some land as low as 240 feet above sea level in the extreme southeast. The general surface slope of the area is downward from the northwest to the east and southeast.

The county can be divided into three distinct topographic divisions attributed to the different lithologies of the underlying rock formations.

The dominant rock types of the area are volcanic in origin and occupy a broad belt extending from the southwestern to the northeastern corner and cover the central portion of the county. Differential weathering, stream action and the attitude of these rock types combine to produce a series of steep sided undulating ridges dissected by a network of southeast flowing streams.

Igneous plutons located principally in the northwestern and southeastern sections of the county form rounded to dome-shaped hills with the steeper slopes usually occurring on their eastern flanks. These topographic features have an altitude of 400 to 600 feet above sea level.

Rocks of Triassic age, located in the extreme southeastern section of the county form a low lying, undulating to gently rolling topography that ranges in elevation from 240 to 450 feet above sea level.

Drainage

Three major drainage systems are present in Orange County.

The Eno River originates in the northwestern section of the county and flows almost due south for approximately 10 miles. Then, changing to a more erratic eastwardly course, the river flows out of Orange County into Durham County where it merges with the Flat River to form the Neuse River.

The North Fork Little River and South Fork Little River head up in the northeastern section of the county and flow in a southeasterly direction out of the area until they merge in Durham County to form the Little River. These two rivers and their tributaries drain the northeastern section of the county.

New Hope Creek, Bolin Creek and Morgan Creek located in the southeastern section of the county flow in a southeasterly direction out of the county and merge with the New Hope River in Chatham County. These three major creeks and their tributaries drain the southeastern section of the county.

The southwestern section of Orange County is drained by a network of small streams that flow in a southwesterly direction into the Haw River. The major streams are Cane Creek, Bear Creek and Collins Creek.

Soils

The variety of rock types in Orange County are the parent material for the six major soil types found in the area. Soils formed from the volcanic rocks can be grouped into three distinct soil associations (Lee and Goldston, 1955): (1) The Georgeville-Tirzah, a red silty clay loam with red, firm, silty clay medium-thick subsoils, found in the northern half of the county; (2) Herndon-Georgeville, a gray to yellowish-red soil with yellowish-red to red firm silty clay thick subsoils. This soil type is located in the southern half of the county with the exception of the Chapel Hill area and (3) Alamance-Orange located in the northeastern corner of the county is a gray silt loam soil with yellow to gray and yellow friable silty clay loam to firm silty clay medium-thick subsoils. The Chapel Hill area has been mapped as Cecil-Lloyd, a light "red clay loam" soil with firm red clay thick subsoils. The northwestern corner of the county contains Helena-Wilkes, a gray sandy loam with yellow to brown friable to very firm sandy clay loam to sandy clay or clay subsoils, often of mixed textures and somewhat shallow. The soil developed on the Triassic rocks along the southeastern edge of the county is Granville-White Store. This is a gray sandy loam "sandstone" soil with yellow to red friable to very firm clay medium-thick subsoils.

GEOLOGIC SETTING OF ORANGE COUNTY

Previous work in the Carolina Slate Belt

One of the earliest reports on the Carolina Slate Belt was written by Denison Olmsted in 1822. The report contains a descriptive list of rocks and minerals from North Carolina. Olmsted described novaculite, slate, hornstone, whetstone, talc and soapstone from several counties including Orange and Chatham. In 1825, Olmsted described the best known and most important part of the Carolina Slate Belt which he named the "Great Slate Formation." The area, "passes quite across the State from northeast to southwest, covering more or less the counties of Person, Orange, Chatham, Randolph, Montgomery, Cabarrus, Anson and Mecklenburg."

In 1856, Ebenezer Emmons published his report on the "Geology of the Midland Counties of North Carolina." Emmons placed the rocks of the Carolina Slate Belt in his Taconic system, which he subdivided into an upper and lower series. The upper members included argillaceous, or clay slates, chlorite and argillaceous sandstones and brecciated conglomerates. The lower members included talcose slates, white and brown quartzites, conglomerates and agalmatolite. He considered this system to be of sedimentary origin and in his discussion of the slates, he states the following reason: "But for the foregoing slates, with their associates; standing by themselves, though they might be regarded as sedimentary, yet, the proof thereof would be wanting, and geologists might consistently differ as to their origin. But it fortunately happens, that after dilligent search, numerous beds containing rounded pebbles were discovered; and hence it follows, that their origin is established." In his lower quartzite unit, Emmons found what he thought to be fossils and named them "Palaeotrochis." The smaller form he designated "*Palaeotrochis minor*" and the larger form he called "*Palaeotrochis major.*" These were later identified by Diller (1899) as spherulites.

Kerr (1875) recognized and described the distribution of the Carolina Slate Belt rocks east of the area of Olmsted and Emmons and proposed that they were of Huronian age, which according to his classification was a division of the Archean.

Nitze and Hanna (1896) first used the name Carolina Slate Belt. They recognized Emmons' Taconic and Kerr's Huronian rocks but conceded that in time, the rocks must be differentiated and recorrelated after more careful study. They also found in Union County, a considerable area of "little indurated or metamorphosed slates" which were not recognized by either Emmons or Kerr. They considered them to be of Algonkian age and suggested the name Monroe slates in reference to the type locality of an "undulating anticlinorium" at the railroad station in Monroe, North Carolina.

Watson (1903) investigated the plutonic rocks of the Piedmont and through extensive observations came to the conclusion that the granites and gabbros are intrusive into the diorites, and that the granites are the younger of the two.

Laney (1910) writing on the Gold Hill district of North Carolina, recognized the presence of sedimentary slates interbedded with volcanic tuffs, breccias and flows of both andesitic and rhyolitic composition. He also stated that the granites appeared to be the youngest of the igneous intrusives.

Stuckey (1928) published on the pyrophyllite deposits in North Carolina. He described two distinct types of tuffs, breccias and flows, one of which is an acid phase passing from rhyolite to dacite in composition and the other a more basic phase. He stated that the formations represented a period of continuous deposition during which the series was built up without break or unconformity.

Conley (1962) in his publication on the Albemarle quadrangle, North Carolina, stated that the area contains three distinct sequences of rocks. A lower sequence composed predominantly of felsic tuffs, a middle volcanic-sedimentary sequence with a basal tuffaceous argillite unit and an upper graywacke unit and an upper volcanic sequence consisting of andesitic and basaltic tuffs and rhyolites which, "unconformably overlie the first two sequences named." During the same year (1962) Conley published on the geology of Moore County, North Carolina, stating that only the lower and middle units mapped in the Albemarle quadrangle appear to be present in Moore County. He mapped some rhyolites in the area and stated that they could possibly be correlated with the rhyolites in his upper unit of the Albemarle quadrangle. He also mentioned that the exact stratigraphic relationships of some of the rocks in the county are in doubt because of the gradational nature of the contacts.

Conley and Bain (1965) published a composite geologic map of the Carolina Slate Belt with text. Compilation of a reconnaissance mapping project of Durham, Orange, Chatham, Randolph and Person Counties by Bain, coupled with Conley's work in Moore County, North Carolina, and the Albemarle 15-minute quadrangle, North Carolina, apparently provided the authors with sufficient geologic information to project the gross stratigraphy of Moore County and the Albemarle quadrangle throughout most of the Carolina Slate Belt. This area extends from the South Carolina state line to the Virginia state line, and from the Mecklenburg County line on the extreme western edge to the Vance County line in the east. The authors stated that all the metavolcanic and metasedimentary rocks could be divided into their, "natural, mappable rock-stratigraphic units." Both groups and formations were named, and the unconformity previously mentioned as mapped in the Albemarle quadrangle was expanded into a regional unconformity of considerable extent.

STRATIGRAPHY

General statement

Many of the rock types mapped in Orange County are both lithologically and chemically similar to those in other areas of the Carolina Slate Belt outside the county. However, there is some conjecture as to their exact stratigraphic relationships to similar rock types throughout the entire Carolina Slate Belt, and the authors feel that additional detailed mapping of the rocks beyond the limits of Orange County is required before regional correlation is possible. Until stratigraphic control is established for a much larger area of the Carolina Slate Belt than Orange County, formation names should not be assigned. Therefore, the section as presented represents only the interpretation by the authors of the stratigraphy in the Orange County area.

Orange County area

The general stratigraphic succession in Orange County in ascending order is as follows: Unit I is predominantly amygdaloidal basalt lava flows exhibiting local pillow structures with intercalated basalt porphyries and lithic and crystal tuffs of a basaltic composition. Unit II is predominantly andesitic to dacitic lithic and crystal tuffs interbedded with intermediate tuff breccias and phyllites. Occasional amygdaloidal basalt lava flows, some of which exhibit pillow structures are intercalated with the tuffs. Interbedded andesitic to dacitic tuffs occur in the upper part of the unit. Unit III is composed predominantly of felsic tuffs, lithic and crystal lithic tuffs, some volcanic breccias and occasional spherulitic rhyolite flows, rhyolite porphyries and flow tuffs. Dacitic tuffs occur interbedded within the unit. Unit IV is predominantly epiclastic argillites and laminated argillites, graywackes with intercalated argillites and conglomerates containing graywacke interbeds. Intrusive into the metavolcanic-metasedimentary rocks are younger Paleozoic igneous plutonic complexes which are predominantly diorites and quartz diorites. Also present are granites, granodiorites, monzonites, quartz monzonites, gabbros and ultramafics. Undifferentiated interbedded arkoses, sandstones, siltstones, shales, conglomerates and graywackes of Triassic age, occupy a down-faulted basin in the extreme southeastern corner of the county. These sedimentary rocks are cut by diabase dikes of a basaltic composition that are of Late Triassic (?) or Early Jurassic (?) age.

Unit I

Unit I, the basal unit, is composed predominantly of fine grained, massive dark grayish green amygdaloidal basalt lava flows with some intercalated basalt porphyries, dark gray basaltic tuffs, basaltic lithic tuffs and basaltic crystal lithic tuffs (see plates 1 and 2).

The basalt flow rocks are located in the central part of the county. Three flows are located just east and south of the town of Efland, four flows crop out just south and east of Hillsborough, and another occurs just west of New Hope Church. These lenticular bodies of metabasalt follow the regional trend of the volcanic rocks and strike between N. 25° and 35° E. and have nearly vertical dips. The flows range from 0.5 mile to over 6 miles in length and from 0.1 mile to one mile in width.

In outcrop, the basalts are massive, have a hackly fracture and exhibit no apparent layering or cleavage. Weathering of the basalts produces a medium grayish green sharkskin surface which tends to emphasize the flow lines and the knobby weather resistant quartz-epidote-chlorite amygdules. The white and green colored amygdules are spherical to oval in shape and the area around them is distinctly greener than the bulk of the matrix as a result of a concentration of epidote in the vicinity of the amygdules. Sizes of the amygdules are varied, but the majority range in size from a fraction of an inch to more than one inch in diameter (see plate 2, nos. 1, 2 and 3). These amygdules were apparently formed by secondary mineral deposition in vesicles in the basalt flows.

Pillow structures present at several locations in the amygdaloidal basalt flow rocks indicate at least part are of subaqueous accumulation. Crude pillow structures are located just northwest of New Hope Church and west of Highway N.C. 86 and also on the southeast bank of the Eno River just south of Highway U.S. 70, and in outcrops exposed in the flood plane of the Eno River north of Highway U.S. 70. Well-formed pillows are located approximately one mile east of the intersection of Highway N.C. 86 and Secondary Road 1718 and crop out along the east bank of New Hope Creek.

Most of the pillowed outcrops show deformation of the pillows and at these locations, only a few of the pillows exhibit V-shaped bottoms. The shapes of the majority of the pillows in the outcrops exhibiting deformation are mostly loaflike or irregularly subelliptical to amoeboid (see plate 2, no. 5). With few exceptions, the pillows are wider than they are high and vary in length from 1 to 3 feet, with 2 foot lengths the most common. The measured thicknesses of the individual pillows range from 12 to 18 inches.

Many of the pillows observed contained flow structure and quartz-epidote amygdules which, because of weathering, contribute a knobby uneven texture to the pillowed surface. Both amygdules and flow lines are present in the matrix surrounding the rims of the pillows and the flow lines can be easily traced as they wrap around the periphery of the pillows. The tops and bottoms of some pillows are discernible and weathering in concentric rim fractures along their contacts has tended to emphasize the size and shape of the pillows (see plate 2, nos. 4 and 6).

Jointing is present in the pillowed outcrops and tends to parallel the exterior rims of the pillows. However, jointing also bisects the pillows in numerous outcrops and in a few locations three dimensional views of the pillows are exposed.

Usually the basalts have a greater resistance to weathering than the adjacent rocks, thus they frequently form ridges. Cascades and small waterfalls often occur where the basalts are crossed by streams.

Thin section analysis has shown the major minerals of the basalts are epidote, chlorite, albite, quartz, actinolite, sericite, opaques and calcite. Butler (1963)

DESCRIPTIONS OF PHOTOMICROGRAPHS

Unit I

Plate 1

1. Amygdaloidal basalt porphyry of Unit I. Crossed polarizing prisms; magnification 100X. Carlsbad and albite twinning in plagioclase feldspar (P) that is crowded with saussurite grains. Note ragged chlorite fan (C) at upper left.

2. Amygdaloidal basalt porphyry of Unit I (same section as no. 1). Crossed polarizing prisms; magnification 24X. Lath-shaped phenocrysts of albite and carlsbad twinned plagioclase in cryptocrystalline groundmass composed primarily of plagioclase crystal fragments, chlorite, epidote and opaque magnetite.

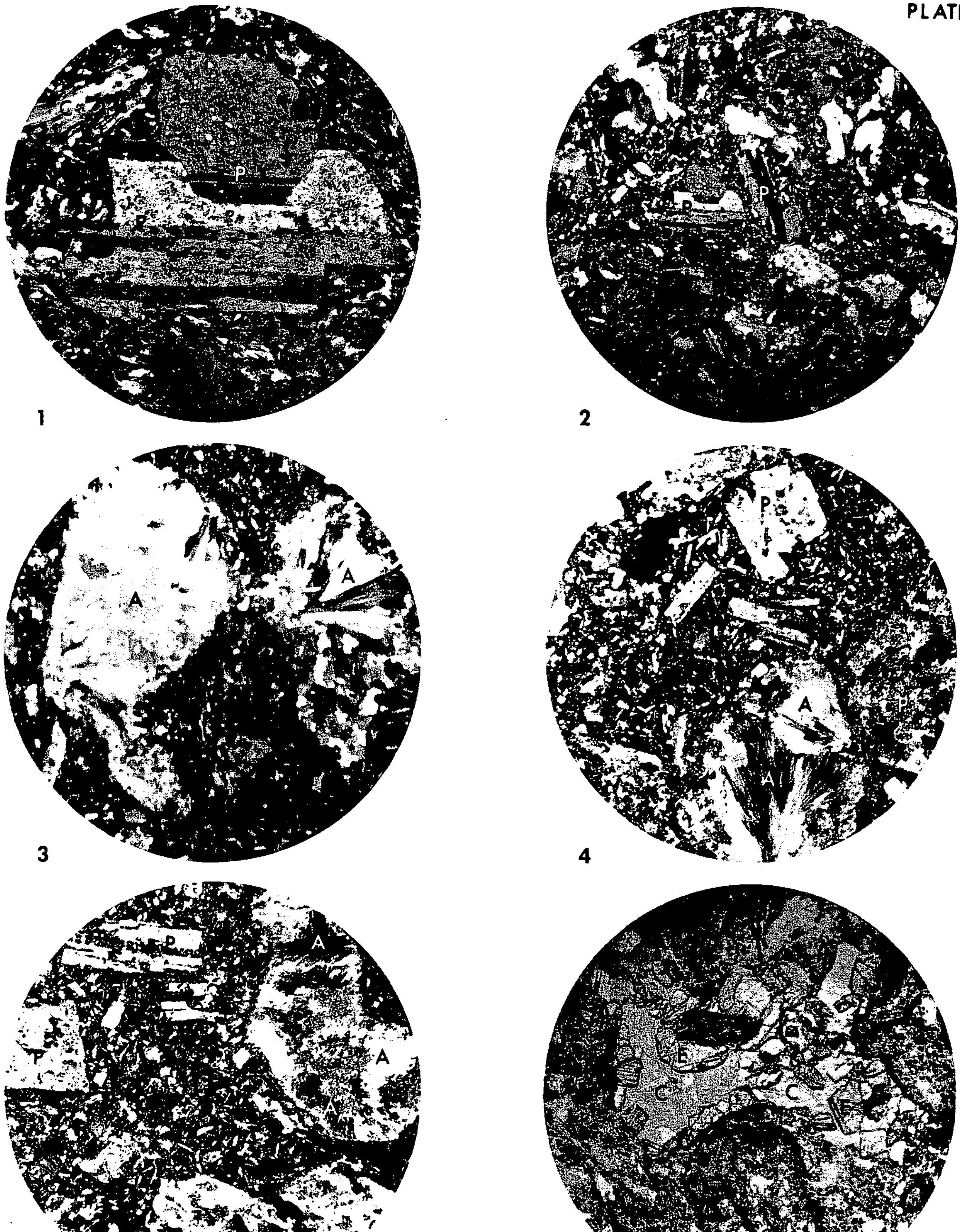
3. Amygdaloidal basalt flow of Unit I. Crossed polarizing prisms; magnification 24X. Amygdule on right consists of fan-shaped actinolite in upper portion and fine-grained epidote and chlorite in lower portion. The larger light-colored amygdule on the left is almost completely composed of fibrous actinolite much of which is cut normal to the fiber length and thus presents a fine-grained appearance.

4. Amygdaloidal basalt flow of Unit I. Crossed polarizing prisms; magnification 24X. Amygdule at bottom consists of actinolite fans (A) with epidote and chlorite grains along upper boundary. Large plagioclase lath (P) in lower right side is severely riddled with epidote inclusions. Cryptocrystalline groundmass consists of minute plagioclase laths, chlorite flakes, epidote grains and dust size opaque grains of magnetite.

5. Amygdaloidal basalt flow of Unit I. Crossed polarizing prisms; magnification 24X. Vesicle in upper right has been filled with actinolite fans (A) forming an amygdule. Note twinned plagioclase laths (P) that are riddled by dust-size epidote and chlorite grains.

6. Amygdaloidal basalt flow of Unit I. Plain light; magnification 24X. Opaque very fine grains of magnetite are scattered through groundmass of rock. Epidote grains (E), exhibiting relatively high relief, line the edge of the amygule while low relief chlorite (C) makes up the central portion.

PLATE 1



DESCRIPTIONS OF PHOTOGRAPHS

UNIT I

Plate 2

1. Hand specimen of weathered amygdaloidal basalt flow from Unit I exhibiting abundant weather-resistant amygdules which range in size from less than one-tenth of an inch to over one inch in diameter.

2. Sawed section of amygdaloidal basalt flow from Unit I exhibiting in cross section characteristics of the basalt flow matrix and the amygdules.

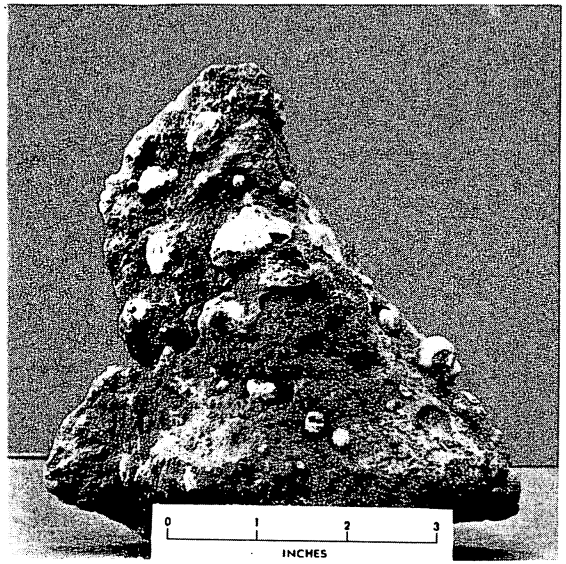
3. Hand specimen of weathered amygdaloidal basalt flow from Unit I exhibiting a two inch long cavity, partially filled with small quartz crystals.

4. Pillowed amygdaloidal basalt flow outcrop located approximately 0.5 mile west of the intersection of Highway N. C. 86 and Secondary Road 1732. The outcrop is located in a wooded area 500 feet south of Secondary Road 1732. Both flow lines and trains of amygdules are present in the outcrop and can be traced around the periphery of the small pillow. Sharkskin texture is evident on weathered surface of outcrop.

5. Pillowed basalt outcrop exhibiting deformed amoeboid-shaped pillow structure. The outcrop is located on the east bank New Hope Creek, 1700 feet downstream from the bridge on Secondary Road 1718.

6. Pillowed basalt outcrop exhibiting well formed V-shaped pillow. The pillowed flow crops out on the east bank of New Hope Creek and is located approximately 800 feet downstream from the bridge on Secondary Raod 1718.

PLATE 2



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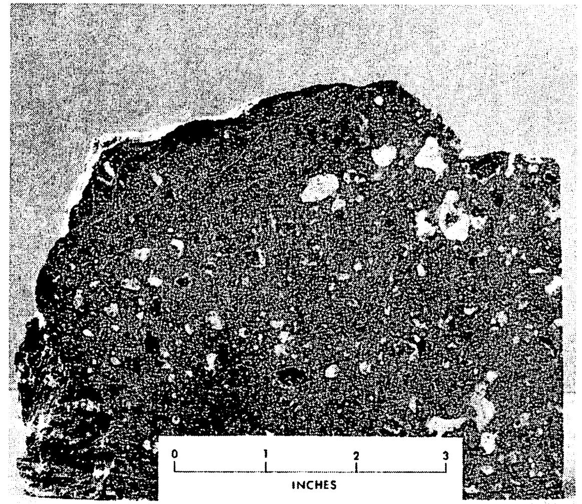

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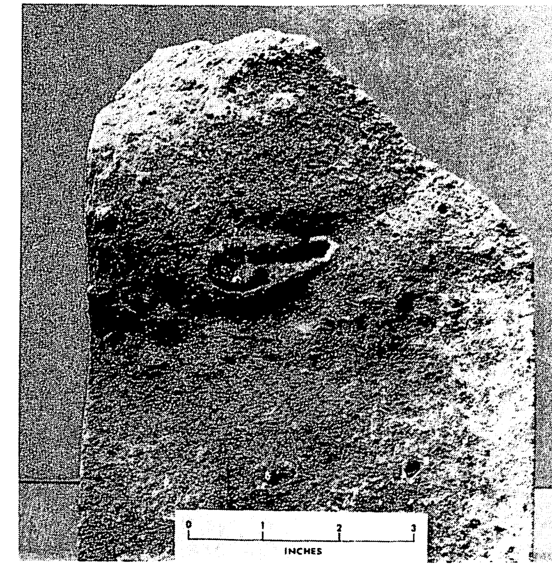

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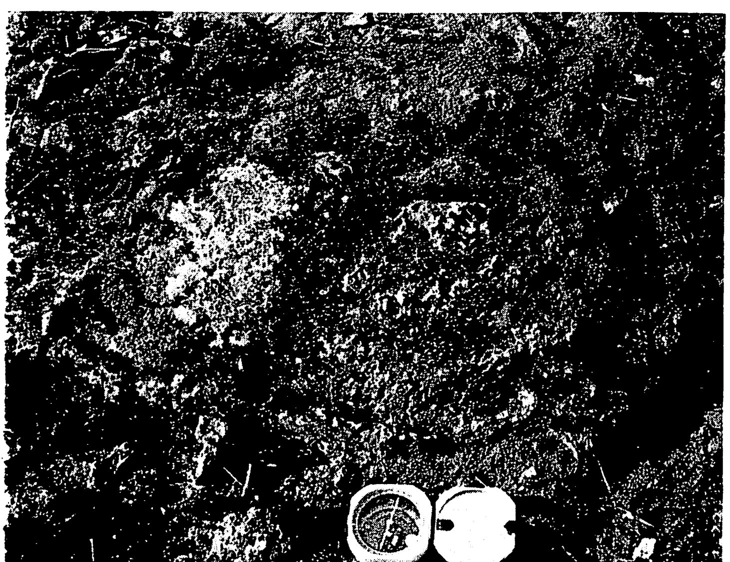

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states that the most common mineral assemblages are:

epidote-chlorite-quartz-plagioclase-(sericite)
epidote-chlorite-quartz-actinolite-(sericite)
epidote-chlorite-quartz-actinolite-plagioclase-(sericite)
epidote-chlorite-quartz-plagioclase-calcite
epidote-chlorite-quartz-(sericite)

Chemical analyses of five randomly selected specimens collected from the metabasalt flows show an average SiO_2 content of 51.5 percent, an average Na_2O content of 3.5 percent and an average K_2O content of 0.65 percent. A comparison of the chemical composition of some basalts is listed in table 1. A graphic plot of silica against the ratio of potassium oxide to total alkalies indicates that the Orange County basalt specimens fall within the chemical norm for the plotted average of spilites as defined by Nockolds (1954) (see figure 5). The presence of these spilitic pillowed amygaloidal basalt flow rocks offers added emphasis to the fact that the metavolcanic-metasedimentary rocks of Orange County, North Carolina, are of eugeosynclinal deposition. The basalt flow rocks are classified as being of the spilitic variety on the basis of the following data:

(1) A very low potassium oxide content which averages 0.65 percent and a relatively high sodium oxide content of 3.5 percent for the chemical analyses of the five basalt specimens.

