Stratigraphy of the Albemarle Group of the Carolina Slate Belt in Central North Carolina

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CONTRIBUTIONS TO STRATIGRAPHY

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STRATIGRAPHY OF THE ALBEMARLE GROUP OF THE CAROLINA SLATE BELT IN CENTRAL NORTH CAROLINA

By ARVID A. STROMQUIST and HAROLD L. SUNDELIUS

Abstract

Detailed geologic mapping in parts of Davidson, Rowan, Cabarrus, Stanly, Randolph, and Montgomery Counties has shown that the volcanic sedimentary rocks of the Albemarle Group in the Carolina slate belt in central North Carolina can be divided into several mappable rock units. From oldest to youngest these units are the Tillery, Cid, and Millingport Formations. The Tillery Formation is characterized by an abundance of alternately laminated siltstone and clay. The volcanic-rich Cid Formation is divided into a lower mudstone member and an upper unit called the Flat Swamp Member which consists of felsic and mafic pyroclastic rocks and related volcaniclastic rocks. The Millingport Formation is divided into the Floyd Church Member and the overlying Yadkin Member. The Floyd Church Member is predominantly argillite, in part graded, but which near the top contains numerous interbeds and layers of intermediate mafic volcanic sandstone or volcanic siltstone. Near the base, this member locally contains discontinuous to widespread interbeds of argillaceous tuff breccia. The Floyd Church Member grades upward into the thick sequence of alternating intermediate mafic volcanic sandstone and volcanic siltstone here called the Yadkin Member.

All formations of the Albemarle Group contain mafic and felsic volcanic rocks, andesitic basalt, and felsic rocks intermediate in composition between a rhyolite and a rhyodacite. The felsic rocks of the Cid Formation are largely aphanitic porphyries and vitrophyres in the lower mudstone member, whereas tuffs and aphanitic breccias, ash flows, and related volcaniclastic rocks occur in the Flat Swamp Member. The mafic rocks include tuff breccias, agglomeratic lapilli tuffs, and tuffs. Although the Millingport Formation is characterized by the presence of many lenses and layers of volcanic sandstone, it also contains a few beds of felsic and mafic volcanic rocks. The Tillery Formation contains a few felsic and mafic lavas and tuffs but is chiefly composed of laminated siltstone and claystone.

The Tater Top Group, previously thought to overlie the Albemarle Group in angular unconformity, apparently does not exist. The rocks previously assigned to the Tatėr Top are volcanic rocks within the Albemarle Group and within the underlying Uwharrie Formation. Some of the volcanic vents undoubtedly persisted through several quiescent and explosive intervals of volcanism.

INTRODUCTION

The Carolina slate belt is composed chiefly of volcanic-rich sedimentary rocks characterized principally by their low grade of metamorphism. These rocks compose much of the eastern part of the Piedmont province (pl. 1) and crop out from south-central Virginia to central Georgia. The history of the term "slate belt" has been discussed by Conley and Bain (1965, p. 118–119).

The Piedmont province has been divided by King (1955) into five geologic belts: the Carolina slate belt (on the east), Charlotte belt, Kings Mountain belt, Inner Piedmont belt, and Brevard belt (on the west). It has been suggested (King, 1955, map; Keith and Sterrett, 1931; Kesler, 1936; and Overstreet and Bell, 1960) that the volcanic-rich slate belt rocks are the stratigraphic equivalents of the more highly metamorphosed Piedmont gneisses and schists to the west. To the east, well and drill-hole data show that the

TABLE 1.—*Stratigraphic summary of the central North Carolina slate belt sequence*

Albemarle Group:

- Millingport Formation (6,000–9,000 ft):
  - Yadkin Member 3,000 ft. Chiefly volcanic sandstone and siltstone and associated andesitic basalt.
  - Floyd Church Member 3,000–6,000 ft. Chiefly argillite or siltstone, in part shaly, and containing some bodies, lenses, and layers of rhyolite-rhyodacite rocks and andesitic basalt volcaniclastic rocks.
- Cid Formation (about 14,000 ft):
  - Flat Swamp Member about 4,000 ft. Contains vitric crystal lithic tuff breccias, bedded tuffs, ash flows, and related volcaniclastic rocks intermediate in composition between rhyolite and rhyodacite; andesitic basalt volcanic rocks.
  - Mudstone member about 10,000 ft. Chiefly mudstone, in part blocky and tuffaceous; contains feldspar porphyries, vitrophyres, and tuffs intermediate in composition between rhyolite and rhyodacite; andesitic basalt bodies and layers; mudstone grades upward into shale.
- Tillery Formation about 5,000 ft:
  - Chiefly thinly laminated siltstone and claystone; includes a few intraformational andesitic basalt volcanic rocks, feldspar porphyries and tuffs intermediate in composition between rhyolite and rhyodacite.

Uwharrie Formation about 20,000 ft.

- Chiefly felsic volcaniclastic rocks.

slate belt continues under the Coastal Plain cover. The relation of the slate belt to the Charlotte and Inner Piedmont belts is one of the outstanding problems of Appalachian geology.

STRATIGRAPHY OF THE SLATE BELT

As a result of recent geologic mapping programs carried out by Federal and State geologists, the rocks of the slate belt in central North Carolina have been divided into several stratigraphic units (pl. 2; table 1).

