INTRODUCTION

The Annandale quadrangle is in the urban part of eastern Fairfax County and includes part of Arlington County and the City of Alexandria, Virginia. The quadrangle covers a small part of two strikingly different geologic terranes: the central Appalachian Piedmont on the west and the Atlantic Coastal Plain on the east. The Piedmont is underlain by metamorphosed rocks of sedimentary, volcanic, and plutonic origin. The crystalline metamorphic rocks of the Piedmont are poorly exposed because of deep weathering and the extensive urbanization. Outcrops, even of saprolite, are largely limited to stream valleys or artificial exposures. The best natural exposures are near the Fall Line, the sinuous, north-northeast-trending boundary between the Piedmont and Coastal Plain. Knowledge of the crystalline rocks of Fairfax County and vicinity has come from work of the past several years (Drake, 1983, in press a); Drake and Lyttle, 1981; Drake and Morgan, 1981; 1983; Drake and others, 1979). This work is briefly summarized below. Emphasis is placed on the rocks of the Falls Church Tonalite (here named) that previously have not been described.

The Coastal Plain is underlain by much younger and generally poorly consolidated sedimentary rocks largely sand and gravel layers with lesser amounts of silt and clay, that have been little changed since deposition except for compaction. Except for surficial deposits, only the inner marginal strata of the Coastal Plain, the Potomac Formation of Early Cretaceous age, is preserved in the Annandale quadrangle. The Potomac Formation constitutes a gently eastward-dipping and -thickening clastic wedge overlying the crystalline rocks. A great variety of thin, lenticular, non-consolidated surficial deposits of late Tertiary to Quaternary age mantle both the Piedmont crystalline rocks and the Coastal Plain strata.

Sedimentary Rocks of the Coastal Plain

Regional geologic mapping of Coastal Plain deposits in Fairfax County and vicinity by Darton (1947), ground-water assessment by Johnston (1964), and studies of spores and pollen of the Potomac Formation by Brenner (1963), provided the basis for recent studies of the area. Regional geologic aspects of the Coastal Plain deposits in Fairfax County were reported by Force (1975), modified nomenclature with coverage expanded to include Arlington and Alexandria were included by Drake and others (1979).

Force and Froelich (1975) prepared a map of the surficial deposits of the Annandale quadrangle. Froelich showed the thickness of overburden (1975a) and contours on the base of saprolite (1975b). Rogers (1975) mapped landforms and Huffman and others (1975) prepared a preliminary geologic map. Obermeier and Hollocher (1976) mapped landslides in the Franconia area (located in the southeast quadrant of the Annandale quadrangle). Obermeier and Froelich (1976) summarized the engineering geology in the same area, and Johnston and Larson (1976) assessed the ground-water resources at Franconia.

Weir (1976) reported on crossbeds in the sands of the Potomac Formation in Fairfax County, and Lindholm (1978) documented the mineralogy and petrology of both light and heavy minerals at the same localities. Force and Monroe (1978) reported on the regional mineralogy of the clay beds of the Potomac Formation, and Lindholm (1978) studied the mineralogy of interstitial clays in the sand layers. Larson and Froelich (1977) mapped the extent, altitude of the base, and thickness of the Potomac Formation in Fairfax County, and Johnston and Froelich (1977) documented the lithofacies and subsurface extent of channel-fill sands in the same unit. Mixon and Newell (1977) reported on the Stafford fault zone, a north-northeast-trending regional structure at the inner edge of the Coastal Plain south of the Annandale quadrangle, but definite evidence to extend this structure was not found, possibly because the area is densely populated. Seiders and Mixon (1981) published a geologic map of the Occoquan and part of the Fort Belvoir quadrangles of southern Fairfax County where strata similar to those in the Annandale quadrangle are well exposed. Froelich and others (1978) reported on Pleistocene deposits of an ancestral Potomac River in eastern Fairfax County and vicinity. Obermeier (1983) summarized the engineering geology and slope design of the Potomac deposits, and Froelich (in press) compiled a comprehensive folio of maps covering all of the geologic and hydrologic aspects of the Coastal Plain in Fairfax County and vicinity.