(2) The presençe of pillow structure in the basalt flow rocks indicates subaqueous deposition.

(3) In places, the basalt flow rocks are interlayered and overlain by basaltic tuffs which exhibit a pronounced graded bedding which is also indicative of subaqueous deposition.

(4) The basalt flow rocks exhibit flow structure and abundant amygdules which are indicators of a true extrusive rock.

(5) The complete chemical composition of the flows places them as true basalts; when their silica content is plotted against their ratio of potassium oxide to total alkalies, the basalts plot within the chemical norm for the plotted average of spilites as defined by Nockolds (1954).

The basaltic tuffs intercalated with the metabasalts are massive, fine grained, dark gray to dark grayish green on unweathered specimens. The crystal clasts which are white to light green in color contrast with the dense fine-grained matrix and the lithic clasts which are, for the most part, darker than the matrix give the tuff a speckled appearance. Upon weathering, these tuffs attain a reddish brown to dark brown color, but still retain visible relict crystal and lithic clasts.

Good exposures of the weathered intercalated basalt flow rocks and basaltic tuffs can be viewed in a roadcut on a gravel road located several hundred feet southwest of Highway U.S. 70 and approximately 0.5 mile southeast of the business and U.S. 70 bypass.

As exposed, the tuffs strike N. 48° E. and dip 68° to the northwest, are reddish brown to dark brown in color and appear in places to be approximately four to six feet thick. However, the thicknesses of the tuffs vary considerably along strike. Graded bedding is evident in several areas of the weathered tuffs along strike in the road cut, and a basal, highly weathered basalt exhibits what appears to be small pillows in an advanced stage of weathering. This sequence would suggest that at least part of this unit is of subaqueous deposition.

In thin section, the more massive basaltic tuffs exhibit lithic clasts that are in general predominantly angular to subangular, are randomly oriented

TABLE I. COMPARISON OF THE CHEMICAL COMPOSITION OF BASALTS

	Orange Co. Allen-Wilson, 1968			Orange Co. Butler 1964	Hawaii Murato Richter 1966	Albemarle Quadrangle Conley 1962	Nockolds "56 average Central Basalts"
Sample No.	8	9	18				
SiO_2	50.5	50.7	50.0	47.48	50.74	53.6	51.33
Al_2O_3	19.4	16.7	18.0	20.42	13.57	18.4	18.4
Fe_2O_3	4.3	3.1	7.3	6.41	1.36	5.2	3.40
FeO	5.7	7.6	2.3	3.61	10.63	—	5.70
MgO	4.7	5.6	5.1	4.53	6.16	5.9	6.01
CaO	6.4	5.8	9.7	10.52	9.94	7.0	10.07
Na_2O	3.9	3.8	3.0	2.0	2.64	1.88	2.76
K_2O	0.27	0.88	0.70	2.30	0.67	0.25	0.82
H_2O-	0.12	0.07	0.11	0.03	0.00	—	—
H_2O+	3.4	3.9	2.3	1.65	0.09	—	0.45
TiO_2	1.0	1.2	0.90	0.52	3.35	*	1.10
P_2O_5	0.13	0.24	0.22	—	0.37	*	0.16
MnO	0.15	0.27	0.26	0.22	0.18	*	0.16
CO_2	0.05	0.05	0.05	0.11	0.01	—	—

*Includes, P_2O_5, MnO, TiO_2

**Total iron content reported at Fe_2O_3.

Note: See Table 5A for sample locations.

and exhibit no apparent layering or sorting. A few of the lithic clasts contain relict glass shards, which indicates clasts within clasts and that a prior tuff, at or near the source area or areas furnished some larger clasts for this later tuff. The clasts appear to have been derived from fine grained to cryptocrystalline rocks. The crystal clasts are predominantly euhedral crystals of plagioclase feldspar exhibiting albite twinning. Quartz appears to compose 25 to 30 percent of the groundmass. The major mineral constituents observed are plagioclase, quartz, chlorite and epidote with minor amounts of sericite, calcite and opaques.

Unit II

Unit II is composed of pyroclastic rocks of andesitic to dacitic composition (see plates 3 and 4). Basalt extrusives, some of which exhibit pillow structures are present within the unit and are intercalated with the pyroclastic rocks but are few in number. A tuff breccia, locally containing lahars, is interbedded with the intermediate pyroclastic rocks. The lahars contain unsorted, randomly oriented clasts varying in size from less than an inch to over three feet in length and these clasts vary in composition from basalt to rhyolite. This sequence suggests that the volcanic cycle was still in a highly explosive phase emanating andesitic to dacitic ejecta over a wide area and for extended periods of time. The occasional basalt flow rocks in Unit II suggests that the extrusive phase of vulcanism had subsided to a considerable extent as compared to the abundance of basalt extrusives described in Unit I. The presence of lahars further suggests that the center or centers of vulcanism were relatively near.

Unit II appears to overlie conformably Unit I throughout the county. The cross section A-A' (see map, plate 13) shows in places that Unit I is directly overlain by Unit III, which appears to represent areas of nondeposition of Unit II rather than erosional unconformities. However, this is not to say that during the deposition of Unit II, the normal erosion-deposition cycle was not in effect.

Phyllites of andesitic to dacitic composition occur within Unit II and excellent exposures of this rock type can be viewed in the Old Duke quarry, one mile southwest of Secondary Road 1161 and 0.1 mile east of the intersection of Highway U.S. 70 and Secondary Road 1161 and in the New Duke quarry located southeast of Secondary Road 1181 and west of the Eno River. The phyllite varies considerably in color but the rock is predominantly dark gray to dark bluish gray with a well developed slaty cleavage that is parallel to the bedding. The average strike and dip of the cleavage and bedding of the phyllites in the Old Duke quarry is N. 45° E., 71° NW.

Table 2. Chemical Analyses of Andesitic-Dacitic Rocks in Unit

Sample Number	No. 2	No. 10	No. 16	No. 20
SiO_2	62.8	62.1	58.2	65.7
Al_2O_3	16.5	14.7	22.6	15.2
Fe_2O_3	5.9	5.2	5.8	3.0
FeO	.50	3.0	1.4	3.1
MgO	1.8	1.9	1.0	1.7
CaO	4.1	3.4	.49	3.3
Na_2O	3.1	4.1	2.7	3.9
K_2O	2.0	2.3	2.3	1.1
H_2O-	.06	.06	.28	.07
H_2O+	1.3	1.5	3.5	1.5
TiO_2	.87	1.1	1.2	.84
P_2O_5	.22	.30	.22	.20
MnO	.20	.20	.14	.30
CO_2	.35	.05	.05	.05
Total	100	100	100	100

Note: See Table 5A for sample locations

The composition of the phyllites varies considerably across strike from southeast to northwest in the Old Duke quarry. The clastic texture of the phyllites decreases in size from southeast to northwest along the quarry face (see figure 2). The southeastern end is composed predominantly of lithic tuffs and breccias containing deformed elongated clasts that are parallel to the bedding and cleavage. The phyllites exhibit excellent normal graded bedding from fine to coarse from northwest to southeast. This suggests subaqueous deposition for these rocks and indicates that the rocks are progressively younger from southeast to northwest through the quarry. Excellent exposures of normal graded bedding is exposed in the northwestern end of the quarry face occurring in a highly weathered reddish-brown phyllite.

The phyllites in the New Duke quarry are identical in appearance and composition to the phyllites in the Old Duke quarry with one major exception, the graded bedding is reversed. Detailed study of the immediate vicinity established the presence of an overturned syncline (see plate 13, cross section A-A').

Butler (1964) states, "The Duke quarry phyllite was derived from argillite, tuff or tuffaceous sandstone, and volcanic breccia. Occurrence of laminated argillites suggests marine deposition."

Four randomly selected hand specimens from Unit II in Orange County have an average SiO_2 content of 62.2 percent which would collectively group the specimens in the andesitic-dacitic range. The SiO_2 range for the four specimens is from 58.2 percent to 65.7 percent which is an SiO_2 range of 7.5 percent. Complete chemical analyses for the four specimens are listed above in table 2.

DESCRIPTIONS OF PHOTOMICROGRAPHS AND PHOTOMACROGRAPHS

Unit II

Plate 3

1. Dacitic tuff breccia from Unit II. Plain light; magnification 24X. Note angular to subrounded clasts randomly oriented. Skeletal opaque magnetite grain (M) is located at lower left and dust-size particles of magnetite are disseminated throughout the groundmass and larger clasts.

2. Dacitic tuff breccia from Unit II. Same as number 1 except crossed polarizing prisms; magnification 24X. In this photomicrograph slightly larger grain sizes in the lithic clasts cause them to standout in the cryptocrystalline groundmass.

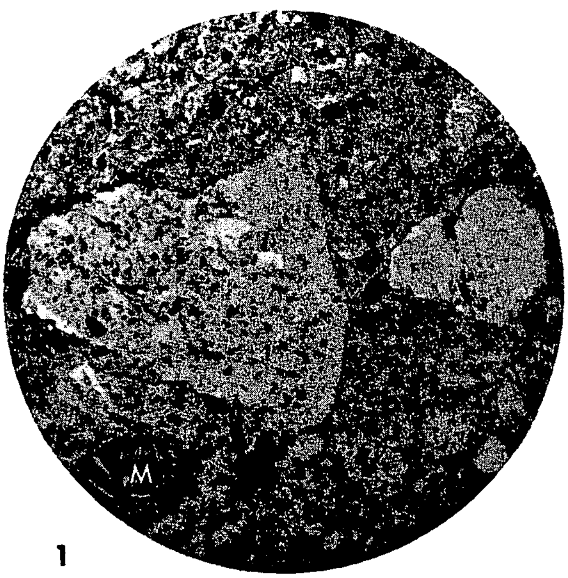
3. Andesitic phyllite from Old Duke quarry in Unit II. Plain light; magnification 24X. Clasts (K) have been stretched and smeared out in lenticular masses. Opaque hematite (H) outlines larger clasts at lower center and upper left. High percentage of finely divided opaque hematite grains give the phyllite its dark bluish gray color.

4. Andesitic phyllite from Old Duke quarry in Unit II. Same as number 3 except crossed polarizing prisms; magnification 24X. The flakey schistosity of this phyllite's lepidoblastic texture results from the general parallel alignment of the abundant sericite, chlorite and chloritoid. Note that many of the deformed clasts (K) contain a slightly larger grain size and usually more abundant quartz which causes them to appear under crossed polarizing prisms as lighter colored lenticular aggregates.

5. Phyllitized tuff from Old Duke quarry in Unit II. Photomacrograph of sawed section; magnification 3X. The flat and elongated clasts (K) range in composition from felsic to mafic and appear to be derived from fine grained or glassy volcanic rocks.

6. Dacitic tuff breccia from Unit II. Photomacrograph of sawed section; magnification 3X. Fractured and randomly oriented lithic clasts and fine-grained groundmass range from felsic to mafic in composition. Note flow banding in light colored broken rhyolite fragment at center.

PLATE 3



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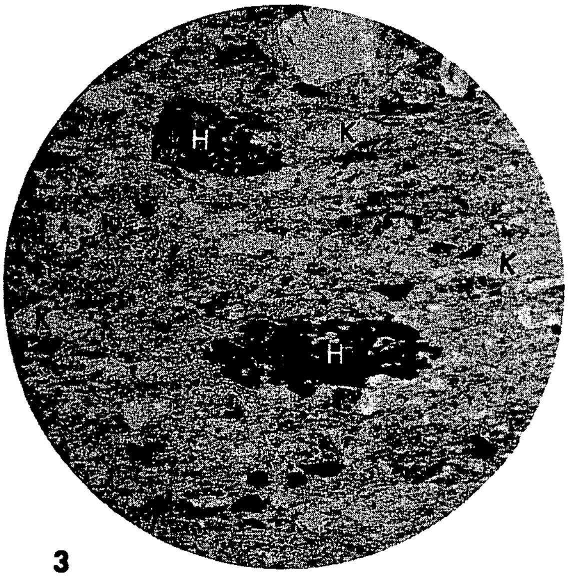

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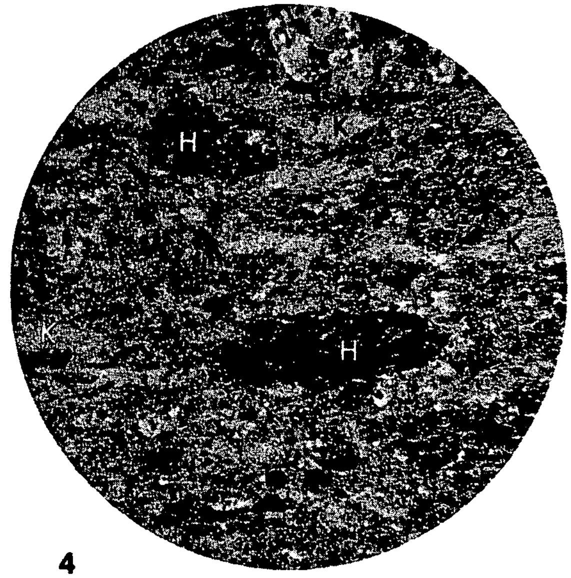

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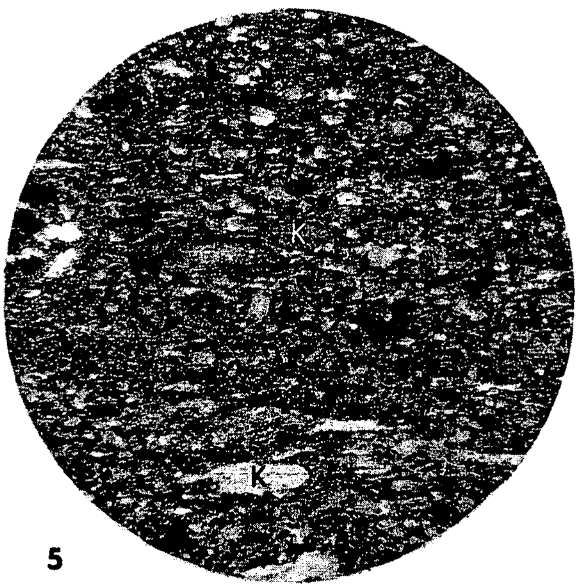

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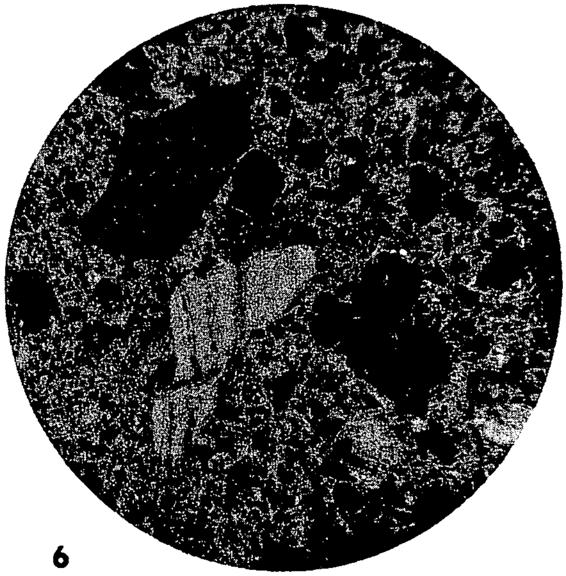

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DESCRIPTIONS OF PHOTOGRAPHS

UNIT II

Plate 4

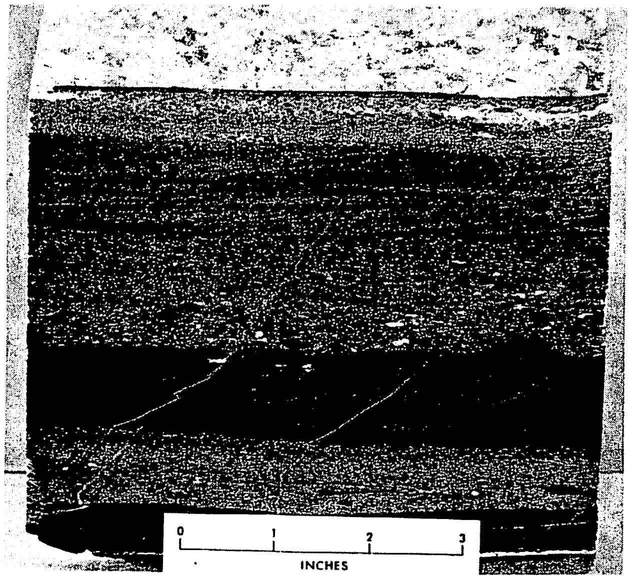
1. Phyllitized lithic tuff from Old Duke quarry, exhibiting normal graded bedding and deformed lithic clasts that are oriented parallel to the cleavage and bedding. Cleavage plane is visible at top of the specimen.

2. Sawed section of tuff breccia from Unit II exhibiting abundant randomly oriented angular to subrounded lithic clasts of varying sizes and compositions which range from mafic to felsic.

3. Same specimen as number 2 illustrating an uneven knobby surface resulting from differential weathering of the matrix and the lithic clasts.

4. Outcrop of phyllite of Unit II on east bank of Eno River located approximately 0.5 mile east of the center of the town of Hillsborough, North Carolina.

5. Twenty foot benched face of exposed phyllite in New Duke quarry in process of being quarried for building stone for use in construction of buildings on the campus of Duke University in Durham, North Carolina. The blocky and slabby characteristics of the stone results from the combination of cleavage and jointing.



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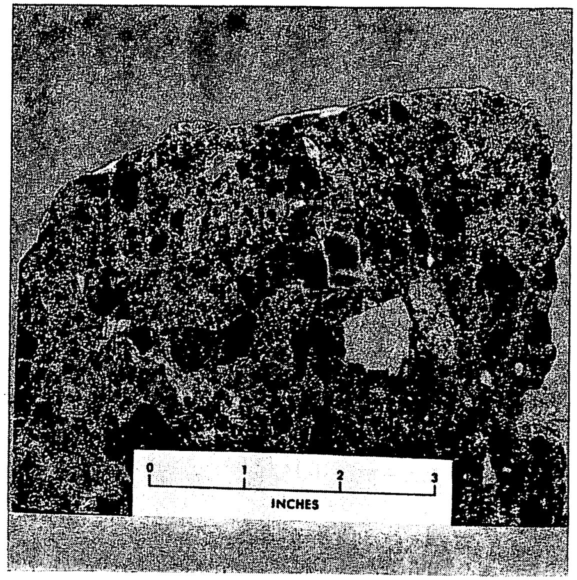

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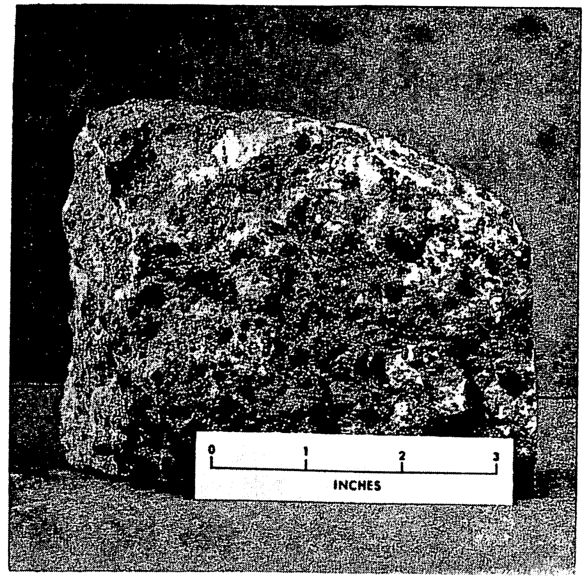

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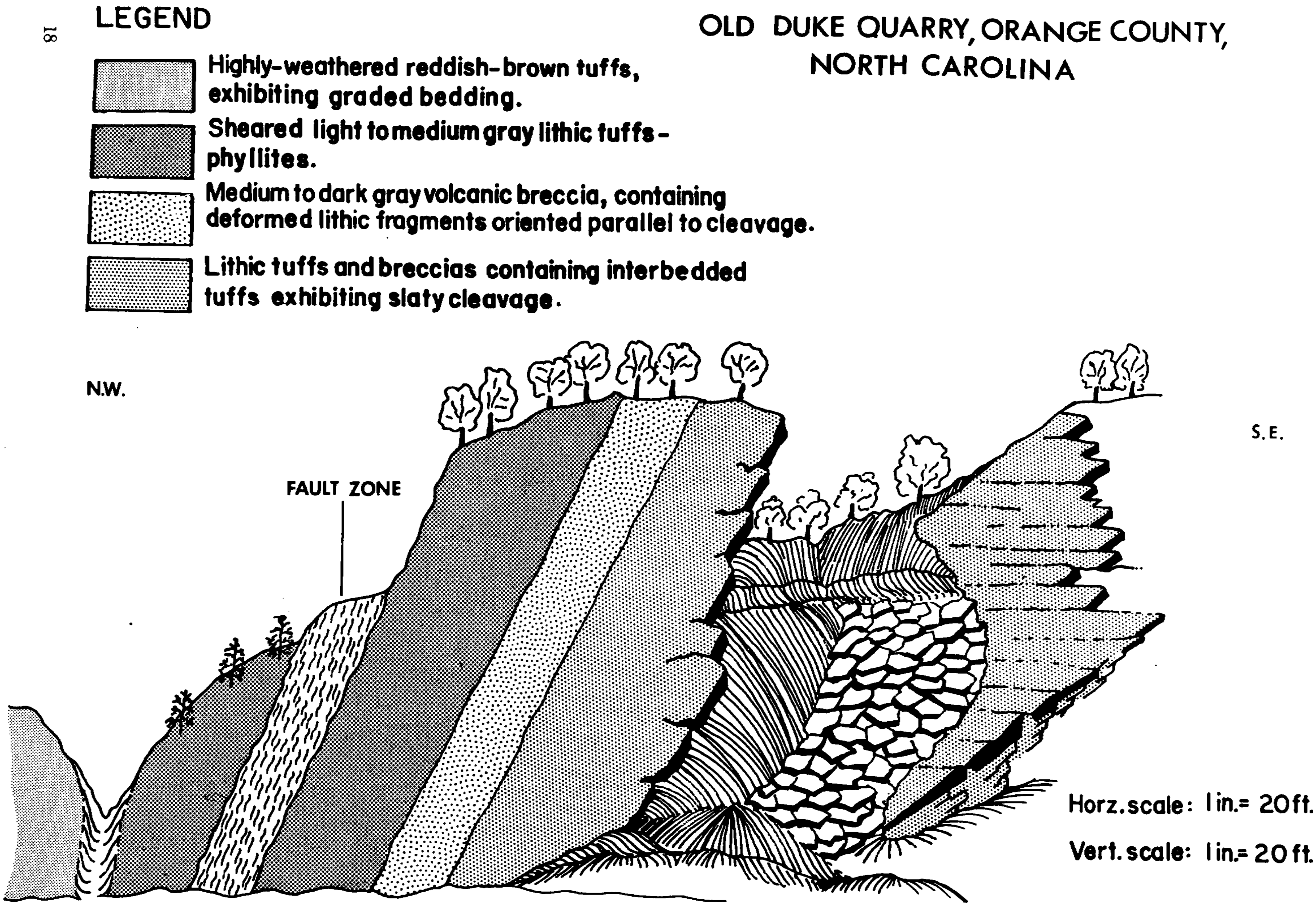


Figure 2. Old Duke quarry, Orange County, North Carolina.