The Uwharrie Formation, Albemarle Group, and Tillery and Yadkin Formations were named by Conley and Bain (1965). The Cid Formation and its members, the mudstone member and the Flat Swamp Member, and the Millingport Formation and its members, the Floyd Church and Yadkin Members, are described below. In this report, the Yadkin Graywacke of Conley and Bain (1965) is redefined as the Yadkin Member of the Millingport

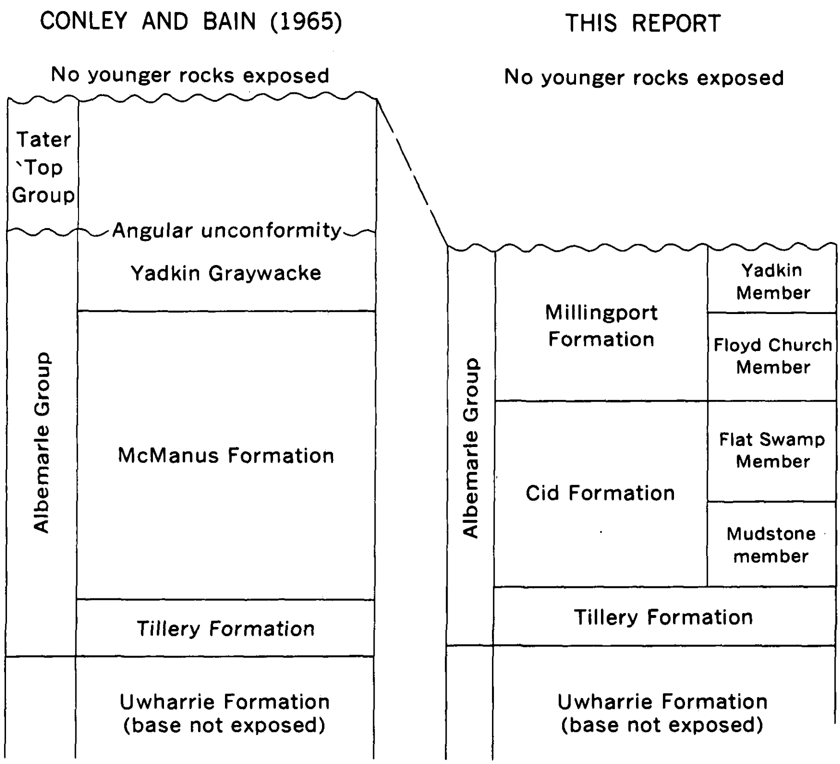

FIGURE 1.—Comparison of stratigraphic nomenclature used in this report with the nomenclature of Conley and Bain (1965).

Formation. The Albemarle Group, as originally defined, included the Tillery and McManus Formations and the Yadkin Graywacke. Figure 1 gives a comparison of the stratigraphic nomenclature used in this report with the nomenclature of Conley and Bain (1965).

The rocks composing the Tillery Formation, the Flat Swamp Member of the Cid Formation, and the Yadkin Member of the Millingport Formation have been of particular value in subdividing the Albemarle Group (pl. 2). The distinctive thinly laminated siltstone and claystone of the Tillery Formation contrasts *sharply* with the thick-bedded or massive rocks of the underlying Uwharrie Formation. The Tillery is also easily distinguishable from the more blocky and partly tuffaceous mudstone and associated felsic and mafic volcanic rocks of the lower Cid Formation. An evenly bedded shale generally occurs at the top of the mudstone member of the Cid Formation; these fissile rocks are quarried locally for flagstone. Above the flagstone horizon are the distinctive volcaniclastic rocks of the Flat Swamp Member, which separate the shale and mudstone of the Cid Formation from the green argillite and siltstone of the Floyd Church Member of the Millingport Formation. The Flat Swamp Member has been traced continuously through the Denton, Gold Hill, Mount Pleasant, and Albemarle quadrangles. The Floyd Church Member of the Millingport Formation is generally distinctly bedded at the base and characteristically weathers to olive, gray, or brown. Finally, the uppermost unit of the Albemarle Group is the distinctive thick volcanic sandstone sequence of the Yadkin Member, which is exposed in much of the Albemarle and Mount Pleasant quadrangles. The Albemarle Group rests upon the generally massive and felsic volcanic rocks of the Uwharrie Formation, but the upper contact of the group is not exposed in the area mapped; it may be found among the more highly metamorphosed rocks west of the Silver Hill fault (pl. 2).

DEFINITIONS OF SELECTED TERMS

As used in this paper, **volcaniclastic rocks** are rocks composed of predominantly volcanic rock fragments of either pyroclastic or epiclastic origin (Fisher, 1961, p. 1409). **Volcanic sandstone** and **volcanic siltstone** are nongenetic terms describing rocks composed of sand- or silt-sized volcanic particles whose pyroclastic or epiclastic origin is uncertain (Fisher, 1961, p. 1412). **Shale** is a fissile siltstone that splits approximately parallel to bedding. **Mudstone,** as used here, is a siltstone and claystone that is partly massive and blocky, partly tuffaceous, and partly poorly to moderately well bedded. **Argillite** is a silt-clay mixture without conspicuous cleavage or parting. **Rhyodacite** is herein considered the extrusive equivalent of granodiorite. The terms "essential" and "accessory" are used as defined by Pettijohn (1957, p. 332). **Agglomerate** is herein defined as volcanic breccia which contains both angular and rounded as well as vesicular and nonscoriaceous fragments of lava.

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ALBEMARLE GROUP

Conley and Bain (1965, p. 126) included in the Albemarle Group all rocks that overlie the Uwharrie Formation; the Tater Top Group was defined as unconformably overlying both the Albemarle Group and the Uwharrie Formation (fig. 1). This interpretation of an angular unconformity is incompatible with the local and regional structures within the map area of plate 2. It is our opinion that rocks of the Tater Top Group are interbedded with those of the Albemarle Group and those of Uwharrie Formation as volcanic interludes; this conclusion is discussed further in the section on the Tater Top Group.