The clastic wedge of sediments of the Potomac Formation in the Annandale quadrangle feathers out at the Fall Line. The contact between the gravelly basal sands of the Potomac Formation and the underlying Piedmont crystalline rocks is an unconformity, which dips gently to the east-southeast at about 100 feet per mile (19 meters per kilometer), as shown by the structure contours. These contours not only depict the eastward structural tilt of the Coastal Plain sediments, but also show erosional irregularities on the pre-Cretaceous surface. Although the thickness of the Potomac Formation in Fairfax County and vicinity exceeds 600 ft (190 m), only the lower 200 ft (60 m) is preserved along the eastern border of the Annandale quadrangle. Most of the lower Potomac is gray to buff, pebbly, medium- to coarse-grained lithic arkose. Lenticular, varicolored, thin-bedded silts and clays are more common upwards in section and to the southeast. The lower, more sandy part of the Potomac is characterized by abundant trough crossbeds, with directional vector sums that indicate predominantly easterly fluvial current flow (Weir, 1976). The crossbedded sands fill elongate east-southeast-oriented stream channels (Johnston and Froelich, 1977). The sands are separated by silts and clays of overbank floodplain deposits. Most of the clays of the Potomac Formation are montmorillonite with minor amounts of illite (Force and Moncure, 1978).

In the western part of the outcrop area, the eroded Potomac is overlain by a series of sheetlike fluvial deposits of late Tertiary-to-Quaternary terrace gravels about 30 ft (9 m) thick. On the basis of a nearly continuous north-northeast-trending break in slope at the boundary between terrace gravel units (Tt_2 and Tt_1), it is possible that the projection of the regional Stafford zone of structures (Mixon and Newell, 1977) may extend as a flexure across the Annandale quadrangle, but field evidence is inconclusive.

Near Mayfield, the Potomac Formation is deeply eroded and overlain by late Pleistocene (Wisconsinan) deposits underlying the gently sloping plain of Hybla Valley at altitudes of 35 to 65 ft (11 to 20 m). Although the Pleistocene fluvial sands and silts crop out in wave-cut cliffs along the Potomac estuary in the Mt. Vernon and Fort Belvoir quadrangles, they are known mainly from drill holes penetrating as much as 150 ft (46 m) of Pleistocene beds in the Mt. Vernon quadrangle just east of Mayfield (Froelich and others, 1978).

Crystalline Rocks of the Piedmont

More than half of the Piedmont terrane of the Annandale quadrangle is underlain by metamorphosed intrusive rocks. The remainder is underlain by metamorphosed sedimentary rocks and a much lesser amount of metamorphosed volcanic rocks.

METASEDIMENTARY AND METAVOLCANIC ROCKS

In northernmost Virginia, the metasedimentary and metavolcanic rocks constitute a stack of four lithotectonic units (Drake and Lyttle, 1981; Drake and Morgan, 1981; Drake, in press a, b). These units include the Popes Head Formation, which is a turbidite sequence, and three thrust-sheet-precursory mélange pairs that have been termed tectonic motifs (fig. 1). A tectonic motif is defined as a lithotectonic unit consisting of a thrust sheet and a subjacent precursory mélange that contains olistoliths of rocks that comprise the thrust sheet (Drake, in press b). In the Annandale quadrangle, only the lowest motif, the Annandale-Indian Run, and the precursory mélange segment of the middle motif, the Peters Creek-Sykesville, are present.

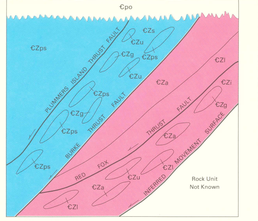


FIGURE 1.—Schematic diagram showing relation of geologic units in the Annandale quadrangle and vicinity. Annandale-Indian Run motif, red; Peters Creek-Sykesville Motif, blue. Refer to Description of Map Units for unit names.