Unit III

Unit III is composed of pyroclastic and flow rocks of dacitic to rhyolitic composition (see plates 5 and 6). Pyroclastic rocks are very abundant; whereas, flow rocks are rare. This suggests that the vulcanism for the length of time represented by the accumulation of the rocks of Unit III was primarily one of explosive ejecta rather than one of outpouring of lavas.

The felsic pyroclastics are predominantly lithic tuffs and crystal lithic tuffs. The tuffs are dense, medium to light gray to light green in color and have a subconchoidal to conchoidal fracture. A speckled appearance, evident in many of the specimens, is caused by an abundance of white to light gray feldspar crystal clasts that are lighter colored than the matrix, and lithic clasts that are darker colored than the matrix (see plate 6, no. 4). The lithic clasts are randomly oriented, angular to subrounded and vary from two to twenty millimeters in size. The clastic texture is obvious in hand specimens but is more pronounced on weathered outcrops. In such outcrops, the tuffs weather to a white or buff color, but the clasts in general are more resistant to weathering than the matrix, causing a knobby appearance on the weathered surface. Some of the tuffs exhibit a high degree of welding and have a significant ring when struck with the hammer. This suggests that some of the pyroclastics were above the welding temperature when emplaced and were able to retain this temperature until welding was accomplished.

Evidence of devitrification was observed in thin section analysis of specimen number 3 (table 3), a felsic vitric crystal lithic tuff. In this specimen, vitroclastic texture was observed in the lithic clasts occurring in the tuffaceous matrix. The outlines of compacted glass shards were observed in various degrees of preservation and appeared to be confined solely to the lithic clasts rather than occurring in the matrix. Butler (1963, p. 180) describes the presence of vitroclastic texture occurring in flinty aphanites collected from Orange County, North Carolina, and postulates that "most of the flinty aphanites may be vitric-crystal tuff in which the vitroclastic texture was destroyed by subsequent metamorphism."

Rhyolite flow rocks occur at several locations in Orange County associated with felsic vitric crystal and vitric lithic tuffs. One such flow occurs on a northeast-trending ridge located approximately one mile north of the Cross Roads Baptist Church just east of Secondary Road 1134. In outcrop, the rhyolite forms a prominent ridge that strikes N. 55° E. and exhibits a poorly developed cleavage that dips approximately vertical. The rhyolite appears to have been a highly vitric porphyritic flow and contains abundant spherulites. It is a dense, light to medium gray siliceous rock exhibiting flow banding which is highly prominent on weathered surfaces. This flow structure is quite apparent and is easily traceable as it wraps around the spherulites. The spherulites disclose on weathered surfaces, grayish white concentrically arranged aggregations of feldspar and quartz that radiate outward from a common center or nucleus. The nucleus is usually composed of quartz and secondary epidote or a primary feldspar crystal. The spherulites range in size from less than one-tenth of an inch to over four inches in diameter.

Table 3. Chemical Analyses of Dacitic-Rhyolitic Rocks in Unit III.

Sample Number	No. 3	No. 7	No. 14	No. 19
SiO_2	70.6	70.3	71.7	65.2
Al_2O_3	14.8	14.2	14.2	14.3
Fe_2O_3	1.7	1.7	1.3	2.5
FeO	1.1	.93	1.4	1.8
MgO	.58	1.4	.37	.97
CaO	.94	2.1	1.8	3.2
Na_2O	4.6	3.7	4.6	2.7
K_2O	3.9	2.5	3.1	4.1
H_2O-	.05	.08	.07	.05
H_2O+	.65	1.1	.73	1.4
TiO_2	.38	.40	.40	.63
P_2O_5	.00	.08	.06	.10
MnO	.20	.12	.18	.20
CO_2	<.05	1.2	<.05	2.8
Total	100	100	100	100

Note: See Table 5A for sample locations

Trains of small spherulites are evident under thin section examination and can be traced as they wrap around larger spherulitic structures in the cryptocrystalline groundmass. These facts, along with the absence of lithic clasts, indicate that the rhyolite flow rock was a molten lava rather than a mobile welded ash flow.

The presence of spherulitic structures in the rhyolite extrusive provides further evidence of widespread devitrification among the felsic volcanic rocks of Unit III. Ross and Smith (1961, p. 37) have described the formation of spherulites occurring in devitrified rhyolites and welded tuffs and state that the spherulitic structures developed in welded tuffs differ in no way from those occurring in many rhyolite flow rocks. They further state that the identity of such rocks may be determined from geologic relations, and inclusions of materials of clastic origin may indicate ash-flow origin. Because of the absence of inclusions of clastic materials and the existence of flow lines, it is believed that the rock containing the spherulites is a flow.

Four randomly selected hand specimens from Unit III in Orange County have an average SiO_2 content of 69.5 percent. The SiO_2 range for the four speci-

DESCRIPTIONS OF PHOTOMICROGRAPHS AND PHOTOMACROGRAPHS

Unit III

Plate 5

1. Devitrified felsic vitric crystal tuff of Unit III. Crossed polarizing prisms; magnification 24X. Devitrified lenticular vitric clast (V) in upper center and portion of plagioclase crystal clast (P) at bottom. Note how the flow lines in the cryptocrystalline groundmass curve around the clast. The apparent mineral constituents of the groundmass are sericite, quartz and crystal fragments of alkali feldspar. Circle on lower part of lenticular clast is air bubble.

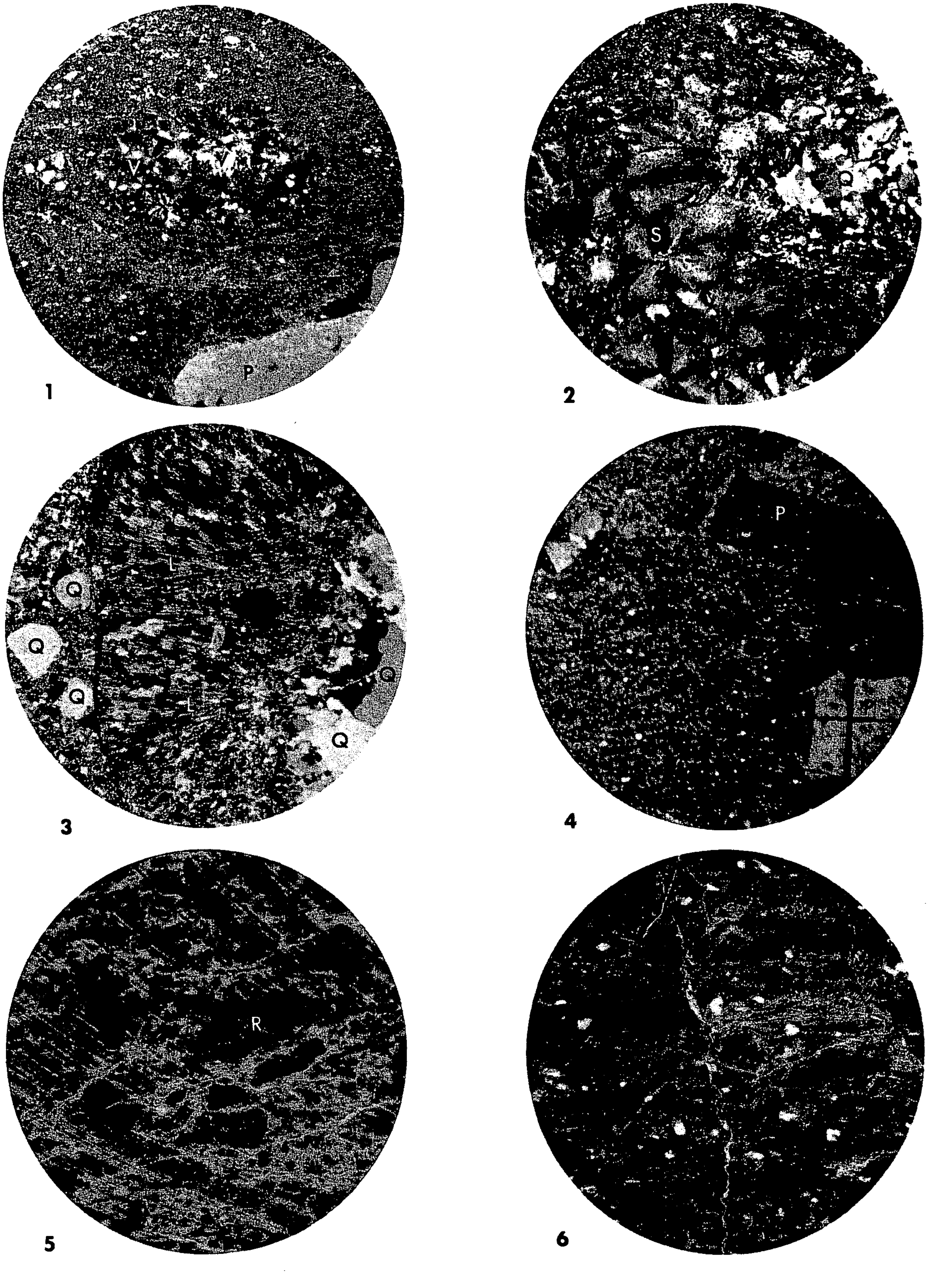
2. Devitrified felsic vitric crystal tuff of Unit III. Crossed polarizing prisms; magnification 100X. Enlargement of devitrified texture of vitric clast in number 1. Spherulites constitute most of outer portion of devitrified clast while fine granular quartz (Q) is concentrated on the interior. The larger spherulite (S) displaying the extinction cross at the lower left measures approximately 0.1 mm. in diameter. White specks at center of spherulite are sericite flakes.

3. Spherulite in devitrified felsic vitric crystal tuff of Unit III. Crossed polarizing prisms; magnification 24X. Center of spherulite at right is composed of granular quartz (Q). Note how the radial pattern of feldspar and quartz laths (L) have developed independently and partially mask the original vitric and shard structure. Remnants of quartz phenocryst (Q) and shards occur at left in cryptocrystalline groundmass.

4. Devitrified felsic vitric crystal tuff of Unit III. Crossed polarizing prisms; magnification 24X. Plagioclase crystals (P) at right exhibit carlsbad and pericline twinning. Albite twinning is also common. Note corroded borders of plagioclase crystals and how cryptocrystalline groundmass appears to flow around them.

5. Felsic lithic tuff of Unit III. Photomacrograph of sawed section; magnification 3X. Note the parallel alignment of some of the larger clasts in the light gray aphanitic groundmass. The largest somewhat rounded fragment at right center is hematite-red rhyolite (R). Even though most of the large clasts appear dark gray and reddish gray in color they are felsic in composition.

6. Devitrified felsic vitric crystal tuff of Unit III. Photomacrograph of sawed section; magnification 3X. Note marked parallel alignment of the darker devitrified lenses and shards. Also observe the abundance of the ragged white feldspar phenocrysts and how many seem to serve as the nucleus of the darker lenses in the aphanitic groundmass.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DESCRIPTIONS OF PHOTOGRAPHS

Unit III

Plate 6

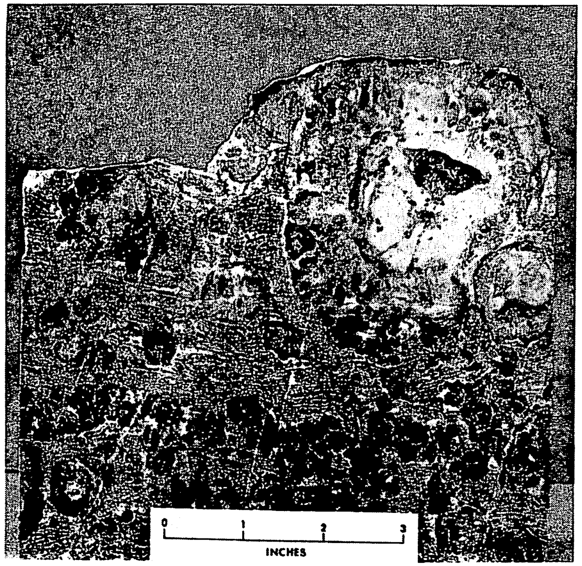
1. Sawed section of spherulitic rhyolite flow from Unit III exhibiting abundant spherulites which range in size from 0.05 inch to 4 inches in diameter. Trains of minute spherulites give the rock a banded appearance and can be traced around the peripheries of the larger spherulites. Outcrops of the spherulitic flow are located approximately 2.5 miles southwest of the center of Hillsborough, North Carolina, on a ridge between Secondary Roads 1006 and 1134, 0.6 mile south of Interstate Highway 85.

2. Sawed section of felsic crystal lithic flow tuff from Unit III exhibiting a buff colored irregular weathered zone, 0.25 inch thick at top of specimen. Light colored feldspar crystals and dark-colored spherulites give the specimen a speckled appearance. Deformed elongated dark-colored shards indicate compaction. The deformed shards and trains of spherulites are aligned from upper right to lower left.

3. Same hand specimen as number 2 illustrating the weathering characteristics of the felsic crystal lithic flow tuff. Small spherulites are easily visible on the weathered matrix and wrap around the large lighter colored lithic clast located on the extreme left of the specimen. Flow lines and spherulites are easily discernible in the upper right-hand corner of the specimen.

4. Close up view of massive felsic crystal lithic tuff that is further described under photograph number 5. Note random orientation of the lithic clasts and the light colored feldspar crystals.

5. Outcrop of massive felsic crystal lithic tuff containing relatively large lithic clasts which range up to 8 inches in length. Outcrop is located on east side of Highway N.C. 86, 0.3 mile north of intersection with Secondary Road 1723.



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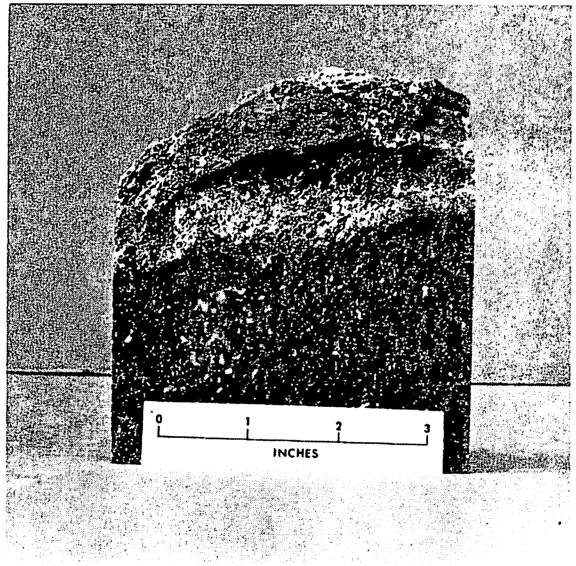

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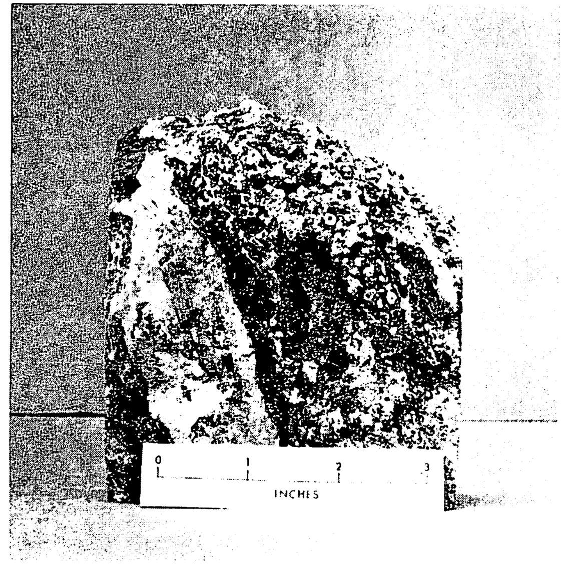

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mens is from 65.2 percent to 71.7 percent which is a SiO_2 differential of 6.5 percent. Complete chemical analyses of the four specimens are listed in table 3.

Unit IV

The metavolcaniclastic sedimentary rocks of Unit IV consist of argillites, graywackes with intercalated argillites, and conglomerates with graywacke interbeds (see plates 7 and 8). The sequence strikes N. 48° E. dips vertically and appears to overlie conformably the volcanic rocks in Unit III. These epiclastics (Fisher, 1961, pp. 1409-1443) are composed of detrital fragments of pre-existing volcanic rocks, both flows and pyroclastics, that have been subaqueously deposited through the process of weathering, erosion and transportation. The volcaniclastic sedimentary sequence of basal conglomerates contains well rounded tuff, rhyolite and quartz pebbles and cobbles with intercalated graywackes. This sequence is overlain by graywackes with argillite interbeds which is in turn overlain by argillites and laminated argillites. This suggests that positive source areas were present and that slow moving saturated currents deposited the sediments below wave base in the relatively quiet-water zone. The evidence of graded bedding in the volcaniclastic sedimentary rocks indicates sedimentation below wave base and the laminated argillites are indicative of quiet-water deposition. "Only in the absence of any bottom turbulence could such laminations remain undisturbed" (Pettijohn, 1957, p. 593). The presence of laminated argillites was also noted by Butler (1963, p. 181) in which he stated, "The argillite and slate originated by accumulation of clay and silt-sized particles. The presence of laminations suggests a lacustrine or marine environment. The laminations must have been formed by intermittent changes in depositional conditions such as seasonal variations, periodic currents, or regularly-spaced eruptions of volcanic ash."

Chemical analyses of three randomly selected hand specimens of epiclastics from Unit IV appear in Table 4, p. 25. Specimen number eleven is the analysis for an argillite which compares favorably to similar rock types listed in the literature (Pettijohn, 1957, p. 344). The graywacke, specimen number twelve, compares favorably to the chemical composition of the average of twenty three graywackes listed by Pettijohn (1957, p. 307, Table 52). The conglomerate is felsic in composition, 66.3 percent SiO_2, a fact which may be attributed to the abundance of cryptocrystalline pebble to cobble sized, well rounded, sub-spherical to spherical felsic volcanic particles.

On outcrop, the conglomerate is light to medium greenish gray in color and contains an abundance of sand to cobble size, well rounded, moderately spherical to spherical particles of both flow and pyroclastic material that is predominantly darker gray in color than the matrix, but is felsic in composition. This suggests that the sediments were derived from positive areas of pre-existing felsic volcanic rocks. The roundness and sphericity of the pebbles and cobbles within the conglomerate further shows that the particles were transported. Brown to buff to white, rounded, moderately spherical to spherical quartz particles are present, but numerically compose only a minor fraction of the rounded pebbles and cobbles. Intercalated within the conglomerate are graywacke interbeds that are strikingly similar to the matrix of the conglomerate. The graywackes are predominantly light to medium greenish gray and have a speckled appearance because of the abundance of darker gray lithic particles and white crystal particles disseminated throughout the matrix. Clarke (1957) mapped a sedimentary sequence south of the town of Chapel Hill, North Carolina, on Morgan Creek which he called a "wacke conglomerate," Clarke described the sequence as a narrow east-west band 1.7 miles long and 1200 feet wide that dips vertically and is conformable with the underlying "slate series." The rock type was described as "a poorly sorted aggregate of varied grain size. About 75 percent of its volume is pebbles." The matrix was described as a "fine-grained groundmass, highly chloritized and moderately epidotized." Eaton (1908) recognized the presence of a sedimentary sequence in Orange County. He stated the rocks "consist of a series of conglomerates, sandstones, and flint-like slates lying in places upon felsite." Eaton also pointed out that the slates are bedded alternately with sandstones and conglomerates and that conglomerates are composed of well-rounded pebbles of several kinds of volcanic rocks, but are by no means volcanic agglomerates. Eaton noted that "the slates are coincident in dip with the sandstones and conglomerates with which they are associated, and from all field evidence obtainable, seem to have been deposited as regular members of the sedimentary series." Eaton describes the "slates" as being laminated or stratified and postulates that they were derived from "felsites" or rhyolites and were deposited in deep water. The authors are of the opinion that the "slates" which Eaton describes are not slates but are rather laminated argillites that occur in the sedimentary sequence mapped as Unit IV in Orange County. The intercalated conglomerates are conformably overlain by graywackes with intercalated laminated argillites. The graywackes appear as previously described and consist of sub-rounded to rounded quartz grains and small sub-rounded to rounded particles of pre-existing cryptocrystalline metavolcanic rocks and some fragments of feldspar crystals. Thin section examination of the graywackes further revealed albite and carlsbad twinning in the feldspars. Opaques present within the thin section were identified as being predominantly magnetite. The graywacke exhibits a fine-grained groundmass composed primarily of chlorite and epidote.

The intercalated laminated argillites on fresh surfaces are light to medium gray fine-grained rocks that are composed predominantly of quartz, chlorite and sericite in their order of abundance. Weathering of the argillites produces a buff to yellowish-buff rind, that when rubbed between the fingers has a distinctive silty feel. These intercalated argillites locally grade upward in the sequence of a zone of laminated argillites with no apparent graywacke interbeds. The strike and dip of the argillites are coincident with the underlying conglomerates and graywackes which is N. 48° E. and dip vertically. The cleavage of the argillites is parallel to the bedding. Sections or slabs ¼-inch thick can easily be cleaved. The laminations within the argillites are probably a result of the topography, climate and aqueous depositional characteristics that existed during the formation of this volcaniclastic sedimentary sequence. It appears that the sedimentary sequences found within the county are only small remnants of a larger area of similar epiclastics that have been destroyed through subsequent metamorphism, folding, faulting, weathering and erosion.

Three randomly selected hand specimens of epiclastics from Unit IV in Orange County have an average SiO_2 content of 64.1 percent which would collectively group the specimens in the dacitic range. The SiO_2 range for the three specimens is from 61.5 percent SiO_2 to 66.3 percent SiO_2 which is an SiO_2 differential of 4.8 percent. Complete chemical analyses for the three specimens are listed below in table 4.

Table 4. Chemical Analyses of Epiclastics in Unit IV.