GEOLOGY OF THE ALBEMARLE GROUP

All the volcanic-rich units in the Albemarle Group contain intrusive rocks that seem to be comagmatic with the volcanic rocks. Petrography and chemical analyses show that the quartzo-feldspathic volcanic rocks of the Albemarle Group are intermediate in composition between rhyolite and rhyodacite. Some of the vitrophyres may be volcanic plugs. The mafic volcanic rocks of the Albemarle Group are andesitic basalt flow and pyroclastic rocks. Their silica contents are all less than 52 percent, but in texture and color index they resemble andesite. The sodic nature of the plagioclase is probably due to metamorphism. Previous workers in the slate belt of North Carolina have described similar rocks as basalts; we will use the term "andesitic basalt." The presence of mafic lapilli and bombs in many of the andesitic basalt as well as the association of sill-like and stocklike bodies of gabbro throughout the slate belt suggest a comagmatic relation.

Felsic volcanic rocks

In the mapped areas of the slate belt, the felsic volcanic rocks of the Albemarle Group are round to irregular lenslike bodies that extend along strike for distances of less than a mile to as much as several miles. Porphyritic lavas, vitrophyres, vitric crystal tuffs, and vitric crystal lithic tuffs occur in these bodies. Some of the rocks are recognized as tuffs only after examination in thin section because most of the felsic rocks are fine grained to aphanitic. Except for the explosive ejecta in the Flat Swamp Member of the Cid Formation, the felsic volcanic rocks were largely viscous porphyries that apparently did not extend far from their sources.

Siltstone or claystone fragments are rarely present in the tuffs; those observed were probably incorporated when the lava erupted through a sedimentary cover. Most of the volcanic rock fragments are devitrified volcanic glass. Some fragments are amygdaloidal; others contain relict microlites of albitized plagioclase more or less alined about the feldspar phenocrysts, a feature suggesting flowage.

The rhyolite-rhyodacite lavas and tuffs are medium gray and contain feldspar laths, grains, or fragments as much as 3 mm in diameter set in an aphanitic groundmass. Secondary quartz is present sparingly as amygdules and as small mosaic patches and veins. In most hand samples, small disseminated grains of biotite are discernible with the aid of a hand lens. In some samples, a few scattered grains of pyrite or pyrrhotite and magnetite can be seen. Leucoxene has been noted in most of the thin sections studied, and stilpnomelane has been observed in a few sections.

In one lava, flow banding occurs as varicolored irregular swirls that can be measured in feet or yards, for example on Bald Mountain near Yadkin River in the southwest part of the Denton quadrangle (pl. 2). In most places, however, the flow bands can be recognized on the weathered surfaces of the rocks as more or less linear ridges that are only a few millimeters apart and a few millimeters high.

Plagioclase phenocrysts of the porphyries and tuffs are saussuritized and largely converted to albite. A few of the albite grains contain patchy intergrowths of microcline that compose 5–90 percent of each grain. These intergrowths probably represent original sanidine altered to albite and microcline.

The groundmass of the porphyries, vitrophyres, and tuffs is devitrified quartzo-feldspathic material. The texture of the groundmass is locally spherulitic and locally micrographic. In places, the groundmass contains rudely alined relict plagioclase microlites, a feature suggesting flowage. In the vitrophyres, the groundmass contains few or no microlites of albite; these rocks may be volcanic plugs or fissure fillings that were too viscous to move very far. Some of the devitrified glasses show microperlitic structures. No vitroclastic structures have been recognized, except in the lenses or lentils of tuffaceous breccia of the Flat Swamp Member of the Cid Formation and in the lentils of argillaceous tuff breccia of the Floyd Church Member of the Millingport Formation. As described later, both these breccias contain reworked volcanic debris together with essential volcanic dust and devitrified shards.

The felsic volcanic rocks of the Albemarle Group contain the following metamorphic minerals: quartz, albite, microcline, biotite, chlorite, sericite, clinozoisite, and epidote. In general, these rocks belong to the quartz-albite-microcline-epidote-biotite subfacies of the greenschist facies of Fyfe, Turner, and Verhoogen (1958, p. 223).

Andesitic basalt lavas and volcaniclastic rocks

Interbedded with and in part interfingering with the sedimentary rocks of the Albemarle Group are thick lenticular bodies of greenish-gray andesitic basalt and mafic volcaniclastic rocks. These bodies are as much as 5,000 feet wide and several miles long. Some of the thick deposits lens out within a few thousand feet. The rocks consist of amygdaloidal lavas, agglomeratic lapilli tuffs, lithic crystal tuff breccias, tuffs and fine tuffs, and volcanic sandstones and siltstones. Some of the flows are vesicular or amygdaloidal; chlorite, epidote, quartz, biotite, and, locally, calcite fill the cavities. Most of the rock fragments of the tuff-breccias seem to be fresh ejecta, particularly the angular lapilli and the scoriaceous pyroclastic bombs. Some subrounded lithic fragments are found which may have come from reworked volcanic debris.

The volcanic sandstones and siltstones are greenish gray and even grained. Basal beds show slump effects and contain bent angular plates and slabs of the underlying sedimentary rocks. Mineralogically, these volcanic sandstones and siltstones resemble closely the matrix of the fine-grained volcaniclastic rocks of the area. Their greenschist mineralogy and relict shard(?) structure suggest that these sandstones are composed of primary reworked mafic pyroclastic material.

The coarse pyroclastic rocks are mostly obscurely bedded, but the fine-grained tuffs and volcanic sandstones and siltstones are distinctly bedded in many areas. The fine-grained volcaniclastic rocks grade into light-greenish-gray siltstone and claystone. Where sheared, especially west of the Silver Hill fault, the andesitic basalts are schistose dark-greenish-gray rocks. Locally these sheared rock are injected with small lenses of quartz monzonite, which are also sheared.