Sample Number	No. 11	No. 12	No. 13
SiO_2	61.5	64.5	66.3
Al_2O_3	19.1	15.8	15.2
Fe_2O_3	3.3	5.9	3.6
FeO	2.9	1.3	2.4
MgO	1.8	1.8	2.0
CaO	1.6	.91	1.5
Na_2O	1.7	2.4	2.8
K_2O	3.4	3.0	2.4
H_2O-	.54	.33	.11
H_2O+	2.5	2.8	2.5
TiO_2	.82	.85	.72
P_2O_5	.11	.06	.13
MnO	.18	.18	.27
CO_2	<.05	<.05	<.05
Total	99	100	100

Note : See Table 5A for sample locations.

ENVIRONMENT AND MODE OF DEPOSITION

General statement

The occurrence of volcanic-sedimentary rocks in a long narrow zone extending for a length of approximately four hundred miles from central Georgia to southeastern Virginia and a width that in some places exceeds one hundred and twenty miles, suggests deposition under eugeosynclinal conditions.

Stuckey (1965) states that there seems to be little doubt that the rocks of the Carolina Slate Belt were formed in a eugeosyncline containing island arcs. He postulates that the volcanic rocks in the geosyncline came largely from beneath the surface by volcanic eruptions. The nonvolcanic sediments or landwaste in the form of clay, silt, mud, sand and rounded quartz pebbles were derived from narrow belts of uplift that were present in or adjacent to the trough.

Orange County area

Features observed in the rocks of the volcanic-sedimentary units in Orange County, North Carolina, indicate both subaqueous and subaerial environments of deposition. It is reasonable to infer that during the lengthy formative period of the units, events of predominantly volcanic character occurred, although they undoubtedly included periods of erosion and sedimentation. The rock sequences show that there were periods of lava outflows with violent periods of explosive pyroclastic discharges. The unit sequence also suggests that the order of vulcanism was from an initial basic phase gradually changing to an acid phase prior to quiescence.

Pillow structures present at several locations along strike in the spilitic amygdaloidal basalt lava flow rocks indicate at least part of the basalts accumulated in water. The extent and lithologic uniformity of the basalts suggest relatively near-source areas capable of extruding large quantities of material over a wide area. Intercalated basaltic lithic and crystal tuffs associated with the basalt flow rocks is further evidence for explosive pyroclastic discharges from source areas relatively near and are also indicative of a pulsating volcanic cycle that produced both extensive massive basalt extrusive rocks and thick accumulations of mafic pyroclastic rocks.

The andesitic to dacitic lithic and crystal tuffs, tuff breccias and phyllites which conformably overlie the basalt flow rocks exhibit characteristics for further evidence of subaqueous and subaerial deposition in the area. The presence of a well developed graded bedding

DESCRIPTIONS OF PHOTOMICROGRAPHS AND PHOTOMACROGRAPHS

Unit IV

Plate 7

1. Argillite from Unit IV. Crossed polarizing prisms; magnification 24X. Fine silt to clay-sized particles of sericite, chlorite, quartz, feldspar and epidote are the major mineral constitutents of the matrix of this argillite. The sparsely scattered coarse silt-sized grains are quartz, feldspar and epidote. The white appearing quartz grain (Q) near the center of the photomicrograph measures 0.05 mm. in diameter. The dark-colored grain to the right of center is epidote (E). Alkali feldspars (F) were noted. Under higher magnification some grains display carlsbad and albite twinning.

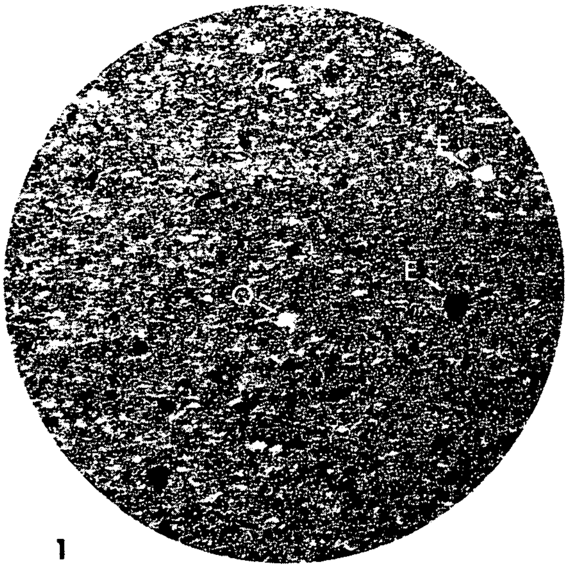
2. Graywacke from Unit IV. Crossed polarizing prisms; magnification 24X. Large quartz clast (Q) at lower right measures 0.5 mm. in maximum diameter. The silt and clay-sized matrix has the same mineral composition as the argillite in number 1. The larger coarse silt and sand-size clasts are fragments of quartz and alkali feldspar crystals (F). Quartz appears clear while feldspar is often slightly clouded by minor inclusions and many grains display carlsbad and albite twinning.

3. Conglomerate of Unit IV. Plain light; magnification 24X. Shows large angular and rounded fragments of pre-existing volcanic rocks in a mixed graywacke and argillite matrix similar to number 1 and number 2. Note opaque hematite grains disseminated throughout the groundmass and some of the lithic fragments (K).

4. Conglomerate from Unit IV. Same as number 3 except crossed polarizing prisms; magnification 24X. Note how the concentration of hematite in the lithic clast (H) at the upper center causes it to stand out and the large clast (K) at the bottom is still faintly recognizable by its slightly coarser grain size. Most of the lithic clasts appear to blend in with the matrix in this black and white picture since their grain size and composition of quartz and feldspar are very similar. However, when viewed in color the matrix is made conspicuous by its higher content of sericite and chlorite.

5. Laminated argillite of Unit IV. Photomacrograph of sawed section; magnification 3X. Normal bedding in lamina grades from coarse silt size on bottom to fine clay sizes at top. Note how dark-colored lamina (L) in upper portion of section has been offset by microfault (F). Darker grains along fault plane are epidote (E). Sericite (S) constitutes lighter sections.

6. Graywacke from Unit IV. Photomacrograph of sawed section; magnification 3X. Bedding in graywacke layer grades from coarse near bottom to fine at top. Note intercalated laminated argillite (A) at bottom of field.



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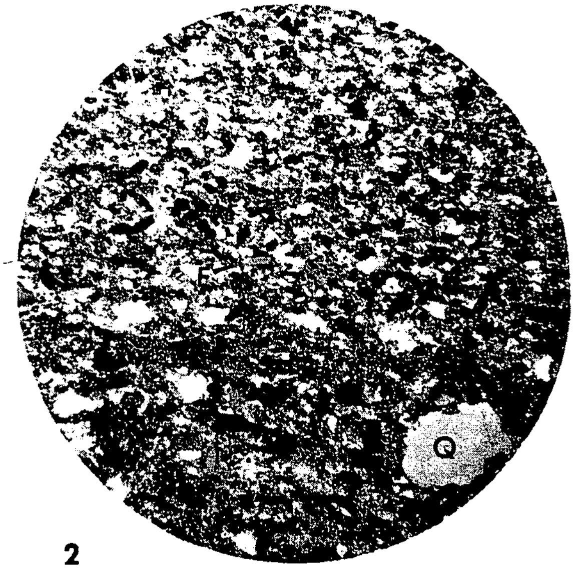

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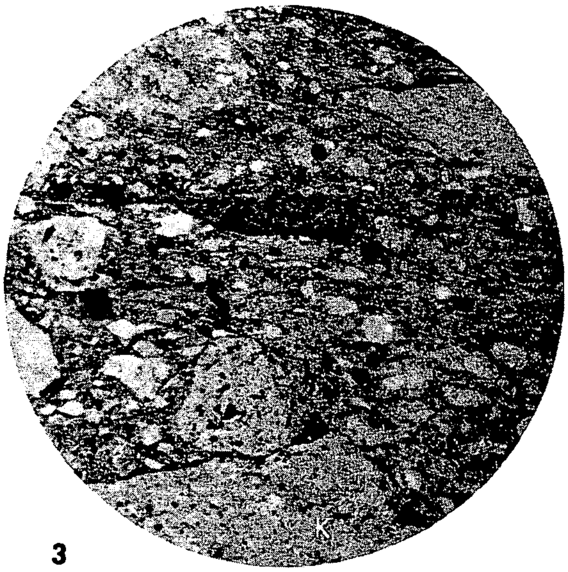

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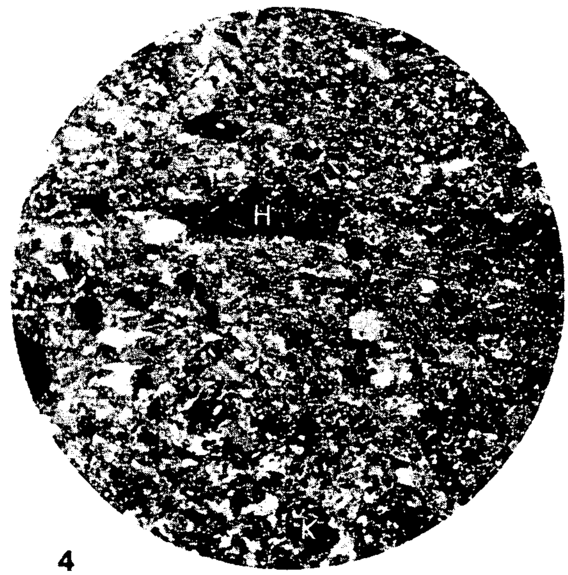

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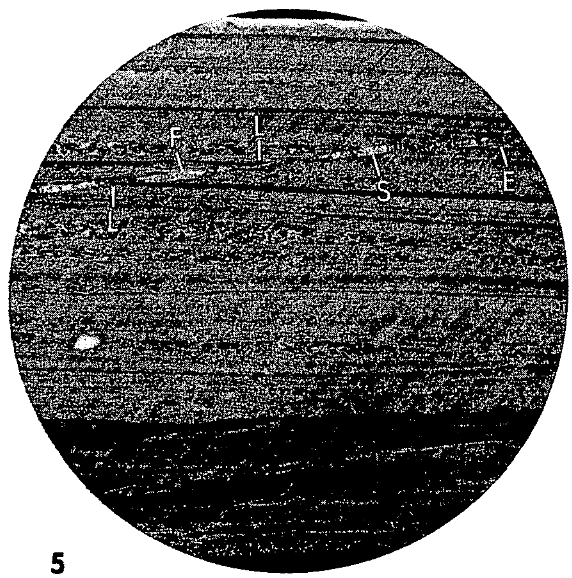

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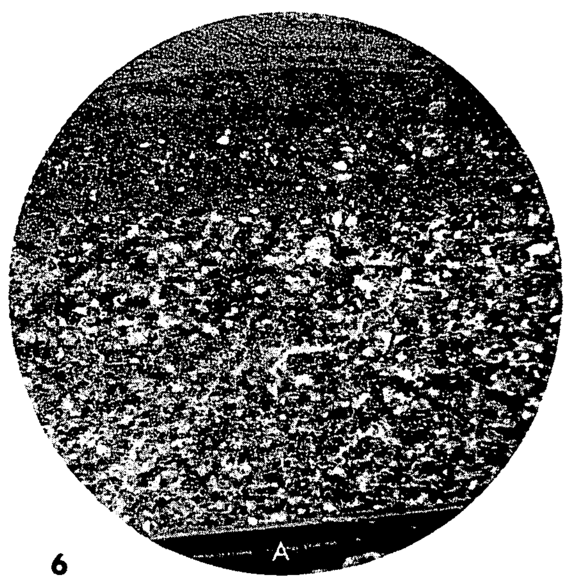

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DESCRIPTIONS OF PHOTOGRAPHS

Unit IV

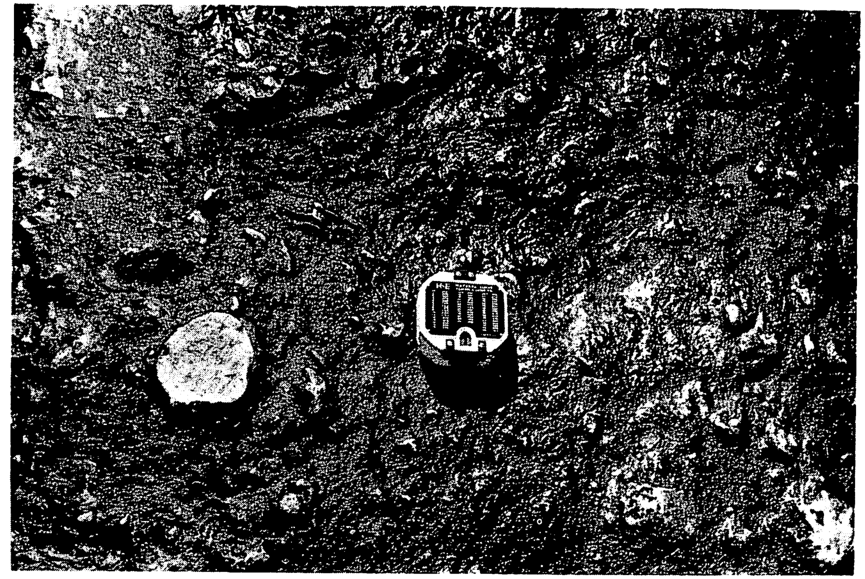
Plate 8

1. Small exposed cut of the volcaniclastic sedimentary sequence approximately 2 to 2.5 feet high located on the west bank of the Eno River, 3 miles northwest of the center of Hillsborough, North Carolina. The cut illustrates an epiclastic sequence of light to medium gray laminated argillites intercalated with light to medium gray graywackes. The grading sequence is from coarse on the right to fine laminated argillites on the left. The sequence strikes N. 41° E. and has a vertical dip. The cleavage and the bedding in the sequence are parallel.

2. Conglomerate of the volcaniclastic sedimentary sequence. The conglomerate contains sub-rounded to well rounded predominantly felsic volcanic particles that range from sand through cobble sizes. Some rounded quartz pebbles are also present. The matrix of the conglomerate resembles, and in some places is identical to, the intercalated graywacke. The presence of some hematite-red graywacke was noted in the sequence.

3. Sawed section of the conglomerate of the volcaniclastic sedimentary sequence, illustrating in cross section the sub-rounded to well-rounded nature of the particles. Note the well rounded quartz pebble in the lower right corner of the specimen. The fine-grained graywacke matrix is light greenish gray in color.

1



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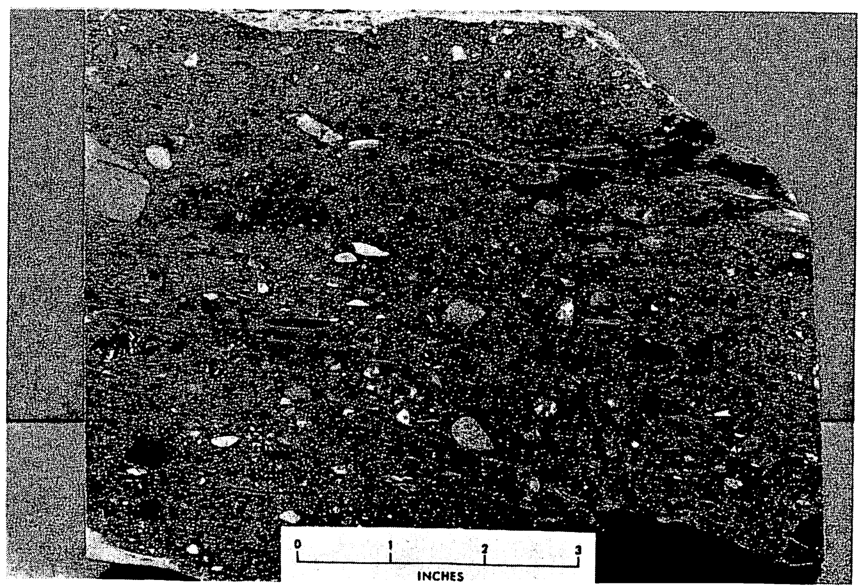


3

indicates a subaqueous origin for many of the tuffs. However, many of these interbedded lithic tuffs show some degree of welding and contain randomly oriented clasts which suggests a subaerial rather than a subaqueous deposition. The abundance of intermediate pyroclastics is also indicative of highly active vulcanism which continued over a long period of time to emplace volcanic materials of considerable thicknesses in the area.

The tuff breccias with associated tuffaceous interbeds contain assorted clasts ranging in size from ½ inch to more than two feet in diameter and appear to compose approximately 35 to 40 percent of the rock. The presence of larger clasts in certain areas of the unit, suggests that the source area or areas were relatively near. Parts of the unit contain lahars, accumulations of unsorted volcanic debris that result from water saturated volcanic material resting on the flanks of vents then moving downslope as slides or flows.

Phyllites associated with the intermediate tuffs and breccias exhibit features indicative of subaqueous deposition which have not been destroyed by folding and shearing. These phyllites which were derived primarily from pre-existing tuffs, lithic tuffs and breccias show a pronounced graded bedding throughout much of the sequence. In places the graded bedding is normal and in other areas the graded bedding is overturned.

The argillites, graywackes with intercalated argillites and the conglomerates with intercalated graywackes which occur in the volcaniclastic sedimentary unit represent a normal uninterrupted conformable sedimentary epiclastic sequence derived from pre-existing metavolcanic rocks.

CHEMICAL AND SPECTROGRAPHIC ANALYSES

General statement

Chemical and spectrographic analyses of twenty hand specimens were made from rocks of volcanic origin collected by the authors from Orange County during the latter part of 1966 (see tables 5, 5A and 6). The specimens were collected from each of the major stratigraphic units mapped in the volcanic-sedimentary sequence previously discussed. These specimens were selected and obtained from outcrops which showed no apparent weathering or pronounced hydrothermal alteration.

The analyzed rocks contain between 50.0 and 71.7 percent SiO_2 with an average SiO_2 content of 62.3 percent and an SiO_2 differential of 21.7 percent. Using a standard of 50 to 55 percent SiO_2 content for basaltic volcanic rocks, 56 to 66 percent SiO_2 content for volcanic rocks in the intermediate andesitic-dacitic range and above 66 percent SiO_2 content for felsic volcanic rocks, the analyses indicate that five specimens are in the basaltic range, six in the intermediate andesitic-dacitic range and eight in the felsic volcanic range (specimen no. 1 not included in above calculations).

Alkali-lime index

The alkali-lime index is a plot of total alkalies (Na_2O+K_2O) and lime (CaO) plotted against silica (SiO_2). The percentage of silica at which the alkalies (o) and lime (x) intersect is called the alkali-lime index. The alkali-lime index is subdivided into four divisions. Alkalic is less than 51 percent silica, alkali-calcic is from 51 to 56 percent silica, calc-alkalic is from 56 to 61 percent silica and calcic is greater than 61 percent silica.

Chemical analyses of twenty rocks of volcanic origin from Orange County including flows, pyroclastics and epiclastics were used to determine the alkali-lime index as shown in figure 3. The intersection of the alkali-lime plots gives an alkali-lime index of 59.9 percent which is in the calc-alkalic range and is consistant with the figure of 59 percent plotted by Butler (1964) of analyses of volcanic rocks from the Virgilina area, Albemarle area and from Orange County, North Carolina.

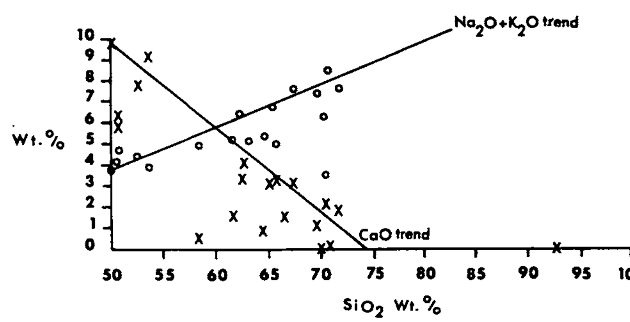


Figure 3. Plot of lime and total alkalies against silica.

Silica range

Figure 4 is a plot of the silica range and content of 19 rock specimens of volcanic origin collected from Orange County, North Carolina. Five specimens fall within the basaltic range of 50 to 55 percent silica, seven specimens fall within the intermediate range of 55 to 66 percent silica and seven specimens fall within the felsic range of 66 or greater percent silica. Each

TABLE 5. CHEMICAL ANALYSES OF ROCK SPECIMENS FROM ORANGE COUNTY, NORTH CAROLINA

SAMPLE NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SiO_2	92.6	62.8	70.6	53.6	67.4	52.6	70.3	50.5	50.7	62.1	61.5	64.5	66.3	71.7	70.1	58.2	69.8	50.0	65.2	65.7
Al_2O_3	2.5	16.5	14.8	16.4	15.4	17.1	14.2	19.4	16.7	14.7	19.1	15.8	15.2	14.2	10.8	22.6	14.5	18.0	14.3	15.2
Fe_2O_3	1.1	5.9	1.7	6.0	2.2	2.5	1.7	4.3	3.1	5.2	3.3	5.9	3.6	1.3	11.9	5.8	1.9	7.3	2.5	3.0
FeO	.18	.50	1.1	4.0	1.0	6.2	.93	5.7	7.6	3.0	2.9	1.3	2.4	1.4	.58	1.4	1.8	2.3	1.8	3.1
MgO	.30	1.8	.58	3.5	.96	5.1	1.4	4.7	5.6	1.9	1.8	1.8	2.0	.37	.18	1.0	.92	5.1	.97	1.7
CaO	.11	4.1	.94	9.2	3.1	7.8	2.1	6.4	5.8	3.4	1.6	.91	1.5	1.8	.00	.49	1.1	9.7	3.2	3.3
Na_2O	.06	3.1	4.6	3.1	4.2	3.8	3.7	3.9	3.8	4.1	1.7	2.4	2.8	4.6	.60	2.7	4.8	3.0	2.7	3.9
K_2O	1.2	2.0	3.9	.77	3.3	.64	2.5	.27	.88	2.3	3.4	3.0	2.4	3.1	2.9	2.3	2.0	.70	4.1	1.1
H_2O-	.07	.06	.05	.06	.05	.07	.08	.12	.07	.06	.54	.33	.11	.07	.04	.28	.09	.11	.05	.07
H_2O+	.73	1.3	.65	1.5	1.1	2.5	1.1	3.4	3.9	1.5	2.5	2.8	2.5	.73	1.3	3.5	1.5	2.3	1.4	1.5
TiO_2	.15	.87	.38	.97	.45	1.0	.40	1.0	1.2	1.1	.82	.85	.72	.40	1.3	1.2	.54	.90	.63	.84
P_2O_5	.00	.22	.00	.16	.10	.23	.08	.13	.24	.30	.11	.06	.13	.06	.02	.22	.13	.22	.10	.20
MnO	.22	.20	.20	.23	.22	.25	.12	.15	.27	.20	.18	.18	.27	.18	.11	.14	.15	.26	.20	.30
CO_2	<.05	.35	<.05	<.05	<.05	.10	1.2	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	2.8	<.05
Sum	99	100	100	99	99	100	100	100	100	100	99	100	100	100	100	100	99	100	100	100

1. Meta-siliceous sinter
2. Dacitic lithic tuff
3. Devitrified felsic vitric crystal tuff
4. Basalt porphyry
5. Felsic lithic crystal tuff
6. Amygdaloidal basalt
7. Felsic lithic tuff
8. Amygdaloidal basalt
9. Amygdaloidal basalt
10. Dacitic tuff
11. Argillite
12. Graywacke
13. Conglomerate
14. Felsic crystal tuff
15. Phyllitic bedded tuff
16. Andesitic lithic tuff
17. Felsic tuff
18. Amygdaloidal basalt porphyry
19. Dacitic tuff
20. Dacitic breccia