The andesitic basalts of the Albemarle Group contain the following metamorphic minerals: albite, tremolite-actinolite, quartz, epidote, chlorite, sphene, and calcite. These minerals are characteristic of mafic rocks in greenschist facies of Fyfe, Turner, and Verhoogen (1958, p. 223).

Sedimentary rocks

The sedimentary rocks interbedded with the volcanic rocks of the Albemarle Group have many similar properties. They are interbedded siltstone, claystone, shale, and mudstone, which are bluish gray to greenish gray when fresh but which weather to hues of gray, yellow, white, pink, olive, and brown. These rocks form the lowlands and plains that surround low hills of volcanic and intrusive rocks. Random samples show that the principal minerals, mostly secondary, in the sedimentary rocks are: quartz, feldspar, sericite, and chlorite. Epidote, sphene-leucoxene, biotite, and pyrrhotite or pyrite are present in minor amounts. Chemical analyses (Pogue, 1910, p. 41; Laney, 1910, p. 28; Councill, 1954, p. 13) indicate that some of the sedimentary rocks are characterized by high ratios of sodium oxide to potassium oxide. This led to the conclusion that volcanic debris constitutes the bulk of the "slates" of the slate belt (Pogue, 1910, p. 42; Councill, 1954, p. 15). A small fraction of the sedimentary rocks is certainly volcanic, because thin layers of coarse pyroclastic debris occur at intervals within the various sedimentary rocks. Shards are sparse if not entirely absent, however, in most of the sedimentary rocks. The few shards observed by us are in samples from lentils of argillaceous tuff breccia interbedded locally with the sedimentary rocks; these rocks are described on page B14. In addition to an accumulation of volcanic debris, factors that might account for the high sodium oxide-potassium oxide ratios are: composition of the source areas, diagenetic changes in chemical composition, and introduction of sodium oxide from outside sources. Grain size of the sample analyzed may be a factor also, because in varved glacial sediments summer silt has a higher Na_2O content than winter clay (Pettijohn, 1957, p. 345). Presumably, this factor might apply to nonglacial silt and clay as well.

TILLERY FORMATION

The Tillery Formation first appeared on a map compiled by Bain (1964) but was formally named and described by Conley and Bain (1965). The type locality is on North Carolina Route 109, on the southeast side of the bridge crossing the Uwharrie River in the Albemarle quadrangle. The Tillery is also fairly well exposed where North Carolina Route 73 crosses the formation (pl. 2), and good outcrops occur locally along the north-south country roads between Martha and North Carolina Route 109 and between Uwharrie and North Carolina Route 73 (pl. 2). We place the upper contact of the Tillery Formation stratigraphically lower in the area near Badin than do Conley and Bain (1965), because we have chosen the base of typical tuffaceous mudstone of the Cid Formation as the top of the Tillery.

Thin laminations are the most characteristic feature of the Tillery Formation. The laminations range in thickness from less than 0.1 mm to about 8 mm and average 1–3 mm in thickness. Most of the laminations grade from silt at the base to clay at the top and have a corresponding increase in the amount of sericite and chlorite and a decrease in the amount of quartz and feldspar from the base upwards. Generally, the upper, clayey part of a lamination is of fairly uniform thickness in any given section.

Locally, the siltstone-claystone of the Tillery Formation breaks along bedding planes but does not split into even large slabs like the shale at the top of the Cid Formation described below. Part of this lack of fissility is due to the cyclic deposition of silt and clay; the clay fraction commonly persists uniformly over large areas, whereas the silt fraction varies in thickness. The shale of the Cid Formation is largely even grained, and, consequently, it splits along the bedding planes. Axial-plane cleavage related to regional folding also causes the rock of Tillery Formation to break up more readily than the shale of the Cid Formation.

Flakes of spongy reddish-brown biotite that lie randomly across the laminations and that have ragged but roughly hexagonal cross sections are another characteristic feature of the Tillery; some consist of sericite and chlorite and remnants of biotite. These flakes may be altered metacrysts but could also be pyroclastic debris dropped in from an ash cloud or brought in as part of a turbidity current.

CID FORMATION

The Cid Formation is here named for the community of Cid in the northwestern part of the Denton quadrangle (pl. 2). Cid was part of the Cid mining district described by Pogue (1910). The type area is along North Carolina Route 8 between Flat Swamp Road and North Carolina Route 49 (pl. 2). Most of the felsic volcanic rocks in the Albemarle Group are in the Cid Formation. The mudstone member of the Cid Formation characteristically contains felsic lavas that apparently did not extend far from their sources and that were associated with the eruption of much andesitic basalt. Later, when the felsic lavas erupted more violently, the pyroclastic rocks of the Flat Swamp Member were deposited and formed a distinct stratigraphic unit.

Although there is no single adequate exposure of the entire formation, additional characteristic features can be seen in some scattered localities. In the abandoned quarry at Bald Mountain (pl. 2), characteristic felsic flow rock is associated with the mudstone member of the Cid Formation. Here the rock is an aphanitic porphyry with conspicuous flow banding. Other good exposures of the felsic volcanic rocks are Crouse Mountain, Steep Rock, and the several peaks in the Morrow State Park (Conley, 1962, map). In these latter exposures the rocks are either aphanitic porphyries with obscure flow banding or aphanitic crystal lithic tuffs. Typical crystal lithic andesitic basalt tuff is exposed in the railroad cut paralleling Yadkin River just north of Bald Mountain. This type of rock can also be observed along the east shore of Badin Lake north of Badin and in the northeast quarter of the Denton quadrangle. An agglomeratic andesitic basalt can be seen at Davidson Hill just south of the intersection of North Carolina Routes 49 and 109. Similar agglomeratic tuff breccia occurs in the Denton quadrangle 1 mile northwest of New Jerusalem Church. North Carolina Routes 8, 27, and 109, within the area shown on plate 2, have fair to good exposures of the sedimentary facies of the formation and, in part, the volcanic rocks of the Flat Swamp Member. The geologic maps of the Denton (Stromquist, 1966) and Albemarle quadrangles (Conley, 1962) show the distribution of the rock units.

Mudstone member

Mudstone constitutes most of the mudstone member, but andesitic basalt and felsic volcanic rocks like those common elsewhere in the Albemarle Group are also found. Good exposures of mudstone and associated volcanic rocks occur along Cid Road from 1 mile west of Cid to half a mile east of Jackson Creek. Thus, we consider the exposures along this stretch of road to be the type area for the mudstone member.

The basal contact of the member is gradational with the characteristic varvedlike laminated siltstone-claystone of the underlying Tillery Formation. The increase in the number of associated mafic and felsic igneous rock bodies suggests a revival of volcanic activity which had been largely dormant since deposition of the Uwharrie Formation. The lower parts of the mudstone member commonly contain beds 1–2 feet thick of fine-grained bluish-gray blocky tuff that typically weathers white. Numerous discontinuous small lenses and layers of felsic pyroclastic debris also occur.

A lull in the volcanic activity is indicated by scarcity of volcanic rocks in the upper part of the mudstone member. This quiescent interval precedes the explosive phase represented by the volcanic rocks of the Flat Swamp Member. Typical outcrops of the shale in the upper part of the member, in the Nor-Carla Bluestone quarries of the Jacobs Creek Flagstone Co. in the southern part of the Denton quadrangle (pl. 2), have laminations ranging from 1 mm to 1 cm in thickness. Descriptions of these rocks are given by Councill (1954, p. 8–14). The Nor-Carla flagstones split easily into smooth slabs several yards long and as thin as one-half inch. The rock breaks consistently parallel to the bedding rather than along the weakly defined axial-plane cleavage that formed during the gentle regional folding (pl. 2). The flagtones contain about 75 percent quartz and feldspar, 15–20 percent sericite, small amounts of chlorite, and traces of epidote and sphene-leucoxene. Spongy orange to yellowish-brown biotite occurs locally. Also present locally are limestone concretions about 6–8 inches in diameter, roughly circular in plan, and 1 inch or less thick. At the tapering edge of the concretions, noncalcareous argillite grades into calcareous argillite, and thin dark-gray laminae persist for about 1 inch into the concretions.

Flat Swamp Member

The Flat Swamp Member is here named for Flat Swamp Mountain in the west-central part of the Denton quadrangle (pl. 2). The rocks of the member are best exposed on Flat Swamp and Wildcat Mountains and in the roadcuts across these ridges, the type area for the member. Particularly good exposures of local phases of the member are in cuts along the Winston-Salem Southbound Railway cuts paralleling the northeast shore of High Rock Lake and Yadkin River. Typical andesitic basalt crystal lithic tuff breccia, of the Flat Swamp Member, is well exposed in the cut where the railroad tracks pass under North Carolina Route 49. Additional good outcrops are found in cuts along county roads north of Wildcat Mountain and along the county road that leads westward from North Carolina 109 at Blaine to North Carolina Route 49 near the intersection of Route 49 with North Carolina Route 8. The member is poorly exposed in the Gold Hill quadrangle, and very little of it extends around the nose of the Denton anticline within the Mount Pleasant quadrangle. The member is locally well exposed in roadcuts in the Albemarle quadrangle.

The Flat Swamp Member contains felsic volcanic rocks and andesitic basalt like those in other units of the Albemarle Group, but it is composed chiefly of vitric crystal lithic tuff-breccia, vitric tuff, stratified tuff, and tuffaceous breccia, all of felsic composition. The bedded fine-grained rocks of the Flat Swamp Member are felsic volcaniclastic rocks rather than siltstones, claystones, or shales as in the other units. The felsic volcanic rocks of the Flat Swamp Member are largely tuffs rather than porphyries. In brief, the rocks of the Flat Swamp Member largely represent the fragmental material and volcanic ash resulting from explosive action about centers of eruption.

Felsic volcanic rocks

The breccias and tuffs of the Flat Swamp Member are in part welded tuffs and in part reworked volcanic rocks deposited in a largely subaerial environment. The bedded fine-grained felsic volcaniclastic material may be water laid.

Vitric crystal lithic tuff breccia exposed in the railroad cut near the outlet of High Rock Lake consists of laths and fragments of albite, scattered accessory felsic rock fragments as much as 3 cm in diameter, and lenticular aphanitic fragments as much as 5 cm long elongated parallel to a crude stratification. All rock fragments and mineral grains are set in a granoblastic quartzo-feldspathic matrix. Also present are scattered grains of pyrite, pyrrhotite, magnetite, sphene-leucoxene, grains of metamorphic biotite, chlorite, sericite, epidote, clinozoisite, and calcite.

In many places, the tuffaceous rocks contain irregular dark splinters as much as 25 mm long that consist of microscopic grains of biotite, chlorite, and feldspar. Such aggregates are well exposed in a small quarry where North Carolina Route 8 crosses Flat Swamp Mountain, north of Denton Road.

Along the crest of Wildcat Mountain, the vitric tuff breccias contain pale-colored areas of very fine grained felsic material. These areas have various shapes and sharp outlines; some are elongated and have curved edges. They seem to be bent or stretched recrystallized essential rock fragments. Others have fuzzy borders and indefinite shape. The general scarcity of angular fragments of preexistent rocks, poor sorting, and the general lack of stratification suggest that these rocks are ash flows.