TABLE 5A. ROCK SPECIMEN LOCATIONS

SAMPLE NUMBER	ROCK TYPE	UNIT	LOCATION IN ORANGE COUNTY, NORTH CAROLINA
1	Meta-siliceous sinter	III	Located on E. side of S.R. 1126, 0.3 mile NW. of intersection with S.R. 1006
2	Dacitic lithic tuff	II	Located on E. side of S.R. 1114, 0.7 mile S. of intersection with S.R. 1124
3	Devitrified felsic vitric crystal tuff	III	Located on S. side of Morgan Cr., 0.3 mile W. of intersection of N.C. 54 Byp. and S.R. 1919
4	Basalt porphyry	I	Located on N. side of I. 85, 0.6 mile W. of intersection with N.C. 86
5	Felsic lithic crystal tuff	III	Located on S. side of I. 85, 0.8 mile W. of intersection with S.R. 1712
6	Amygdaloidal Basalt	I	Located on S. side of I. 85, 0.6 mile E. of intersection with S.R. 1709
7	Felsic lithic tuff	III	Located at end of S.R. 1566, 1.2 miles N.E. of intersection with U.S. 70.
8	Amygdaloidal basalt	I	Located on N. side of U.S. 70 Bus., at intersection with S.R. 1154 in the town of Hillsborough, N.C.
9	Amygdaloidal basalt	I	Located on N. side of U.S. 70, 0.7 mile E. of intersection with S.R. 1562
10	Dacitic tuff	II	Located on S. side of U.S. 70, 0.4 mile E. of intersection with S.R. 1562
11	Argillite	IV	Located on W. bank of Eno River, 0.1 mile upstream from end of S.R. 1306 and 1.0 mile E. of intersection with S.R. 1338
12	Graywacke	IV	Same as above, but 0.11 mile upstream
13	Conglomerate	IV	Same as above, but 0.12 mile upstream
14	Felsic crystal tuff	III	Located on S. side of S.R. 1335, 0.8 mile W. of intersection with N.C. 86
15	Phyllitic bedded tuff	II	Located in Old Duke Quarry, 1.9 miles W. of the center of Hillsborough, N.C.
16	Andesitic lithic tuff	II	Located in New Duke Quarry, approx. 2000 ft. W. of Old Duke Quarry
17	Felsic tuff	III	Located on S. side of S.R. 1306, 0.2 mile W. of intersection with S.R. 1346, near eastern edge of Mebane, N.C.
18	Amygdaloidal basalt porphyry	I	Located on S. side of U.S. 70, 1.5 miles W. of intersection with S.R. 1327 on E. side of Efland, N.C.
19	Dacitic tuff	II	Located on N. side of U.S. 70 Byp., 0.15 mile E. of Eno River and 0.5 mile W. of intersection with S.R. 1561
20	Dacitic breccia	II	Located on E. side of Eno River, 0.1 mile N. of end of S.R. 1569, and 1.1 miles NW. of its intersection with S.R. 1567

Table 6. Semiquantitative Spectrographic Analyses of Rocks From Orange County, North Carolina*

SAMPLE NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ba	.03	.07	.01	.02	.1	.05	.1	.01	.03	.1	.07	.05	.05	.15	.05	.05	.07	.015	.15	.03
Be	0	0	<.0001	0	<.0001	0	<.0001	0	0	<.001	<.0001	<.0001	<.0001	<.0001	0	<.0001	<.0001	0	.0001	0
Ce	0	0	0	0	0	0	.01	0	0	.01	.015	.01	0	0	0	0	0	0	.01	0
Co	0	.0015	0	.003	.0005	.002	.0003	.003	.002	.001	.001	.0015	.001	.0003	.0003	.001	.0003	.003	0	.0007
Cr	0	.001	0	.0007	.0005	.01	0	.005	.0015	0	.002	.005	.002	0	.0007	.002	0	.01	0	.0005
Cu	.007	.0007	.002	.03	.005	.02	.0015	.02	.02	.0003	.007	.003	.007	.0007	.002	.007	.001	.005	.01	.05
Ga	.0003	.0015	.001	.001	.001	.001	.0015	.001	.001	.001	.0015	.001	.001	.001	.001	.001	.001	.001	.001	.001
La	0	.005	.005	0	.005	0	.007	0	0	.007	.01	.007	0	.005	.003	.003	.003	0	.007	0
Mo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.0003	0	0	0	0	0
Ni	0	<.003	0	<.003	0	.003	0	<.003	<.003	0	<.003	<.003	<.003	0	0	<.003	0	.003	0	0
Pb	0	0	.002	.003	.002	.001	0	0	.002	0	.001	.0007	.002	0	.003	.0005	.0005	.0015	.002	.0015
Sc	.0005	.0015	.001	.003	.0007	.003	.0007	.003	.002	.002	.0015	.002	.0015	.0005	.0015	.003	.0015	.002	.001	.002
Sn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.001	.003
Sr	.0005	.07	.02	.07	.05	.07	.02	.07	.05	.05	.02	.015	.015	.03	.002	.05	.02	.07	.02	.03
V	.001	.007	.001	.03	.005	.02	.002	.02	.015	.01	.01	.01	.01	.002	.007	.01	.002	.015	0	.005
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.007
Y	0	.002	.003	.002	.0015	.0015	.002	.0015	.0015	.003	.003	.002	.0015	.0015	.0015	.002	.003	.001	.003	.002
Yb	0	.0002	.0003	.0002	.00015	.00015	.0002	.00015	.00015	.0003	.0003	.0002	.00015	.00015	.00015	.0002	.0003	.0001	.0003	.0002
Zr	.005	.015	.03	.007	.015	.007	.015	.005	.005	.02	.015	.03	.015	.02	.03	.015	.015	.007	.02	.01

Zero was recorded for the following elements: Ag, As, Au, B, Bi, Cd, Ge, Hf, Hg, In, Li, Nb, Pd, Pt, Re, Sb, Ta, Te, Th, Tl, U, Zn

*Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15 and 0.1, etc.; which represent approximate midpoints of interval data on a geometric scale. The assigned interval for semiquantitative results will include the quantitative value about 30% of the time. The above specimens 1-20 were also used in Table 5 for chemical analyses.

specimen appears on the plot (see figure 4) as a vertical line with the specimens' individual number appearing directly above the line. The height of the vertical lines indicates the percentage of silica for each specimen. The horizontal distance from the first to the last line in each group denotes the silica range. The horizontal distance also shows the relative position of each group within each of the three ranges. Specimens number 18, 8, 9, 6 and 4 plotted within the basaltic range and vary in content of 50.0 percent SiO_2 for specimen number 18 to 53.6 percent SiO_2 for specimen number 4. This is a silica range of 3.6 percent between the lowest and highest percent silica for the five specimens. Specimens number 16, 11, 10, 2, 12, 19 and 20 plotted within the intermediate range and vary in silica content from 58.2 percent SiO_2 for number 16 to 65.7 percent SiO_2 for number 20. This is a silica range of 7.5 percent for the seven specimens. The relative position of the silica range within the group indicates that the majority of the specimens fall within the dacitic range. Specimens number 13, 5, 17, 15, 7, 3 and 14 plotted in the felsic range and vary in silica content from 66.3 percent for specimen number 13 to 71.7 percent SiO_2 for specimen number 14. This is a silica range of 5.4 percent. The relative position of the silica range within the felsic unit indicates that the specimens are rhyodacitic to rhyolitic in composition.

Variations in silica and alkalies

Figure 5 is a diagram (modified after Butler, 1964) of a plot of silica against the ratio of potash to total alkalies. Coincidence to two points on the diagram does not necessarily denote that the two specimens are chemically identical, but in many instances they are chemically similar. The complete analyses must be compared before evaluation and conclusions can be made about their origin.

The basalts are chemically similar to the analyses of basalts published by (Clarke, 1959, p. 460), (Nockolds "56 average Central Basalts") and basalts from Hawaii (Murata and Richter, 1966). The basalts fall below the line connecting averages for the igneous rocks and are characterized by an average K_2O content of 0.65 percent and an average Na_2O content of 3.5 percent. The basalts fall within the plotted average for spilites. They are chemically different from the porphyritic phase of the greenstones of the Virgilina district but are similar in composition to the tuffaceous phase of the greenstones (Laney, 1917, pp. 33-34).

The composition of the argillite is similar to published analyses for this rock type (Pettijohn, 2nd edition, p. 344).

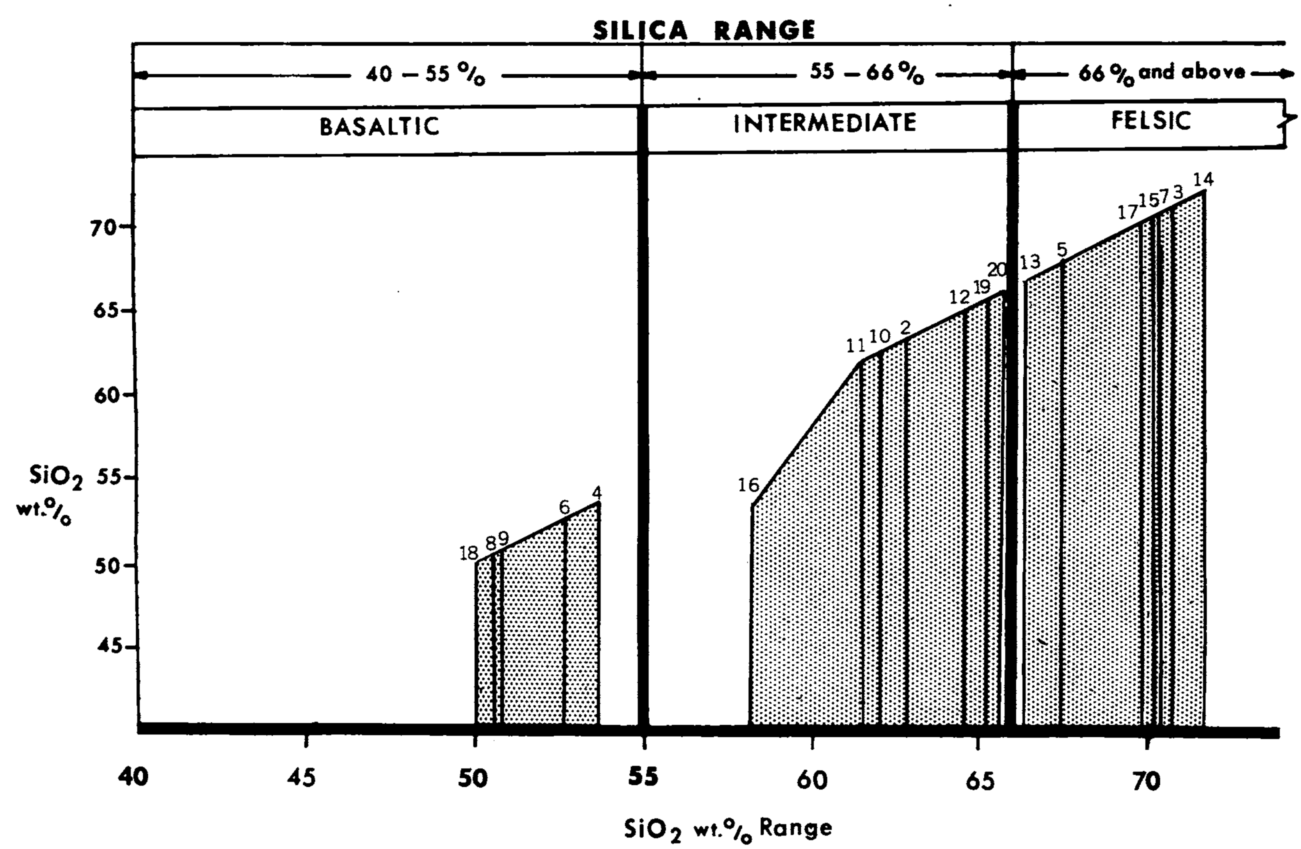


Figure 4. Plot of silica range and content, of 19 rock specimens of volcanic origin from Orange County, N.C.

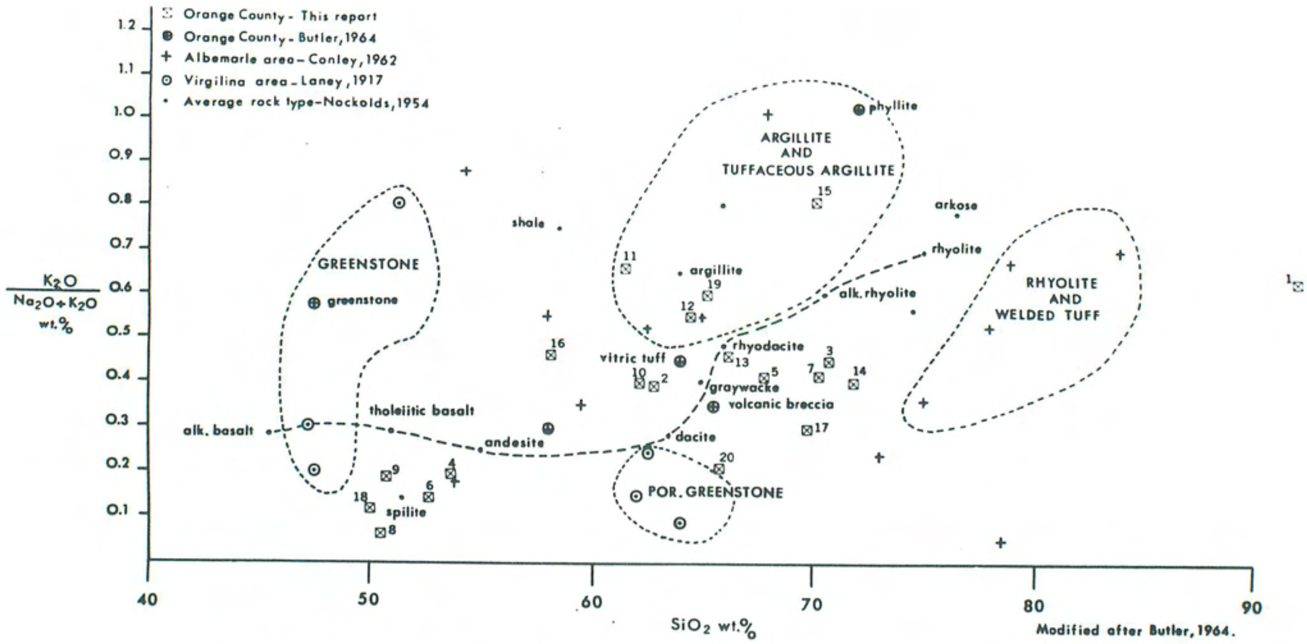


Figure 5. Plot of the ratio of potash to total alkalies against silica.

The remaining plotted specimens fall within the norm of their rock types, are calc-alkalic and range in composition from andesitic-dacitic to felsic in composition. The exception is specimen no. 1, which has been classified as a meta-siliceous sinter of probable fumarolic origin.

The values for the average rock types are from Nockolds (1954) and Pettijohn (1957), except for argillite, which is from Reed (1957). The greenstones and tuffaceous greenstones from the Virgilina area are from Laney (1917, p. 34). The porphyritic greenstones are from Laney (1917, p. 33).

STRUCTURE

General statement

The northeast trending metavolcanic and metasedimentary rocks of Orange County which exhibit in places a well developed northeast trending foliation, have been tightly folded and faulted into a series of asymmetrical folds. The average distance between the limbs of the folds is from one to two miles. The dip of the axial plane cleavage varies from vertical to steeply northwest. The older metavolcanic and metasedimentary rocks were intruded by younger igneous rocks of varying compositions that appear to have been injected along fractures and shear zones. Undoubtedly, because of the high degree of weathering of the metavolcanic and metasedimentary rocks and the relative scarcity of good exposures, some faulting in the area remains undetected. Shear zones of varying widths and lengths are common throughout the units and parallel the regional northeast trend of the metavolcanic rocks. In some instances, zones of shear could be traced for over a mile with no apparent major displacement observed in the rocks. No obvious angular or erosional unconformities were observed in the metavolcanic and metasedimentary rocks; however, the presence of hiatuses (sequence gaps) were noted at various locations in the county.

Cleavage

Orange County contains a variety of rock types which exhibit well developed slaty and bedding plane cleavage. The phyllites exposed in the deep cuts of the Old Duke and New Duke quarries are prime examples of both types of cleavage. The volcanic lithic clasts that occur in the sheared phyllites have been deformed, elongated and flattened in the plane of cleavage. The deformation of these clasts of volcanic origin is often parallel to the bedding. Therefore, the phyllites not only cleave parallel to the bedding planes, but also cleave parallel to the alignment of the elongated and flattened lithic clasts that occur within the individual beds and the chlorite and sericite that occurs within their matrix (see plates 3 and 4).

The laminated argillites that occur within the volcaniclastic epiclastic sequence exhibit an excellent bedding plane cleavage which enables the argillite to cleave into laminae only a few millimeters thick. Rocks of this type can be viewed in several locations throughout the county. One area in particular is located a few hundred feet north of Secondary Road 1306 in the west bank of the Eno River (see plate 8).

Cleavage in the more massive basalt flows in Unit I is poorly developed to absent. In places where cleavage was noted in the basalts, it is steeply dipping to vertical, with vertical cleavages most commonly recorded. The vitric crystal tuffs, volcanic breccias and rhyolite flow rocks exhibit no megascopic alignment of minerals and for the most part show only poorly developed cleavage.

The volcaniclastic conglomerates described in Unit IV (see plate 8), exhibit a pronounced grading in particle size of coarse to fine from the bottom of the sequence to the top. The conglomerate contains intercalated graywacke beds that enable hand specimens to be cleaved along these graywacke-conglomerate bedding planes.

Butler (1963) plotted a contour diagram of poles of cleavage planes on a stereographic net on readings taken from the phyllites in the southwestern part of Orange County and stated, "The diagram shows that strikes of cleavage planes range from about N. 30° E. to E.-W. and dips are high, generally near vertical. The maximum concentration of points which is the approximate mean attitude of cleavage planes is at N. 52° E., 81° NW."

Folds

The metavolcanic and metavolcaniclastic rocks of Orange County have been folded into a series of northeast trending tightly folded asymmetrical anticlines and synclines some of which have been overturned to the southeast. These folds have been further deformed by the intrusion of younger igneous complex rocks injected along zones of shear, or other zones of weakness. The axial plane is vertical in many of the folds while in others the axial plane dips steeply northwest (plate 13, cross section A-A'). The average distance between the limbs of the folds is from one and one-half to two miles.

Because of the wide range of rock types located within the county, the competency of the rocks varied. As a result, some rocks folded more readily than others, while other rocks experienced shearing and rupture and were healed by secondary silica-rich solutions which now occupy the fracture zones as quartz veins. The rupture strength of some of the rock types found in Orange County can be approximated by the figures obtained in the following table.

Table 7*

Rupture Strength of Rocks
(In kilograms per square centimeter)

Rock	Compressive Average	Range	Tensile Range	Shearing Range
Granite	1480	370-3790	30-50	150-300
Diorite	1960	960-2600	—	—
Gabbro	1800	460-4700	—	—
Felsite	2450	2000-2900	—	—
Basalt	2750	2000-3500	—	—
Sandstone	740	110-2520	10-30	50-150
Slate	1480	600-3130	250	150-250

Figures taken from: Structural Geology, 2nd edition, Marland P. Billings, p. 17, 1955, Prentice-Hall, Inc., New York.

Folding of the metavolcanic and metavolcaniclastic epiclastic rocks of Orange County has produced noticeable changes in many of the rock types in the area. The basalt flow rocks of Unit I which are the most competent metavolcanic rocks in the area show only minor effects of folding in the form of jointing or fractures that are now healed by quartz veins and epidote stringers.

The phyllites of Unit II exhibit the most pronounced visible change of the metavolcanic rocks. Folding exerted stress which in turn caused a strain on the lithic clasts that occur within the phyllites. This resulted in a deformation of these clastic particles. The clasts have been flattened and elongated and exceeded the elastic stage of deformation but show no signs of rupture. It is, therefore, assumed that the plastic stage of deformation was reached. As the clasts deformed, the volume of these rock types decreased while their density increased. Therefore, the phyllites as they exist today probably represent a rock type of decreased volume and an increase in overall density.

The dacitic to rhyodacitic rocks of Unit III exhibit only minor effects of folding. Numerous shear zones occur within the rocks, but because of the scarcity of good outcrops, no apparent displacement was observed. The lithic clasts which occur in many of the tuffs do not show the deformation that is exhibited in the phyllites of Unit II. Jointing and fractures are present within these rocks and many fractures are healed by quartz veins.

The laminated argillites of Unit IV exhibit, in sawed sections, small lenses and microfaults which cut the laminations at different angles. Noticeable displacement in the laminations cut by these faults are visible (see plate 7, no. 5).

Faults and shear zones

Faults and shear zones of varying widths and lengths tend to parallel the regional northeast-southwest trend of the metavolcanic and metavolcaniclastic sedimentary rocks of Orange County. Because of the lack of good rock exposures and the high degree of weathering, overland mapping of the fault and shear zones was difficult and in numerous places often impossible. The best exposed faults and shear zones are located along roadcuts, stream banks and quarry faces. In these locations, purplish gray colored, hematite-enriched fault and shear zones associated with the medium to dark-gray phyllites of Unit II and white to light buff colored quartz-sericite fault and shear zones associated with the predominantly felsic rocks of Unit III are apparent. Some zones could be traced overland for a considerable distance. One fault zone exhibiting excellent mylonitization with a northeast-southwest trend is located approximately 2.7 miles west of the center of the town of Hillsborough, North Carolina. In places along strike, the white to light-buff mylonite zone was approximately 500 feet wide and was traced for over one mile with no apparent major displacement observed in the rocks. Observable areas of actual displacement by faulting within the metavolcanic rocks in the county are difficult to distinguish because of the interlayering and repetition of similar lithologies that occur within these rocks.

In most instances, the shear zones are less weather resistant than the surrounding country rock, consequently they experience more rapid weathering and deterioration. Some shear zones acted as avenues for moving solutions and are silicified and mineralized. This induced silicification and mineralization imparts a high degree of induration to the shear zones. As a result, these zones standout as more weather-resistant ridges than the adjacent rocks. An excellent example of silicification and mineralization in fault and shear zones is exhibited in the Piedmont Minerals Company pyrophyllite mine at Hillsborough, North Carolina. It is also apparent, that many of the diabase dikes of Late Triassic or Early Jurassic age which are present in the metavolcanic rocks of the area, occupy shear or fault zones.

METAMORPHISM

Metamorphism of the volcanic and sedimentary rocks of Orange County is low-rank and has formed mineral assemblages typical of the chlorite zone of the green-schist facies. Recrystallization of some of the tuffs and crystal lithic tuffs has produced mineral assemblages of chlorite-epidote-quartz with minor amounts of sericite, calcite and opaque minerals. The plagioclase crystal clasts are highly altered to epidote and chlorite and the periphery of the crystals exhibit a ragged appearance in thin section.

Minerals indicative of medium to high-grade metamorphism were not observed in the metavolcanic units. However, light blue to greenish-blue andalusite is abundantly disseminated throughout much of the pyrophyllite in the Hillsborough pyrophyllite mine in Hillsborough, North Carolina. In much of the deposit, the andalusite appears to be considerably more abundant than the pyrophyllite. With the exception of the andalusite in the pyrophyllite, the most abundant minerals present in the metavolcanic rocks are chlorite, epidote, quartz, plagioclase and calcite.

Evidence of devitrification is found in some of the felsic pyroclastic rocks of Orange County. Devitrification apparently results in a destruction of tuff structures. The most severe destruction of tuff structures appears to be the result of the development of spherulites with formation of radial aggregates of feldspar and quartz. Ross and Smith (1961) have described in detail similar evidences of devitrification in devitrified felsic flows and welded tuffs in the volcanic rocks of the western United States.