The vitric crystal tuff breccias grade vertically and probably horizontally along strike into vitric and fine-grained vitric crystal lithic (?) tuff of the same composition as the coarser vitric tuff breccias just described. These rocks consist of nearly equidimensional albite fragments as much as 1 mm in diameter set in a finer grained granoblastic quartzo-feldspathic groundmass. The fragments are in part embayed and have fuzzy borders. Although no positive evidence of welding has been observed, tiny aggregates of leucoxene arranged in swirls and wisps suggest a vitroclastic structure.

Locally, the vitric crystal tuffs are stratified, particularly in the transition zones close to the bottom and near the top of the Flat Swamp Member. Near the base of the member, the volcanic rocks indicate a change from subaqueous deposition of the underlying shale to largely subaerial conditions. A similar transition occurs where the subaerial volcanic rocks of the Flat Swamp Member pass upward into water-laid siltstone and claystone of the Floyd Church Member of the Millingport Formation.

The transitional rocks are tuffaceous siltstone and claystone. Most of these rocks have cream-colored, pale-gray, or dark-gray laminae 1 to several millimeters thick that bifurcate or pinch and swell. The layering is emphasized by thin dark layers of argillite between thicker lighter colored layers of tuff. The rock is speckled with irregular areas of sulfides. Sedimentary structures resembling planoconvex laminae (Pettijohn, 1957, pl. 22, p. 294) are indicative of shallow-basin deposition. Thin sections reveal that the light-colored layers are composed of feldspar crystals and quartz grains and the dark layers are fine-grained tuff(?) and kaolinized land waste. The crystal-rich layers are interpreted as tuff dropped in the basin of deposition during a time when the influx of fine land waste was too slow to obscure crystal debris. Diagenetic or metamorphic pyrite or pyrrhotite straddle the bedding as irregular laths or granules. In some rocks, the sulfide grains are elongate in form or are in stringers parallel to bedding. In other samples, the fact that sulfides parallel the cleavage suggests that they are in part syntectonic.

These transition rocks are exposed in the Denton quadrangle along Flat Swamp Road where it approximately parallels the gradational contact between the Flat Swamp Member and the Floyd Church Member; along the county road between North Carolina Route 49 and Blaine, particularly in the cuts of this road south of the Davidson-Montgomery county line in the southern part of the Denton quadrangle; in roadcuts along North Carolina Route 740 about 150 feet northwest of Badin Lake in the Albemarle quadrangle; and, locally, in the railroad cut about 2,000 feet north of the outlet of High Rock Lake southward (pl. 2).

Lentils of tuffaceous breccia

Lentils of poorly sorted tuffaceous breccia containing reworked felsic rock fragments and abundant plagioclase clasts occur in the fine-grained to aphanitic felsic tuffs of the Flat Swamp Member. The fragments and clasts are set in a brown matrix of fine shard-bearing tuff; small pumice fragments are also present locally. No welding or flattening of pumice fragments was seen. In the Denton quadrangle, these breccia lenses range from 20 to

200 feet in thickness. Some lenses persist for only a few hundred feet along strike; others are several miles long. The volcanic debris may have resulted from small eruptions from nearby volcanic highlands; during these eruptions the debris avalanched down the volcanic slopes. A good example of the scouring effect of an avalanching slurry of volcanic debris can be seen at the base of a lens of tuffaceous breccia along the east shore of High Rock Lake about 3,000 feet north of the outlet of High Rock Lake southward. Here slabs of the underlying stratified crystal tuff have been incorporated by the avalanche as it scoured a channel.

Andesitic basalt

Andesitic basalt agglomerates, crystal lithic tuff breccias, and fine-grained tuffs occur in the Flat Swamp Member. In addition to these types of rocks, an andesitic basalt flow breccia occurs which is composed of a mixture of basaltic rock fragments in a matrix similar in composition to the rock fragments. The matrix contains plagioclase laths in more or less parallel alinement around the rock fragments. Secondary chloride, tremolite, epidote, and brown leucoxene dust are interstitial to the plagioclase laths. Locally, the interstices of the autobreccia are filled with calcite, albite, and chlorite. Accidental fragments of the felsic rocks occur locally in the basaltic crystal lithic tuff breccias of the Flat Swamp Member. Some of these fragments have bluish-gray centers and greenish-gray borders, possibly the result of heating or low-grade metamorphism. In other respects, the andesitic basalt rocks of the Flat Swamp Member are similar to those of the other formations of the Albemarle Group.

MILLINGPORT FORMATION

The Millingport Formation is here named for the town of Millingport in the Mount Pleasant quadrangle; the type area is along North Carolina Route 71 (pl. 2). The formation is chiefly composed of volcanic sandstone, siltstone, and argillite and contains a minor amount of volcanic rocks. It is subdivided into two members, the Floyd Church Member and the overlying Yadkin Member.

Floyd Church Member

The Floyd Church Member, which is extensively exposed in the southeast half of the Mount Pleasant quadrangle and in the northwest quarter of the Denton quadrangle, is here named for

Floyd Church in the Denton quadrangle; the type area is along North Carolina Route 8 west of Flat Swamp Mountain (pl. 2).