AGE

Emmons (1856) placed the rocks of the Carolina Slate Belt in his Taconic system which he regarded as "the oldest sediments which we can recognize."

Kerr (1875) classified the rocks of the Carolina Slate Belt as Huronian in age, which in his classification is a division of the Archean, rocks of the original earths crust.

Weed and Watson (1906) considered the rocks to be Precambrian in age. They stated, "The rocks are pre-Cambrian in age and represent an area of ancient volcanics similar to others described from numerous localities along the Atlantic Coast region from eastern Canada to Georgia and Alabama."

Laney (1917) stated that the rocks of the Virgilina district are probably of early Paleozoic age.

White, et. al, (1963) state that lead-alpha ages determined for zircons collected from felsic crystal tuffs from the southeastern part of the Albemarle 15-minute quadrangle indicate a probable Ordovician age for these rocks. The unit sampled "is part of a sequence of acid lithic tuffs in the lower volcanic unit as mapped by Stromquist and Conley (1959) and by Conley (1962)." The indicated ages were based on the Holmes time scale. Sample number one's calculated age in millions of years was 440 ± 60. Sample number two differed only slightly and was calculated as 470 ± 60 million years.

St. Jean (1964) reported the discovery of two abraded trilobite specimens in stream rubble from Island Creek, Stanly County, North Carolina. The rock type was identified as a finely laminated recrystallized argillite occurring in upstream outcrops. St. Jean classed the specimens as a new species questionably assigned to the Middle Cambrian genus *Paradoxides*. He further stated that no megapleurites were observed indicating that the species does not belong to the Lower Cambrian Olenellidae, and that "Although the generic assignment is questionable, the morphologic characters of the two specimens indicate an age no younger than Middle Cambrian and no older than the age of the oldest known Early Cambrian trilobites."

St. Jean stated that the trilobite find was significant because they represent the first authentic fossil material from the Piedmont south of central Virginia.

No rock samples were collected from the metavolcanic rocks of Orange County for the purpose of age determination. However, the authors consider these rocks to be contemperaneous in age with the other metavolcanic and metasedimentary rocks of the Carolina Slate Belt which are classified as late Cambrian or early Ordovician (Hills and Butler, 1968)

INTRUSIVE ROCKS

General statement

Intrusive into the rocks of the Carolina Slate Belt are igneous plutons and plutonic complexes of varying sizes and mineralogical compositions. The intrusive rocks range in composition from acid through intermediate to basic and ultrabasic. The exact age of the intrusives is questionable, but their age of emplacement is thought to be from middle to late Paleozoic.

The most significant and complete recent work on the petrography and mode of emplacement of the intrusive rocks in the metavolcanic and metasedimentary rocks of the Carolina Slate Belt was conducted by graduate students at the University of North Carolina under the supervision of V. I. Mann. This work was published in 1965 by the Department of Conservation and Development, Division of Mineral Resources, as Special Publication number one. The report contains complete petrographic descriptions of the igneous intrusive rocks of the Chapel Hill quadrangle, with interpretations as to their source, modes of emplacement and relative ages. Because of the comprehensive descriptions of the plutons, which are also representative of the intrusive rocks in Orange County, the authors feel it would be a duplication of work to try to improve upon the rock descriptions, and will instead present further information from field evidence as to their types, modes of emplacement and possible sources.

Igneous complexes

Intrusive into the metavolcanic rocks of Orange County, North Carolina, are igneous plutons and plutonic complexes of middle to upper Paleozoic age. The intrusives have been identified as a series of rocks grading from granites, adamellites, granodiorites, tonalites, diorites, gabbros and ultramafics (see plate 9). Also intrusive into the area are dikes which have been identified as lamprophyres and aplites and may be associated with, but a later phase of, the igneous plutons. Quartz veins and epidote veinlets occur in the area and appear to have been emplaced by later hydrothermal solutions associated with the igneous activity of the plutons. Diabase or "trap" dikes of Triassic (?) or possible Jurrasic (?) age cut the metavolcanic rocks in the county; some of these have been traced for a distance of approximately eight miles.

The igneous plutons which have intruded the metavolcanic rocks of Orange County appear to have been emplaced along zones of shear and fractures. Xenoliths of the surrounding metavolcanic country rock are found along the peripheries of some of the plutons. This mode of emplacement is evident in the rocks quarried from the Bacon quarry which is located approximately 5 miles northeast of the town of Hillsborough, North Carolina (see plate 9, nos. 1 and 5). The tonalite or quartz diorite contains metavolcanic xenoliths which constitute approximately 20 percent of the rock that has been recently quarried. These xenoliths range from less than one inch to more than 20 feet in maximum diameter with two inch to two-foot sizes being the most common. The majority of the xenoliths are subangular and exhibit a sharp line of contact with the intrusive which indicates a low to moderate temperature and pressure of the pluton and little assimilation occurred.

Many of the intrusive rocks are denoted on the geologic map as igneous complexes because of the gradational nature of the mineralogical content of the rock. Variation in mineral composition with the increase or decrease of one or more minerals, is most commonly found in the diorites, and occasionally the diorites grade into tonalites.

Field relationships indicate that the diorites are the oldest igneous intrusives. Previous authors who have made careful studies of the distribution and character of the intrusives suggest that the diorite-gabbroic rocks appear to be the first igneous rocks formed. Smith (1916) described the diorites occurring north of Chapel Hill along Bolin Creek. Through field evidence, he stated that the amount of quartz decreases outwardly from the center of the intrusives. He also stated that near the contact zone between the diorite and granite intrusives, inclusions of the diorite occur frequently in the granite showing the greater age of the diorite. Mann, et. al, (1965) stated that field evidence suggests that the more basic igneous plutons were the first igneous rocks formed and may have been the result of solutions from a common magma. Wagener (1965) stated that the intrusions in the Farrington 7½-minute quadrangle are apparently comagmatic and were injected along fractures around the eastern stock, from a relatively shallow magma chamber.

Transitional contacts or transitional zones between the igneous intrusive rocks and surrounding meta-volcanic rocks have been discussed in the geologic literature for a number of years. Clarke (1957) stated that the granites and diorites in the Chapel Hill quadrangle are separated from the volcanic rocks by a transitional contact zone caused by a metasomatic replacement of the "Slate Series materials." Field work in Orange County has shown that many of the igneous-volcanic contacts are distinct and that the periphery of many intrusives (diorites to granodiorites) suggests a chilled contact rather than metasomatic replacement or magmatic assimilation of the surrounding metavolcanic rocks. Igneous intrusive rocks observed in a number of localities are finer grained nearer the contact than the rest of the igneous body which suggests marginal cooling. Recent chemical analyses of the Farrington intrusive rocks by Ragland, (personal communication, 1966) has shown that the western stock of the Farrington Complex in the Farrington quadrangle is normally zoned. However, the eastern stock is of a uniform chemical composition with no apparent zoning. It is his opinion that these intrusives are not comagmatic. It is also evident in Orange County that the chemical composition of the intrusive rocks is unaffected by either felsic or mafic metavolcanic rocks. This would suggest that the chemical composition of the intrusive rocks depends entirely upon the nature of the original magma, and not the surrounding country rock.

Dike rocks

Intrusive into the Orange County area are dikes of aplite, lamprophyre and diabase. The aplites and lamprophyres do not appear on the geologic map owing to the fact that even though they were observed cutting the igneous intrusive rocks in numerous places, they were too thin to be traced accurately for any great distance. The aplites and lamprophyres are a network of dikes and stringers that appear to be associated with, but a later phase of the granitic and related intrusive rocks. They are possibly the final phase of the igneous intrusive magma. This is suggested by the fact that both the aplites and lamprophyres have been observed cutting the igneous intrusive rocks in the county. Field observations have also shown that in places the aplites are cut by the dark greenish-brown lamprophyres and in other locations, the lamprophyres are cut by the aplites. This would suggest a contemporaneous emplacement for this dike series. Mann, et. al. (1965, pp. 24-25) have described highly-weathered lamprophyres occurring in road cuts on the N.C. 54 bypass around the south side of Chapel Hill and state, "the age may be determined by the fact that some of the aplites cut the lamprophyres, and some of the lamprophyres cut the aplites. They appear to have been developed at the same time."

The diabase dikes of Late Triassic (?) or possible Early Jurassic (?) age cut the Triassic sedimentary rocks and have been traced from the Triassic sedimentary rocks into the crystalline rocks and have been observed cutting both the igneous intrusive rocks and the metavolcanic rocks. These dikes exhibit a high degree of spheroidal weathering, and in places, narrow baked zones in the surrounding country rock have been observed along the contacts. In several locations it was observed that even though the diabase dikes themselves were weathered to saprolite, the adjacent baked country rock exhibited a high degree of induration which formed a narrow weather-resistant ridge. This appears to indicate that the baked country rock in many instances in the ridge former rather than the dike itself. Field evidence indicates that numerous diabase dikes have been injected along fault zones and zones of shear and some of the diabase dikes are faulted. This fact indicates that additional faulting occurred subsequent to the emplacement of these diabase dikes.

Quartz veins and epidote veins and veinlets have been observed in the area and appear to have been later hydrothermal solutions injected along zones of shear or fracture. The absence of these veins and veinlets cutting the Triassic rocks suggests that the hydrothermal injections were pre-Triassic in age.

TRIASSIC ROCKS

General statement

Sedimentary rocks of Triassic age occur in the extreme southeastern corner of Orange County. These rocks occupy a downfaulted area known as the Durham basin which is the northward extension of the great northeast trending, trough shaped downfaulted Deep River basin. The Triassic sedimentary rocks in the Deep River basin are considered of Upper Triassic age and are assigned to the Newark Group, a name given to them by W. C. Redfield because of their similarity to Triassic rocks in the vicinity of Newark, New Jersey. Emmons (1852) recognized certain differences in the rocks and subdivided them into three divisions without formal names. Later in 1856, Emmons subdivided the rocks now known as the Newark Group into four divisions: Lower sandstone, Coal slate and coal, Salines and Upper sandstones. Later, Russell (1892) applied the term Newark Group to the rocks of both the Dan River and Deep River basins of North Carolina with the idea that possibly future workers might subdivide the group into a number of formations. Campbell and Kimball (1923), stated that, "the Newark group in the Deep River basin consists of three generally recognizable parts, called formations." They named these formations the Pekin, Cumnock and Sanford. The Pekin Formation is the basal unit and is overlain conformably by the Cumnock Formation, a coal bearing sequence containing the Gulf coal bed and the Cumnock coal bed. These coal beds are approximately 250 and 200 feet respecrively above the base of the formation.

The Cumnock Formation is overlain conformably by the red to brown shales and sandstones of the Sanford Formation. Stuckey (1965) states, "As no key horizons exist along the margins of the basins, the Pekin and Sanford formations should be considered sedimentary facies rather than time-stratigraphic units." Reinemund (1955) states that the strata within the Sanford Formation are laterally gradational and lenticular in shape with few distinctive beds and no subdivisions that are consistently mappable. He considers the Sanford Formation between 2,000 and 3,000 feet thick at the south end of the Durham basin and states that more than three-fourths of the rocks within the formation are red, brown or purple fine grained clastic sediments.

The rocks of the Deep River basin also contain concordant and discordant diabase intrusives that are present in the form of dikes, sills and sill-like masses that are only partly controlled by bedding. Reinemund (1955) states that sills and sill-like masses are not present in the pre-Triassic rocks but are present in all the Triassic formations and they are thickest and most extensive in the Cumnock Formation. The diabase dikes are extensively distributed in the pre-Triassic rocks of the Piedmont plateau and in the pre-Cretaceous rocks beneath the Coastal Plain.

Orange County

Triassic sedimentary rocks occupy the extreme southeastern corner of Orange County and extend northeastward from the Orange-Chatham county line for approximately 8.5 miles and vary in width westward from the Durham-Orange county line from 0.25 mile to 2.25 miles. Efforts were made to map accurately the western border of the Triassic rocks; however, because of the limited extent of these sedimentary rocks in the county and the presence of few distinctive beds, no attempt was made to differentiate the Triassic rocks into formations.

The Triassic rocks in Orange County are considered to be of the Upper Triassic Newark Group and belong to the Sanford Formation. The rocks are fine grained clastic sediments and interbedded conglomerates that were apparently derived from the older metavolcanic and igneous intrusive rocks that occur west of the Durham basin. These clastic sediments contain a variety of rock fragments and range in color from light buff, buff, yellow, orange, brown, reddish brown, red, maroon and gray to purple. Rock types appear to vary laterally in lithology and in color throughout the area with buffs, reds and browns occurring most frequently. Sandstone, arkose, siltstone, shale and conglomerate are the predominant rock types and are interbedded. Crossbedding was observed in a buff to orange arkose in a 10 foot roadcut located on the north side of Ephesus Church Road, 0.2 mile east of Highway U.S. 15-501 bypass on the east side of Chapel Hill, North Carolina (see plate 10, nos. 1 and 2). In this roadcut, the crossbedded arkose overlies a reddish-brown siltstone which strikes to the northeast and dips at a low angle to the southeast.

Pronounced baked zones resulting from the intrusion of diabase dikes of Late Triassic (?) or Early Jurrasic age(?) are frequently found occurring in roadcuts throughout the area. These baked zones are prominent features that are easily recognized. One such baked zone occurs on the north side of Ephesus Church Road in a small roadcut 0.4 mile east of Highway U.S. 15-501 bypass on the east side of Chapel Hill. A reddish-brown siltstone has been intruded by a narrow diabase dike. The dike exhibits excellent spheroidal weathering and is grayish black on fresh surfaces weathering to a rusty brown color (see plate 10, no. 4). Extending inward from the reddish-brown siltstone towards the diabase, the siltstone assumes a dark maroon color that grades into a narrow charcoal colored baked zone that is approximately four feet wide on either side of the dike. At this site, the baked zones adjacent to the dike are no more indurated than the adjacent siltstone. However, in several locations within the county, it was observed that even though the diabase dikes themselves were weathered, the adjacent baked zones exhibit a high degree of induration which formed narrow weather-resistant ridges paralleling the dike. Reinemund (1955) states that baked zones usually extend less than 30 feet from the intrusives with some zones in claystones extending only 10 feet. The principal metamorphic effect in claystones is a blackening of the rock caused by the development of magnetite, while in general shales and siltstones become much harder as the result of the recrystallization of the quartz. Several large diabase dikes are located just east of Chapel Hill with a north to northeast trend (see geologic map, plate 13). These dikes are easily mapped because of the abundance of large residual boulders occurring on the surface which are a direct result of the spheroidal weathering that is characteristic of the diabase intrusives. The dikes have been traced overland for distances of 5 to 8 miles and appear to have been injected along fault zones that parallel the resequent faultline scarp that separates the metavolcanic and igneous intrusive rocks on the west from the Triassic rocks to the east. Numerous small diabase dikes were observed through out the county, but were too small to show on the geologic map.

One area of significant interest in the Triassic rocks of the county is an arkose-capped hill with an elevation of approximately 450 feet above sea level. This area is the highest point in the county on which Triassic rocks occur. The hill affords a commanding view of the low lying, gently rolling topography of the Durham basin, that ranges in elevation to the south and southeast from 240 to 340 feet above sea level. This area is located 0.4 mile north of the intersection of Secondary Roads 1717 and 1305 (see plate 10, no. 3). The yellow to orange arkose contains an abundance of petrified wood fragments that range in size from several inches to fragments as large as two feet in diameter. This anomalously high area of Triassic rocks is apparently a result of faulting, and reflects Harrington's (1951) view on the structural picture along the western border of the Triassic basin which is, "The basin is not a simple graben structure with two similar sides. The movement along the west border was a slumping action with minor displacement on many faults and perhaps major displacement on a few."

The most recent estimate of the thickness of the Triassic rocks in the Durham basin has been given by Mann and Zablocki (1961). Based on a gravity study of the area and they state, "The residual curve across the Durham basin along the traverse from Hillsborough to Raleigh suggests that the basement rock in the northwestern half of the basin lies much closer to the surface than it does in the southeastern half of the basin." They further state, "The anomaly difference between bedrock and basin sediments is 4½ milligals. Therefore, the thickness of the sediments in the basin at its deepest point is estimated to be 3,100 feet," along the traverse from Hillsborough to Raleigh, North Carolina. They concluded from gravitational interpretation that the maximum thickness of the Triassic sediments in the Durham basin is 6,500 feet.

ECONOMIC GEOLOGY

General statement

Orange County contains numerous prospects and old mine sites that have in the past been prospected or worked for gold, copper and iron. All of the abandoned mines and prospects are small but are interesting and some show good evidence of metallization. It is interesting to point out that the metallization appears confined primarily to the predominantly felsic pyroclastics and that in numerous instances, these felsic pyroclastics which contain the metallization are in contact with igneous intrusive rocks, mainly diorites and tonalites. Goodwin (1965) states that the massive sulphide deposits in the Porcupine-Kirkland Lake-Noranda Region in Canada occur in felsic breccias and tuffs and that the larger ore bodies in the felsic zone occur in contact with rhyolite, diorite or porphyry. Goodwin infers that the metal content of the volcanic complexes, deposited or formed during vulcanism, migrated locally within the complexes to favorable structural and chemical sites as a result of later structural and metamorphic events.

Even though good exposures are limited in Orange County, overall field evidence has convinced the authors that the igneous activity that emplaced the intrusive rocks also conditioned the felsic pyroclastics with structural channels and chemical environments favorable for the metallization now present in the area.

A zonal trend of areas of metallization was recognized in Orange County. This trend extends from the Chapel Hill iron mine, located approximately 0.2 mile west of Secondary Road 1759 and one mile

DESCRIPTIONS OF PHOTOMACROGRAPHS AND PHOTOGRAPHS OF IGNEOUS INTRUSIVES

Plate 9

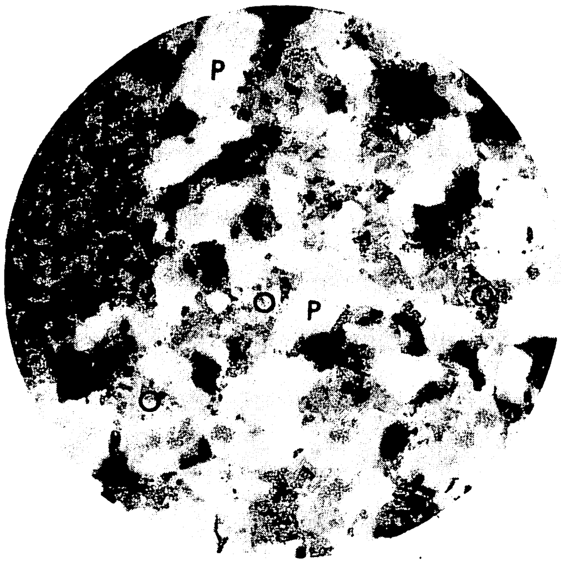
1. Volcanic xenolith in quartz diorite intrusive rock from Bacon quarry, which is located 5 miles northeast of Hillsborough, North Carolina. Photomacrograph of sawed section; magnification 3X. The intrusive rock is a medium to dark gray fine to coarse-grained quartz diorite which contains light greenish-gray plagioclase (P) and pinkish-gray orthoclase (O) with clear quartz (Q). The dark patches are composed of chlorite, epidote and black opaques with occasional calcite and sericite. The greenish gray fine-grained xenoliths are composed of a basic mineral assemblage of albite, epidote, actinolite, chlorite, quartz, opaques and minor amounts of calcite.

2. Gabbro outcrops located in front of Nunn's Chapel on north side of Secondary Road 1727, 0.2 mile east of its intersection with Secondary Road 1009 and 0.9 mile north-northeast of Calvander, North Carolina. This dark greenish-gray gabbro consists of subhedral to euhedral crystals of labradorite and large anhedral grains of augite. Other recognizable accessory minerals include chlorite, hornblende, magnetite and pyrite.

3. Mafic volcanic xenolith (left side) in quartz diorite (right side) from the Mebane quarry which is located approximately 2 miles southeast of the town of Mebane, North Carolina. In this shadowgraph (thin section used as negative) the clear quartz (Q) appears as black areas. The cloudy white and light-gray laths are alkali feldspar (F) riddled with fine grains of epidote. Many of the larger laths display albite and carlsbad twinning with extinction angles indicative of sodic plagioclase. Fine grains of epidote, chlorite and hornblende are the major interstitial constituents.

4. Outcrop of ultramafic rock which is located approximately 1.2 miles northwest of the center of Chapel Hill and 0.6 mile southwest of the intersection of Highway N.C. 86 and Secondary Road 1760. This outcrop is located about 300 feet northeast of the intersection of Secondary Roads 1760 and 1759. Typical outcrops are dark greenish gray spheroidal boulders which contain large subhedral laths of hornblende, serpentine pseudomorphs after olivine, talc after pyroxene and olivine, and some magnetite.

5. Photograph showing close-up of the north face of the Bacon quarry. This lower portion of the quarry face illustrates the abundance of dark colored volcanic xenoliths (X) which measure from a few inches to tens of feet in maximum diameter. The lighter-colored areas are the quartz diorite intrusive rock (D).



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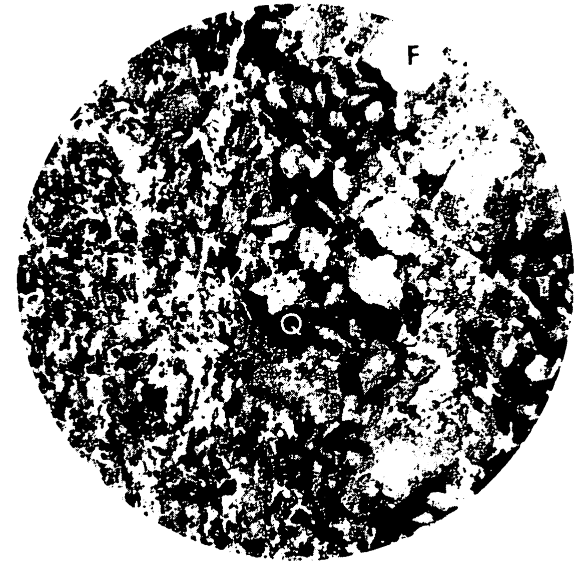

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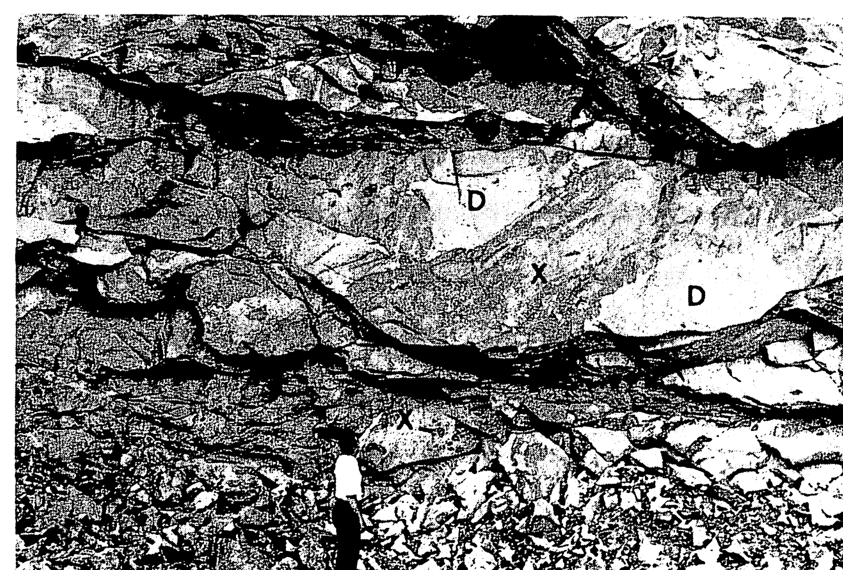

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DESCRIPTIONS OF PHOTOGRAPHS OF TRIASSIC ROCKS

Plate 10

1. Cross-bedded buff to orange-colored arkose of Triassic age located in a 10 foot roadcut on the north side of Ephesus Church Road, 0.2 mile east of Highway U.S. 15-501 bypass on the east side of the town of Chapel Hill, North Carolina.

2. Buff to yellow arkose overlying a reddish-brown siltstone. These sediments of Triassic age strike to the N.E. and dip 35° S.E. and are located in a 7 foot high roadcut on the south side of Ephesus Church Road, approximately 100 ft. west of its intersection with Landerwood Drive. An interlayering of arkose and siltstone is common in this vicinity.

3. A view from an arkose-capped hill looking southeast into the Durham Triassic basin. This yellow to orange arkose of Triassic age contains an abundance of petrified wood fragments that range in size from several inches to fragments as large as two feet in diameter. This area is the highest point in Orange County on which Triassic sedimentary rocks are found.

4. Sawed section of diabase boulder of Late Triassic (?) or Early Jurassic (?) age illustrating pronounced multiple weathering rings that range from a dark gray interior through a medium gray to a rusty brown exterior. These weathering rings are characteristic of the diabase boulders throughout the Triassic area in Orange County, North Carolina.

PLATE 10

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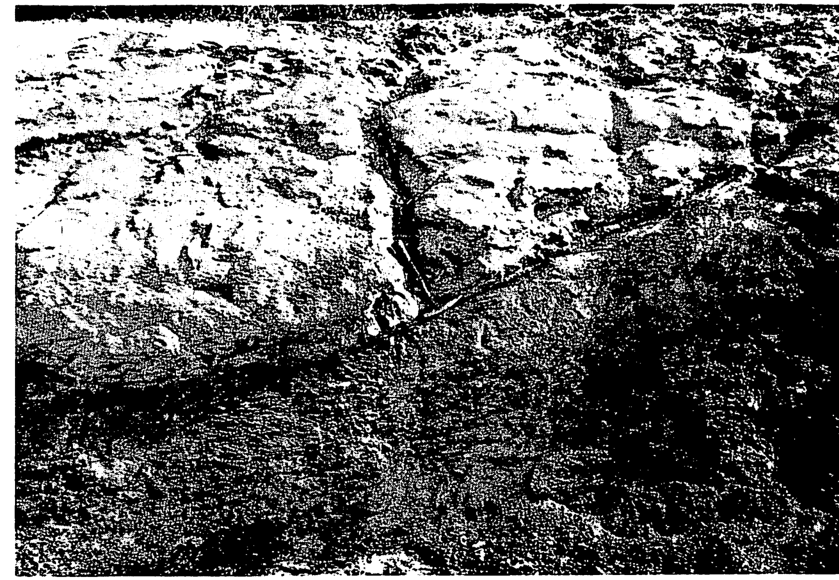

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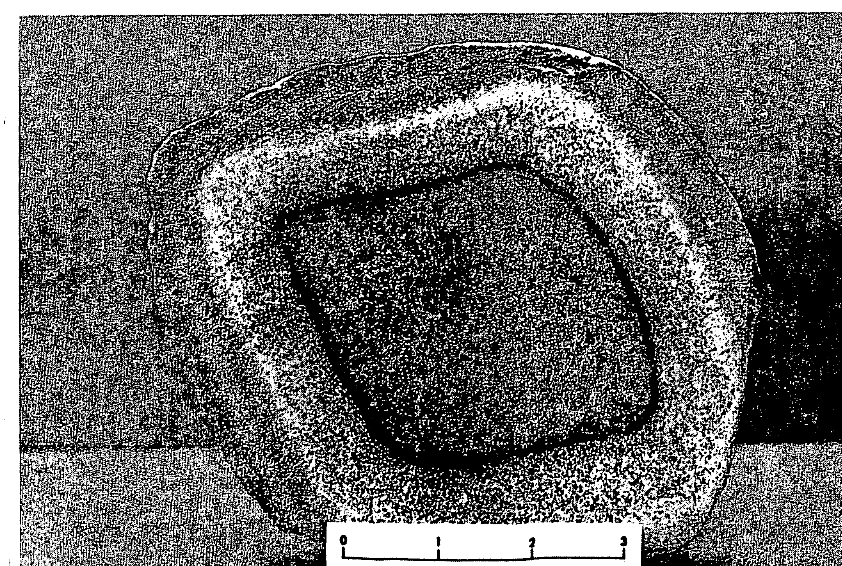

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southwest of the intersection of Highway N.C. 86 and Secondary Road 1760, for approximately five miles on a N. 27° E. strike and appears to terminate in the vicinity of the Duke Forest prospect located in Duke Forest, 0.65 mile south of Secondary Road 1718 and 0.35 mile west of the intersection of Secondary Roads 1718 and 1719. One abandoned mine and three old prospect sites are located along this trend, and in each instance, areas of older felsic metavolcanic rocks are in contact with younger igneous intrusive rocks which are diorites and quartz diorites. These facts may indicate the following:

(1) The younger diorites and quartz diorites intruded zones of weakness in the older felsic metavolcanic rocks and the metallization now present in the felsic metavolcanic rocks resulted from iron bearing sulphide solutions that were injected into the brecciated felsic metavolcanic rocks as the result of late stage magmatic solutions or emanations from the intrusive igneous bodies, or (2) the younger diorites and quartz diorites intruded zones of weakness in sulphide bearing felsic metavolcanic rocks, brecciating the rock and forming favorable structural channels that were later healed by the remobilized sulphide minerals migrating from the metavolcanic rocks.

During the spring of 1967, a major mining company began a limited exploration program in selected areas of Orange County for possible sulphide mineralization. Drilling apparently failed to delineate an economic ore body. The project was terminated by the company in June 1967, and the options on approximately 1,000 acres of land were dropped.

Gold mines and prospects

North State or Robertson mine: The North State or Robertson mine is located in the southwestern corner of Orange County approximately 0.25 mile south of the intersection of Highway N.C. 54 and Secondary Road 1957. The old workings can be reached by following an old mine road due west for approximately 100 feet, then turning south 10 degrees east for 530 feet. The mine was in operation between the years 1905-1910 (Charles Stanford, personal communication).

The country rock is a sheared felsic volcanic tuff that strikes N. 40° E. and dips 70° NW. In contact with the tuff is a brecciated quartz vein, which is gossaniferous. The metallization present is massive limonite-hematite after pyrite, some pyrite and chalcopyrite. The gold appears to have been contained in the pyrite and chalcopyrite. The amount of gold mined is thought to have been insignificant.

Weaver-Carr prospect: The Weaver-Carr prospect is located in a field approximately 900 feet due south of Secondary Road 1733, 0.65 mile east of the intersection of Highway N.C. 86 and Secondary Road 1733.

One prospect pit, 20 feet long by 12 feet wide and 20 feet deep was sunk on a 6 to 8 foot N. 60° E. trending shear zone that intersects a N. 40° W. trending quartz vein. The country rock is a sheared felsic tuff in contact with an intrusive quartz diorite. Pyrite was disseminated throughout the quartz.

A gold show was reported, but there is no record of production (Issac Newton, personal communication).

Bradsher prospect: The Bradsher prospect is located in a field, 0.35 mile south-southeast of Secondary Road 1306, 0.25 mile east of the intersection of Secondary Roads 1306 and 1312.

The prospect is a small rectangular pit, approximately 20 feet long by 12 feet wide and 6 feet deep which is now mostly filled with trash.

Several small dumps of fractured milky quartz containing disseminated pyrite were present at the site. Information as to the date of prospecting and amount of ore removed, if any, could not be obtained.

Duke Forest prospect: The Duke Forest prospect is located in Duke Forest on the east side of the Concrete Bridge Road, 0.65 mile south of Secondary Road 1718 and 0.35 mile west of the intersection of Secondary Roads 1718 and 1719.

The prospect (see plate 12, nos. 1 and 3) is in a gossaniferous, highly brecciated felsic tuff that strikes N. 30° E., dips vertically and is in contact on the northwestern side with a diorite intrusive.

Two small prospect pits located approximately 80 feet apart and situated along strike are present in the area. Both show only minor excavation. The larger of the two pits is located approximately 30 feet east of the road and is 10 to 12 feet deep, 15 feet wide and approximately 30 feet long. The walls of the pit show highly brecciated quartz fragments healed by hematite and limonite which in places exhibits beautiful iridescence.

Small cubic and rectangular cavaties are present in the brecciated quartz and felsic tuff which suggests that iron sulphides may have been present but are now leached away. Many of the cubic cavaties have a limonitic halo surrounding them. This fact may indicate that the limonite might be transported limonite as opposed to indigenous limonite. Bateman (1958, p. 253) states "Transported limonite thus may form halos around empty voids or it may thoroughly permeate the gangue, or enclosing rock."

The nearness of the diorite intrusive rock suggests the possibility that the felsic tuff and quartz might have been brecciated as a direct result of the intrusive body forcing itself upward through the felsic volcanic rock, developing brecciated channels within the tuff and allowing the iron-bearing solutions easy access to these favorable structural sites.

Copper prospects

Hill prospect: The Hill prospect is located in back of Mickey Hill's Grocery store, 400 feet north of Secondary Road 1002 and 2.4 miles northeast of the intersection of Secondary Roads 1002 and 1538. The country rock is a sheared felsic tuff containing minute specks of finely disseminated pyrite and magnetite. The prospect was originally 30 feet deep, but is now filled with water to within 5 feet of the surface. The prospect pit was sunk on a highly sheared 4 foot wide zone that trends N. 40° E. and dips 75° NW. The shear zone is highly iron stained, but no evidence of copper metallization was observed in the prospect.

Stebbins prospect: The Stebbins prospect is located on the property of John Dilday, approximately 0.2 mile west of Secondary Road 1126 and 0.45 mile northwest of the intersection of Secondary Roads 1006 and 1126. Two small rectangular prospect pits are located on the site. One is approximately 18 feet by 17 feet and filled with water to within 5 feet of the surface. The exact depth is unknown. The other is a much smaller pit which is 3 feet wide by 5 feet long by 2 feet deep. The country rock is a felsic lithic tuff containing disseminated pyrite. Some milky quartz float was observed with pyrite filling the vugs.

A copper show was reported; however, no evidence of base metal was observed at the site.

E.M. Stroud prospect: The E.M. Stroud copper prospect, located on the Stroud property, is situated on the east side of Secondary Road 1954, 0.7 mile south of its intersection with Secondary Road 1005.

The prospect shaft was sunk on a milky quartz vein that contains some copper metallization. The shaft, at present bulldozed shut, is said by the owner to have been approximately 90 feet deep and was opened in the very early 1800's. An elongate and shallow surface depression and comments by the property owner indicate there may have been minor drifting along the vein in search of high-grade ore.

The country rock is a coarse grained weathered diorite, containing minor amounts of disseminated pyrite. North of Mr. Stroud's house and south of the prospect is an outcrop of very fine-grained diorite that has been intruded by small coarse grained diorite dikes.

The diorite intrusive body has intruded felsic volcanic rocks that have been sheared and are now composed primarily of iron-stained sericite with some quartz.

Pyrite and chalcopyrite have been emplaced as blebs in the quartz vein and also deposited along fractures in the quartz. Supergene chalcocite has replaced both pyrite and chalcopyrite. Malachite and azurite have formed on the chalcocite, chalcopyrite and pyrite, indicating that the oxidized zone is overrunning the supergene sulfide zone.

The gangue is composed of quartz and chlorite that contains minor disseminated pyrite.

Iron mines and prospects

Chapel Hill iron mine: The Chapel Hill iron mine is located on the crest of northeast trending Iron Mine Hill, 525 feet above sea level. The crest of the hill is located approximately 0.2 mile west of Secondary Road 1759 and one mile southwest of the intersection of Highway N.C. 86 and Secondary Road 1760.

According to Nitze (1899) the mine was operated at intervals from 1872 to 1882 and chemical analyses of ore from the mine showed a hematite content that ranged from 38 to 65 percent. Nitze also stated that, "at the main shaft the vein has a total thickness of 10 feet. The ore at the sides is very lean but towards the center the proportion of iron increases rapidly and from 6 to 7 feet out of the 10 may be considered good ore."

The country rock is a felsic lithic tuff that in places has been brecciated and injected by hydrothermal solutions, predominantly iron-bearing quartz. The majority of the ore is a dense, steel-gray hematite with fine grained specular hematite occurring along numerous fractures. Finely disseminated magnetite and hematite occur in the felsic tuff.

The remants of two caved adits were observed in the area along with one small open cut 25 feet long, 8 feet wide, 4 to 5 feet deep and an approximate strike of N. 78° W.

Several other minor magnetite-hematite prospects were mentioned by Nitze (1893), which were not investigated by the authors. One occurs on the Cheek farm about 3 miles south-southeast of Chapel Hill and others mentioned occur about 5 miles west-southwest of Hillsborough on the Hastings place.

Pyrophyllite mines and prospects

Hillsborough mine: The Hillsborough mine and plant (see plate 11, no. 1) is located approximately one-half mile south of the town of Hillsborough, North Carolina, in a series of prominent hills known as the Occoneechee Mountains. These hills trend northeast, and from northeast to southwest are often designated as Hill No. 1, Hill No. 2 and Hill No. 3. Hill No. 1, now being mined by the North State Pyrophyllite Company, has a zone of mineralization, exposed by open-cut mining operations, that is approximately 1500 feet long and 100 to 250 feet wide. The mineralized zone strikes N. 50° E. and dips from 60° to 80° NW. The pyrophyllite body has a footwall of dense siliceous rock and a hanging wall of sericite schist. The principal minerals observed in the mine in decreasing order of abundance were quartz, massive and crystalline pyrophyllite, sericite, andalusite and topaz. Topaz occurs as fracture fillings in the quartzose footwall rock (Stuckey, 1967).

Teer prospects: Three pyrophyllite prospects are located in the southwestern corner of Orange County, in the general vicinity of Teer. One site occurs on the northern end of Mitchell Mountain which was prospected by the North State Pyrophyllite Company with a small amount of production reported. The prospect pit, is approximately 100 feet in length, 30 feet wide and 15 feet deep. The cleavage strikes N. 55° E. and dips 75° NW. The pyrophyllite prospect was abandoned when it was determined that there was insufficient tonnage present. About 3 miles almost due north of Teer and between Secondary Road 1117 and Cane Creek, a prospect is located on the farm of Saline Sykes. The small prospect pit contains minor amounts of radiating pyrophyllite. No production from the site was reported and the prospect is now abandoned.

Bradshaw mine: The Bradshaw mine, located on the land of Clarence Bradshaw, about one mile almost due north of Teer and between Secondary Roads 1115 and 1116, was prospected and mined for pyrophyllite by the Carolina Pyrophyllite Company during the years 1958 through 1961. A pit 200 feet long by 100 feet wide at the top and approximately 80 feet deep was excavated. The pyrophyllite content of the prospect was originally 24 percent, but the pit was abandoned when the pyrophyllite content dropped to 11 percent. The cleavage of the rock strikes approximately N. 55° E. and dips 75° NW.

Murray prospect: The Murray prospect is located on a ridge about 5 miles northeast of Hillsborough, North Carolina, near the intersection of Secondary Roads 1538 and 1548. Numerous prospect pits are located along a northeast-trending ridge of predominantly sheared felsic tuffs. The majority of the pits are scattered over an area 75 to 100 feet wide and 500 feet long. Foliated pyrophyllite is present on the dumps and in the sides of the pits as well as in an occasional outcrop. The area may contain pyrophyllite of value (J. L. Stuckey, personal communication, 1966).

Lover's Leap prospect: The Lover's Leap prospect is located on the south side of the Eno River, approximately 0.2 mile upstream from the Highway U.S. 70 bypass bridge.

The prospect is primarily composed of a dense fine grained siliceous rock that has been sheared and fractured. Massive pyrophyllite and sericite now occupy the shear and fracture zones. These mineralized zones are relatively narrow on the surface but they may increase in width with depth. The dense siliceous body strikes approximately N. 35° E., and forms a topographic high which offers a commanding view over a sizeable portion of the immediate area. The crest of the Hillsborough pyrophyllite mine can be viewed from the top of this prospect. This pyrophyllite prospect parallels the regional trend of the metavolcanic rocks, and forms an en echelon pattern with the other pyrophyllite mines and prospects within the county.

Dimension stone

Old Duke quarry: The Old Duke quarry is located on property owned by Duke University one mile southwest of Secondary Road 1161 and 0.1 mile east of the intersection of Highway U.S. 70 and Secondary Road 1161.

The quarry site was first worked during the colonial period and the stone was used in home construction in and around colonial Hillsborough. Prior to 1925, the quarry was worked by Mayo Quarries but the exact dates of operation are unknown. In 1925, the property was purchased by Duke University and the stone was quarried and shipped by Southern Railway to Durham, North Carolina, for use in the construction of the west campus of Duke University.

The quarry has a northeast-southwest trend and is approximately 600 feet long, 250 feet wide and in some locations over 80 feet deep. The rock in the quarry is a medium to dark bluish-gray phyllite which strikes NE. and dips NW. Normal graded bedding from coarse on the botton to fine on top was observed in the northeast face of the quarry, with a well-developed cleavage parallel to the bedding. Quarrying operations were primarily maintained in the interior section of the pit along a zone of phyllitized bluish gray lithic tuffs and breccias. Because of folding and shearing, the clasts occurring in the lithic tuffs and breccias have been badly deformed with their long axis lying parallel to the cleavage and bedding. The strike of the cleavage and bedding is N. 45° E. and the dips average 71° NW. The attitude of the principal joints is a N. 35° E. strike and they dip 35° SE. The phyllites are easily cleaved, and produce dimension stone of excellent size and quality.

New Duke quarry: The New Duke quarry is located in central Orange County on property owned by Duke University, 2.25 miles west of the center of the town of Hillsborough, North Carolina, and 1.5 miles east of the town of Efland, North Carolina. The quarry is situated on the eastern flank of a northeast-trending ridge and is located 2000 feet west of the Old Duke quarry and approximately 300 feet west of the Eno River.

The quarry was opened in the latter part of 1965 for the purpose of obtaining building stone for use in the continuing construction of buildings on the west campus of Duke University in Durham, North Carolina. Efforts to quarry building stone from the Old Duke quarry had ceased because of the difficulty in obtaining usable stone safely from the old quarry site.

The quarry, which presently occupies an area of approximately 8 cleared acres, was first stripped of its shallow-weathered overburden and then benched into the north side of the hill. The floor of the present working area is approximately 20 to 25 feet below the crest of the ridge (see plate 4, no. 5).

The rock in the quarry is a medium to dark bluish-gray phyllite that strikes N. 50° E. and dips 73° NW. Overturned graded bedding of the clasts from fine on bottom to coarse on top is evident in the phyllitized bluish-gray tuffs and breccias. This reversed grading bedding is in contrast to the normal coarse to fine-graded bedding observed in the phyllites of the Old Duke quarry. Field and laboratory studies of rock types from both quarries indicate that the phyllites of the New Duke quarry are situated in the northwestern limb of a tightly folded overturned syncline.

A well-developed cleavage parallel to bedding exists in the phyllites which enables the rock to be easily cleaved to produce dimension stone of excellent quality.

Crushed stone

Bacon quarry: The Bacon quarry (see plate 11, no. 3) is located approximately 5 miles northeast of Hillsborough, North Carolina, in a quartz diorite body that has intruded mafic metavolcanic rocks. Crushed stone is produced here by the North Carolina State Highway Commission for use in road maintenance work throughout Orange County.

Bacon quarry is a roughly rectangular bench-type excavation situated just below the crest of a hill that rises approximately 100 feet above the surrounding terrain. This 350 foot long by 250 foot wide quarry is developed in the western margin of the intrusive and its length parallels the northeast-southwest trend of the main quartz diorite body. In the western corner of the quarry the rock face reaches its maximum height of almost 50 feet above the quarry floor. Overburden ranges from zero to 20 feet thick with an average of 10 feet of red, drab orange and yellow clayey soil.

In the vicinity of Bacon quarry the quartz diorite body is one mile wide. It has been traced by outcrop and float one mile to the northeast and four miles to the southwest. The intrusive is a medium to dark gray fine to coarse grained granitic-textured rock that appears to vary considerably in mineral composition throughout its extent. Most of the quartz diorite exposed in the quarry contains light greenish gray and pinkish-gray feldspar and clear quartz in a granitic texture, generously sprinkled with mafic minerals. Thin section observations reveal the dark patches of mafic minerals to be composed of chlorite, epidote and black opaque minerals with occasional spots of calcite and sericite. Small bundles of fibrous actinolite are often conspicuous and adjacent to the hornfels xenoliths.

Innumerable mafic metavolcanic xenoliths make up approximately 20 percent of the rock that has been recently quarried. The xenoliths range from less than one inch to more than 20 feet in maximum dimension with two inch to two-foot sizes being most common (see plate 9, no. 5). A majority of the xenoliths are still subangular to only slightly rounded with a sharp line of contact with the igneous intrusive thus indicating limited assimilation for the quartz diorite.

Excellent examples of contact metamorphism are exhibited by many of the metavolcanic xenoliths. A green gray colored albite-hornfels facies occurs in the inner portion of the zoned aureols of most xenoliths and grades outward into the dark-gray perimeter of hornblende-hornfels facies that comes into direct contact with the quartz diorite. Because of the low to moderate temperature of this contact metamorphism, recrystallization is imperfect and the paragenesis is partially obscured by the relict minerals from the albite-epidote-hornfels facies persisting in the hornblende-hornfels facies. Both facies correspond to moderate pressure. Indicative of the xenoliths' original mafic volcanic composition is the albite-epidote-hornfels' facies' basic mineral assemblage of albite-epidote-actinolite-chlorite-quartz-opaques and minor amounts of calcite.

Much epidote occurs throughout the rock in Bacon quarry as widely disseminated fine particles and veins. Veins of calcite up to several inches in thickness are also quite common. The most prominent joint planes observed in the quarry strike N. 35° W. and dip 80° SW. and strike N. 35° E. and dip 88° NW.

Eno quarry: The Eno quarry is located on the west bank of the Eno River approximately one mile east of the Eno Steam Station and 0.5 mile northeast of the intersection of Interstate Highway 85 and U.S. 70. The quarry is aligned in an east-west direction, is approximately 700 feet in length, 250 feet in width and 40 to 50 feet in depth. The quarry was opened and operated by Coleman Contracting Company for the purpose of obtaining crushed aggregate for use in the construction of Interstate Highway 85 in early 1960. In 1961, Superior Stone Company purchased the lease from Coleman Contracting Company, moved their crushing facilities to the site and continued to produce crushed aggregate until 1964. In that year, Superior Stone Company relinquished its lease on the property and the property reverted back to its owner, T. S. Coile. The quarry is now abandoned and water-filled to a depth of approximately 15 to 20 feet.

The rock in Eno quarry is a medium greenish gray very fine grained to cryptocrystalline felsic lithic tuff. Thin section analysis of the rock revealed a mineralogical composition of alkali feldspars, quartz, chlorite, sericite, epidote and calcite. Opaques including magnetite, leucoxene and ilmenite are also present.