The unit consists mainly of a gray to greenish-gray argillite composed chiefly of quartz, feldspar, sericite, some chlorite, and minor amounts of biotite, epidote, clinozoisite, pyrite, and sphene-leucoxene. The lower part of the member has moderately distinct beds that are graded in part; the upper part of the member is less obviously bedded. Locally, the lower part of the member contains lenses and persistent beds of argillaceous tuff-breccia. In places, the member contains small lenses and interbeds of poorly sorted volcanic sandstone and siltstone (graywacke?) similar to that composing the bulk of overlying Yadkin Member as well as thin lenses of calcareous siltstone. Thus, the Floyd Church Member seems to be transitional from the waning felsic volcanic activity of the underlying Flat Swamp Member of the Cid Formation to the more mafic volcanic sediments of the overlying Yadkin Member of the Millingport Formation. Locally, the member also contains felsic and andesitic basalt volcaniclastic rocks. The Floyd Church Member typically weathers olive, gray, or brown.

Lentils of argillaceous tuff breccia

Widespread interbeds of argillaceous tuff breccia occur in the lower part of the Floyd Church Member. These are best observed in the Denton quadrangle just west of the Flat Swamp and Wildcat Mountains and in the base of the member in the trough of the Silver Valley syncline. Less continuous argillaceous tuff-breccias occur in the crushed rock quarry near Gold Hill (pl. 2). The interbeds are 20-100 feet thick; some persist for only a few hundred feet along strike, but some continue for several miles. The breccias may represent the final phases of the Flat Swamp Mountain volcanic activity, for they contain essential and reworked felsic volcanic debris. Also present are fragments and slabs of siltstone. Both the reworked and essential debris are in a matrix of tuffaceous siltstone that in part contains devitrified shards. The lower contacts of the breccia interbeds are irregularly scoured by the debris. The siltstone fragments are largest and most abundant near the base of the breccia interbeds; the upper contacts are more regular and grade into the normal siltstone rock of the Floyd Church Member.

Yadkin Member

The Yadkin Graywacke of Conley and Bain (1965) is herein redefined as the Yadkin Member of the Millingport Formation. The unit is composed principally of poorly sorted volcanic sandstone and siltstone. The unit was mapped by Conley (1962, map) and was named and described by Conley and Bain (1965, p. 128–129). The type locality "* * * is a road cut on the west side of N.C. 8 about 100 feet south of where Riles Creek crosses the road, one mile north of the intersection with U.S. 52" (Conley and Bain 1965). Other exposures typical of the unit are found along North Carolina Routes 8, 73, and 740, U.S. Highway 52. (pl. 2).

The Yadkin Member consists of interbedded poorly sorted dark-greenish-gray to greenish-black volcanic sandstone and siltstone. These rocks are composed of quartz, plagioclase, and silt- to fine-sand-sized rock fragments in a fine-grained matrix of sericitic muscovite, chlorite, quartz, and plagioclase. Epidote, clinozoisite, magnetite, ilmenite, and apatite are also present. In places, the unit also contains some interbed andesitic basalt flows, crystal lithic tuff breccia, and tuff. The rocks have been metamorphosed to the greenschist facies. According to Conley and Bain (1965, p. 129), the Yadkin Member is at least 3,000 feet thick, but the top is not exposed in the area of plate 2.

INTRUSIVE ROCKS

Paleozoic intrusive rocks in the Albemarle Group include gabbro, quartz monzonite, a gabbro-diorite complex, and felsic vitrophyres which may be volcanic plugs. Diabase dikes of Triassic age are also common.

Gabbro occurs chiefly east of the Gold Hill fault where it forms silt-like bodies and small irregularly shaped intrusives (pl. 2). The gabbro is a greenish-gray fine- to medium-grained light-colored metagabbro containing oligoclase-andesine, quartz, tremolite-actinolite, epidote-clinozoisite, chlorite, sphene, leucoxene, and magnetite-ilmenite.

Large and small bodies of quartz monzonite occur west of the Silver Hill fault (pl. 2). These bodies consist of a sheared yellowish-gray coarse- to medium-grained rock containing quartz, oligoclase, potassium feldspar, biotite, magnetite, and sphene-leucoxene. Much of the original potassium feldspar is altered to sericite. The quartz monzonite forms a distinctive sandy soil. Intermediate to mafic dikes cut quartz monzonite in many places.

The gabbro-diorite complex occurs west of the Gold Hill fault (pl. 2). The complex is composed chiefly of a fine- to coarse-grained foliated medium- to dark-grayish-green plagioclase-amphibole-biotite-chlorite-epidote rock that in places is gneissic. Locally, it also contains irregular light-colored granitic bodies. The complex is cut by numerous foliated fine- to medium-grained, and in places schistose, dark-colored intermediate to mafic dikes.

Dikes of unmetamorphosed greenish-black diabase composed of augite, labradorite, olivine, and disseminated magnetite cut northwestward across the formations of the area. These dikes are presumably of Triassic age.

AGE OF THE ALBEMARLE GROUP

Fossils have been found in the Albemarle Group in three localities, one in the geologically mapped area of plate 2 and two from the area just to the south. The fossils include: (1) Coalified algae identified by J. M. Schopf (written commun., Jan. 22, 1962) from near the base of the Tillery Formation south of Uwharrie in the Albemarle quadrangle (pl. 2, loc. 1). Schopf considers the algae to be of early Paleozoic age, possibly Ordovician. (2) Impressions that resemble worm burrows described by Conley (1960) in tuffaceous argillite in the mudstone member of the Cid Formation in southern Stanly County 3.7 miles S. 72° E. of the village of St. Martin in the Mount Pleasant quadrangle (pl. 2, loc. 5). (3) A trilobite from Stanly County questionably assigned to the Middle Cambrian genus *Paradoxides* (St. Jean, 1965). The fossil was discovered in stream rubble in Island Creek near the bridge on county road 1115. The locality is in the unmapped quadrangle south of the Mount Pleasant quadrangle, 4.2 miles S. 26° W. of the village of Red Cross in the Mount Pleasant quadrangle (pl. 2, loc. 4). St. Jean describes the outcrop upstream from the discovery site as finely laminated argillite with bedding cleavage. The trilobite possibly came from a shale near the top of the mudstone member of Cid Formation, stratigraphically above the site of the worm burrows also in the mudstone member. The mudstone is stratigraphically above the Tillery Formation in which the algae were discovered.