Tests run by a private company on aggregate collected from this quarry site have shown that the rock is ideally suitable for the manufacture of roofing granules. Physical tests performed by the State Highway Commission's Division of Materials and Tests when the quarry was first opened revealed that the fresh rock from the Eno quarry would meet the most stringent specification requirements for quality in highway construction. Fresh rock from the quarry had next to the lowest Los Angeles abrasion test results ever obtained from a commercial quarry in North Carolina with percentage losses of 14, 14 and 16 percent for the A, B and C grading sizes respectively. The apparent specific gravity for all three of these samples was 2.71 and the weight per cubic foot of solid was 169 pounds. The percentage of absorption averaged 0.1 percent and tests on the minus 40-mesh fines showed the material to have a liquid limit of 21 and to be nonplastic. A ten cycle sodium sulphate soundness test produced a loss of only 0.6 percent.

Mebane quarry: The Mebane quarry is located approximately 0.5 mile northeast of the intersection of Secondary Roads 1142 and 1140 and 0.3 mile south of Interstate Highway 85. The quarry trends northeast, is approximately 800 feet long, 600 feet wide and 60 feet deep. The pit covers an area of 10 to 12 acres. The quarry was opened in 1959 by Superior Stone Company for the purpose of obtaining crushed aggregate for use in the construction of a section of Interstate Highway 85. After completion of the project, the quarry was closed in 1961 and is presently water filled to within 20 to 25 feet of the surface.

Physical tests by the State Highway Division of Materials and Tests show the Mebane stone to be of excellent quality for highway construction purposes. Los Angeles abrasion test results were 15, 14, and 18 percent for the A, B and C grading sizes respectively. Specific gravity for the three samples averaged 2.90. The percentage of absorption was 0.3 percent and tests on the minus forty mesh fines revealed the material to have a liquid limit of 19 and to be nonplastic.

The rock exposed in the Mebane quarry is a varying mixture of medium gray fine to coarse grained quartz diorite intrusive rock and medium to dark greenish gray fine grained mafic volcanic rock. There is now approximately a forty foot depth of water in the quarry but exposures along the southeast face of the quarry indicate the overall composition is about 50 percent quartz diorite and 50 percent mafic volcanic rock.

Somewhat spherical quartz masses up to 0.5 inch in diameter indicate that at least some portions of the mafic volcanic rock may have originally been an amygdaloidal flow. Also, a conspicuous amount of fine dust size pyrite grains noted were disseminated throughout much of the mafic rock.

Quartz aggregate

Laurel Hill quartz deposit: A white quartz deposit, which is exceptionally large for Orange County, crops out along the northeast trending ridge line of Laurel Hill (see plate 12, no. 2). This hill is located approximately 0.7 mile southwest of Calvander crossroads in south-central Orange County, situated on the east bank of Morgan Creek, 0.6 mile south of Secondary Road 1104. The hilltop reaches an elevation of 535 feet above sea level and provides about 90 feet of relief above the normal water level of Morgan Creek.

As indicated by the scattered outcrops and float the overall surface dimensions of the quartz vein, or cluster of veins, are 600 feet in length and 90 feet in width. Outcrops up to five feet high indicate a fairly massive central vein with a length of 400 feet and an average width of 40 feet. This arcuate quartz outcrop, which ranges from a strike of N. 65 E. at its southern end to N. 35 E. at its northern end, apparently dips at a high angle to the northwest.

The rapidly growing popularity of exposed aggregates in modern architectural concrete, especially white vein quartz, has accentuated the potential value of such deposits as the one found on Laurel Hill.

Gravel pits

Chapel Hill gravel pits: The Chapel Hill gravel pits are situated in a highly weathered granodiorite stock and are located approximately 3.5 miles south of the center of the town of Chapel Hill, North Carolina, along the north and northwest sides of Secondary Road 1918. The currently active private and state owned gravel pits are located at the end of Secondary Road 1918, which is approximately 0.8 mile southwest of Secondary Road 1008 (see plate 11, no. 4). A large inactive privately owned gravel pit is situated on the northwest side of Secondary Road 1918, 0.4 mile southwest of its intersection with Secondary Road 1008.

The gravel pits are the bench and open pit types and are easily mined by conventional earth-moving equipment, because of the highly-weathered nature of the granodiorite. The presently active pit measures approximately 1500 feet in length by 1000 feet in width and has an average depth of approximately 30 feet. The inactive pit measures approximately 800 feet by 1200 feet and has an average depth of 30 feet.

Prior to 1955, the North Carolina State Highway Commission leased a small area in this vicinity for the purpose of obtaining gravel for use in the maintenance and stabilization of unpaved county roads.

In 1955, the Geology Section of the State Highway Division of Materials and Tests conducted an extensive exploratory auger-drilling project on a 50 acre tract of land which included the area being mined. A truck mounted 6-inch diameter auger was used and holes were augered at selected locations on the tract. In numerous instances, large spheroidal boulders were encountered at various depths in the granodiorite saprolite which prevented further penetration by the auger bit. In such cases, the auger would be moved slightly to the side and the more resistant boulders easily bypassed. The average depth penetrated by the truck-mounted auger was approximately 30 feet.

Presently, gravel mined from this area is being used by the North Carolina State Highway Commission for the maintenance of secondary roads and by private contractors for driveway and walkway stabilization.

DESCRIPTION OF PHOTOGRAPHS

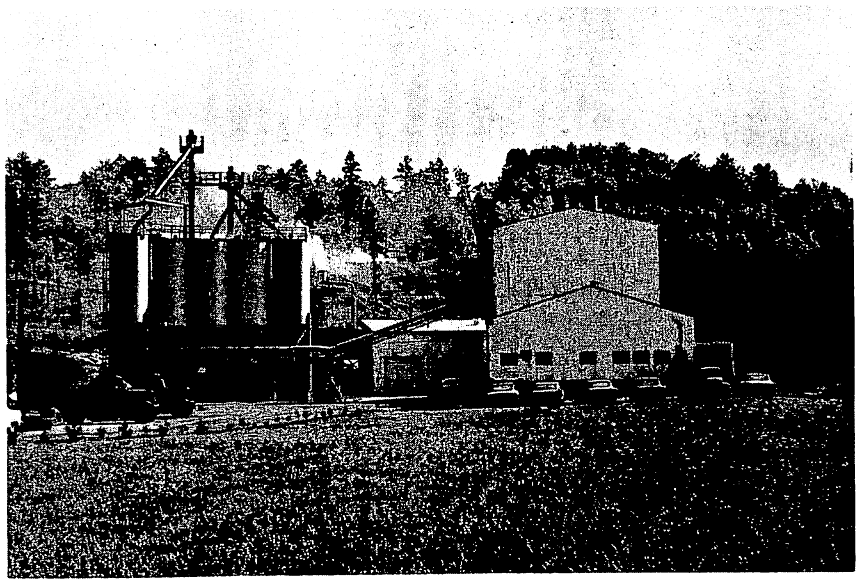
Plate 11

1. Front view of Piedmont Minerals Company, Inc., pyrophyllite processing plant located approximately 0.7 mile south of the center of the town of Hillsborough, North Carolina.

2. Abandoned workings of the Chapel Hill iron mine located approximately 1.2 miles northwest of the center of the town of Chapel Hill, North Carolina.

3. View of the north face of the Bacon quarry which is used by the North Carolina Highway Commission to obtain crushed aggregate for use in highway construction and maintenance. The quarry is located approximately 1.5 miles southwest of the intersection of Secondary Roads 1567 and 1002.

4. Northwest view of a portion of the Chapel Hill gravel mine. The gravel is obtained from a highly weathered granodiorite intrusive rock and is used in the maintenance of secondary roads, private driveways and sidewalks. The gravel mine is located approximately 3 miles south of the center of Chapel Hill, North Carolina.



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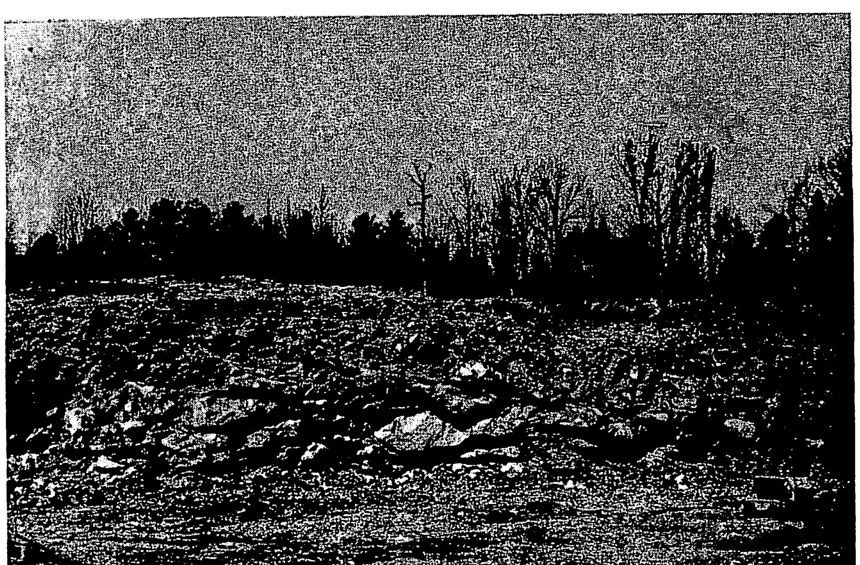

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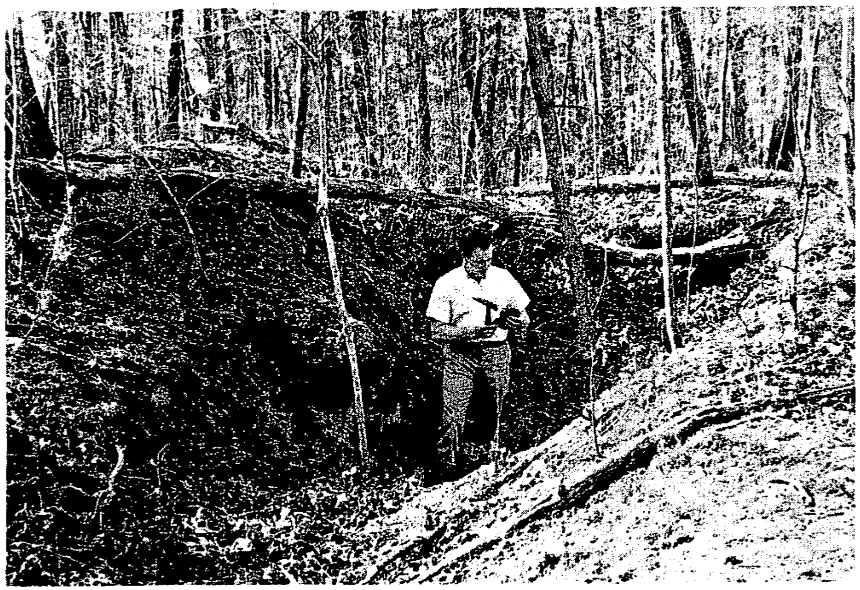
DESCRIPTION OF PHOTOGRAPHS

Plate 12

1. Duke Forest prospect pit is approximately 15 feet wide, 30 feet long, 5 feet deep and strikes N. 20° W. The prospect pit is located on the east side of Concrete Bridge Road, 0.65 mile south of Secondary Road 1718. The prospect is in a gossaniferous, highly brecciated felsic tuff that strikes N. 30° E., dips vertically and is in contact on the northwestern side with a diorite intrusive rock.

2. Laurel Hill quartz deposit is located approximately 0.7 mile southwest of Calvander crossroad in south-central Orange County. This white vein quartz deposit crops out along the northeast trending ridge line of Laurel Hill located on the east bank of Morgan Creek.

3. Hand specimen of a gossaniferous highly brecciated quartz vein obtained from the Duke Forest prospect pit. Small cubic and rectangular cavaties are present in the brecciated quartz and felsic tuff which suggests that iron sulphides may have been present but are now leached away.



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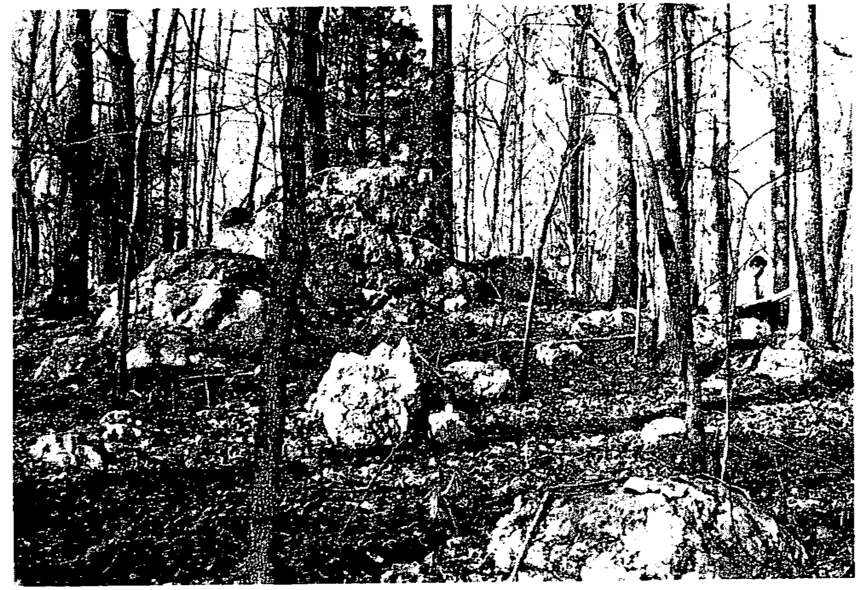

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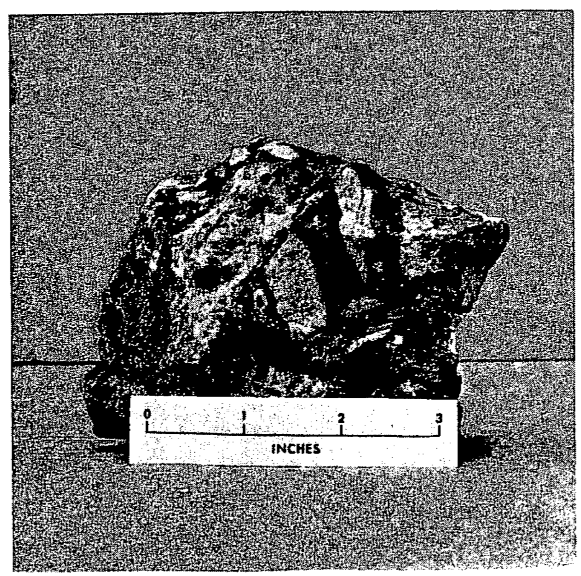

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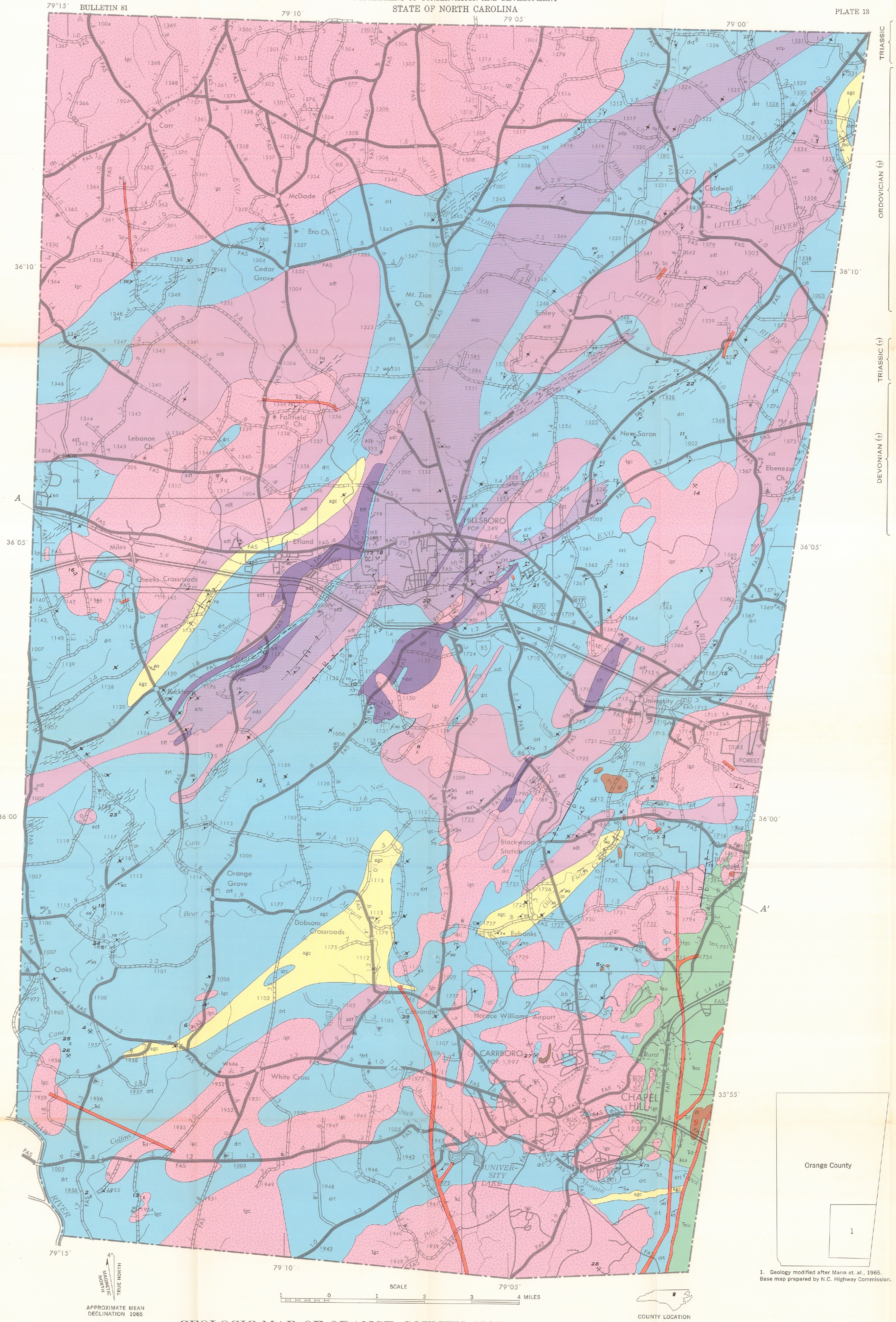
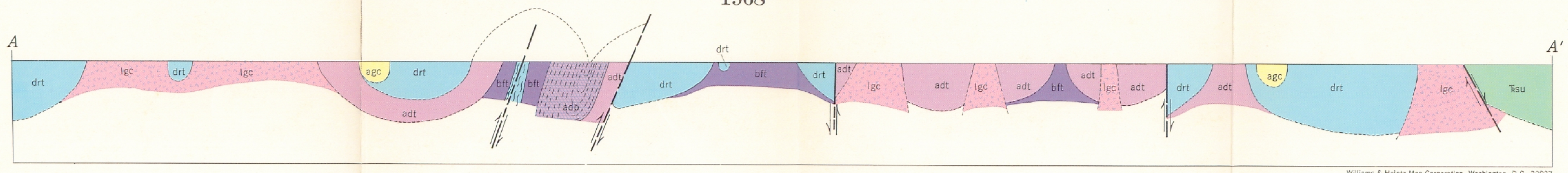
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
STATE OF NORTH CAROLINA



GEOLOGIC MAP OF ORANGE COUNTY, NORTH CAROLINA

By
Eldon P. Allen and William F. Wilson

1968



LEGEND

MESOZOIC — TRIASSIC — Upper Triassic - Newark Group

Tsu — Triassic Rocks Undifferentiated
Undifferentiated sandstones, arkoses, siltstones, shales and conglomerates which range in color from buff, yellow, orange, brown, reddish-brown, red, maroon, and gray to purple.

PALEOZOIC (?) — ORDOVICIAN (?)

agc — Unit IV
Volcaniclastic epiclastics, includes light to medium greenish-gray conglomerates with intercalated graywackies, overlain by light to medium greenish-gray intercalated graywackies and laminated argillites which grade into light to medium-gray laminated argillites.

drt — Unit III
Dacitic to rhyolitic, medium to light gray to light greenish gray dense, and in places welded lithic tuffs and crystal lithic tuffs. Small localized medium to light gray spherulitic rhyolite flows and flow tuffs are present within the unit.

adt / adp — Unit II
(adt) *Andesitic to dacitic medium to dark greenish-gray lithic tuffs, crystal lithic tuffs and tuff breccias, locally containing lahars. Amygdaloidal basalt flows, locally exhibiting pillow structure are present, but are not as abundant or extensive as in Unit I.* (adp) *Andesitic to dacitic dark gray to dark bluish-gray phyllites.*

bft — Unit I
Predominantly fine-grained massive dark grayish-green spilitic amygdaloidal basalt flow rocks, some of which are pillowed, interbedded with dark gray to grayish-green basalt porphyries and basaltic lithic and crystal lithic tuffs.

INTRUSIVE ROCKS

MESOZOIC — TRIASSIC (?)

Td — Triassic (?) dikes
Dark greenish-gray, fine to medium grained basaltic and diabase dikes of Late Triassic or Early Jurassic age, composed predominantly of augite, calcic plagioclase and olivine.

PALEOZOIC — DEVONIAN (?)

lgc — Igneous complexes
Igneous intrusive rocks which range in composition fron granites, quartz monzonites, granodiorites, quartz diorites and diorites to gabbros.

di — Diorite
Dark greenish gray, medium grained, equigranular aggregate of subhedral to anhedral orthoclase, plagioclase, hornblende and plus or minus quartz.

um — Ultramafic
Dark gray coarse-grained rock composed of hornblende, olivine and magnetite with local alterations to chlorite, serpentine and talc.

SYMBOLS

Contact
Dashed where approximately located

Inferred contact

Fault
Showing dip, dashed where approximately located

Vertical fault
Dashed where approximately located

Fault
Showing relative movement

Axis of Anticline
Dotted where doubtful or concealed

Axis of Syncline
Dotted where doubtful or concealed

Shear zone

Strike and dip of beds

Strike of vertical beds

Strike and dip of overturned syncline

Strike and dip of cleavage

Strike of vertical cleavage

Strike and dip of foliation

Strike of vertical foliation

Active mines, quarries and pits

Abandoned or inactive mines and quarries

Prospects

1100 Secondary road numbers

101 State highway

1 U.S. numbered highway

40 Interstate highway

Impassable road or trail

Primitive or unimproved road

Graded and drained road

Soil, gravel or stone surfaced road

Hard surfaced road

Divided highway

MINES, PROSPECTS, QUARRIES AND PITS

GOLD MINES AND PROSPECTS

1. Bradsher prospect
2. Dell Dawson prospect
3. Duke Forest prospect
4. North State or Robertson mine
5. Nunn Mountain mine
6. Ray prospect
7. Secondary Road 1135 prospect
8. Shambly prospect
9. Weaver-Carr prospect
10. Womble prospect

COPPER PROSPECTS

11. Hill prospect
12. Stebbins prospect
13. Stroud prospect

QUARRIES - CRUSHED AGGREGATE

14. Bacon quarry
15. Eno quarry
16. Mebane quarry

DIMENSION STONE

17. New Duke quarry
18. Old Duke quarry

PYROPHYLLITE MINES AND PROSPECTS

19. Bradshaw mine
20. Hillsborough mine
21. Lover's Leap prospect
22. Murray prospect
23. Saline Sykes prospect
24. Teer prospects
25. Oaks prospect
26. Martin Morrow soapstone mine

IRON MINE

27. Chapel Hill iron mine

GRAVEL PITS

28. Chapel Hill gravel pits

QUARTZ AGGREGATE

29. Laurel Hill quartz prospect

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