Although these scattered fossils do not permit precise age assignment of the formations of the Albemarle Group, they indicate that the group is of early Paleozoic age, possibly in part Cambrian(?) and Ordovician(?). Considering the regional correlations and reliability of available datings, we favor Ordovician(?)

over early Paleozoic. This assignment is not in serious conflict with lead-alpha ages (White and others, 1963) of zircon from saprolitized tuff of the underlying Uwharrie Formation in the Albemarle quadrangle (pl. 2, locs. 2 and 3). Zircon from locality 2 had an apparent age of 470 ± 60 million years; that from locality 3 had an apparent age of 440 ± 60 million years. Both these apparent ages would be Ordovician on current time scales. Considering the large analytical uncertainties and possible effect of low-grade regional metamorphism on lead-alpha ages, the Uwharrie Formation is considered to be of Ordovician(?) age. As more information has accumulated, the Cambrian period has been placed farther back in the past—from about 500 million years in 1947 to about 600 million years in 1965 (Holmes, (1965).

Ordovician fossils have been found in the Arvonia and Quantico Slates of Virginia (Watson and Powell, 1911), but the geologic relations of these rocks to those of the slate belt in North Carolina are not known. Projection along strike suggests that such a correlation is possible (pl. 1).

REGIONAL CONSIDERATIONS

Five distinct sedimentary lithologies are found in the Albemarle Group: (1) thinly laminated siltstone and claystone of the Tillery Formation, (2) partly blocky and tuffaceous thick-bedded mudstone with numerous interbeds and lenses of felsic tuff (mudstone member of the Cid Formation), (3) fissile shale at the top of the mudstone member of the Cid Formation, (4) argillite or siltstone (in part distinctly bedded and graded) of the Floyd Church Member of the Millingport Formation, and (5) the thick sequence of alternating layers of volcanic sandstone and volcanic siltstone of the Yadkin Member of the Millingport Formation.

All these sedimetary rocks, except the shale of the mudstone member of the Cid Formation, are interbedded with the felsic and mafic volcanic rocks. Only a small amount of volcaniclastic material is interstratified in the Tillery Formation, but the Cid Formation contains numerous lenses and layers of both felsic and mafic volcanic rocks. The Millingport Formation is characterized by abundant intermediate volcanic sandstone and siltstone and by somewhat less common felsic and mafic pyroclastic rocks.

The sedimentary rocks doubtlessly inherited their distinctive characters largely from their source terranes. Composition of the terrane, distance from source, and intensity of volcanicity probably were the controlling factors.

TATER TOP GROUP

The Tater Top Group (Conley and Bain, 1965), formerly thought to overlie the Albemarle Group unconformably, apparently does not exist, and the name is here formally abandoned. The previous interpretation by Stromquist and Conley (1959) of an angular unconformity between nearly flat-lying volcanic rocks of the Tater Top Group and older folded volcanic-sedimentary rocks of the Albemarle Group is incorrect. The present writers find that the rocks assigned to the Tater Top Group are interbedded with both the Albemarle Group and the Uwharrie Formation. The irregular outcrop pattern of some of the volcaniclastic rocks that were included in the Tater Top Group is due to the accumulation of lava and volcanic debris around sites of eruption. No structural data on the map by Conley and Bain (1965) or on the geologic map of the Albemarle quadrangle (Conley, 1962) support the interpretation that the Tater Top Group overlies the Albemarle Group unconformably. On the other hand, the structural data in the Denton quadrangle (Stromquist, 1966) suggest that all the rocks are conformable. Furthermore, all the rock units in the area of plate 2, those of the Albemarle Group as well as those included in the Tater Top Group, have attained about the same degree of metamorphism. This seems incompatible with an interpretation that some of the rock units rest in nearly horizontal unconformable contact upon the folded Albemarle Group.

ROCKS WEST OF THE SILVER HILL FAULT

Immediately west of the Silver Hill fault, the rocks are more or less sheared, and we interpret them to be the schistose equivalents of rock units from the Cid Formation (pl. 2). The sedimentary rock units have formed shear-cleaved gray argillite, lustrous phyllite, white to cream-colored sericite schist, or green schists where the sediments were largely chloritic. The felsic volcanic rocks have formed phyllites and schists containing flattened chalky feldspars and, where present, the included rock fragments are greatly elongated. The mafic volcaniclastic rocks have formed fine-grained green to greenish-gray chlorite-plagioclase-epidote schists.

Quartz-sericite schist, phyllonite, phyllite, and chlorite-epidote-plagioclase greenschist have been recognized west of the Gold Hill fault but are not subdivided on the geologic maps because of poor exposures. Their similarity to rocks east of the fault, the geologic relations shown on plate 2, suggest that the rocks of the undivided unit are sheared rocks of the Cid Formation also. Intruded into this undivided complex are large to small bodies of quartz monzonite and gabbro-diorite rocks; these intrusive rocks have also been sheared. Still further west is an intimately mixed assemblage of biotite and hornblende schists, amphibolite, and coarse-grained nearly pegmatitic potassium-feldspar-rich granitic rocks. These rocks may also be slate belt rocks that have been recrystallized and granitized. The Silver Hill-Gold Hill fault shear zone may extend to the Virgilina mining district that lies within the postulated Virgilina synclinorium (Laney, 1917) at the Virginia-North Carolina border (pl. 1).

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