The Popes Head Formation (Drake and Lyttle, 1981) unconformably overlies all the other lithotectonic units and consists of the lower Old Mill Branch Metasiltstone Member and the upper Station Hills Phyllite Member. Both of these members contain interbedded felsic and mafic metatuff. These rocks have been interpreted to the Bouma's (1962) turbidite sequence T_{de} and to Mutti's and Ricci Lucchi's (1978) turbidite facies E (suspending deposits) from weak turbidity flows (Drake and Lyttle, 1981). Drake and Lyttle (1981) have suggested that the formation resulted from the bilateral filling of a back-arc basin.

Peters Creek-Sykesville Motif

The Peters Creek-Sykesville motif consists of the Peters Creek Schist and its underlying precursory mélange, the Sykesville Formation. Only the Sykesville crops out in the Annandale quadrangle.

The Sykesville Formation (Drake and Morgan, 1981) is a complicated sedimentary mélange that has a quartzofeldspathic matrix containing exotic rock types. The Sykesville is a classic precursory mélange (Drake and Lyttle, 1973). The mineral assemblage of the Sykesville suggests that it is at biotite ± garnet grade and there is no evidence of polymetamorphism. The Sykesville Formation overlies the Annandale-Indian Run motif on the Burke thrust fault.

Annandale-Indian Run Motif

The Annandale-Indian Run motif consists of the Annandale Group that overlies its precursory mélange, the Indian Run Formation, on the Red Fox thrust fault. The Annandale Group includes a lower fine-grained turbidite sequence, the Accotink Schist, and an upper coarse-grained sequence, the Lake Barcroft Metasandstone (Drake, in press b). The Annandale is a coarsening-upward sequence interpreted by Drake and Lyttle (1981) to be an outer submarine-fan association of rocks. So far as is known, it contains no fragments of ophiolitic rocks.

Accotink Schist.—The Accotink Schist (Drake and Lyttle, 1981) is characterized by the turbidite sequence T_e and T_{de} (Bouma, 1962) and was assigned to turbidite facies D and E of Mutti and Ricci Lucchi (1978) by Drake and Lyttle (1981). The Accotink is polymetamorphic. The first metamorphism resulted in the growth of muscovite and biotite in a first-generation schistosity. The second metamorphism resulted in the growth of new mica in a second-generation schistosity as well as porphyroblasts of garnet and chlorite (Drake and Lyttle, 1981). The unit is at biotite ± garnet grade.

Lake Barcroft Metasandstone.—The Lake Barcroft Metasandstone (Drake and Lyttle, 1981) consists of two lithologies: 1) thick-bedded, quartzofeldspathic granofels with minor muscovite, and 2) thin- to medium-bedded, micaceous metagraywacke containing schist layers. The quartzofeldspathic granofels typically is a metasandstone that has been interpreted by Drake and Lyttle (1981) to be a sequence of T_b turbidites (Bouma, 1962) and to belong to turbidite facies B_2 of Walker and Mutti (1973). Micaceous metagraywacke has been interpreted by Drake and Lyttle (1981) to belong to turbidite facies C of Mutti and Ricci Lucchi (1978) and Walker and Mutti (1973). Although it cannot be demonstrated in the field, the quartzofeldspathic granofels probably occurs as a channel-fill facies within the micaceous metagraywacke.

Indian Run Formation.—The Indian Run Formation (Drake, in press b), like the Sykesville Formation, is a complicated sedimentary mélange of generally similar composition, and was mapped as Sykesville Formation by Drake and Lyttle (1981) and Drake and others (1979). The Indian Run, however, appears to contain more plagioclase and phyllosilicates and less quartz than the Sykesville. The Indian Run differs from the Sykesville because it contains fragments of Accotink Schist and Lake Barcroft Metasandstone rather than Peters Creek Schist olistoliths. The Indian Run apparently has experienced only one phase of prograde metamorphism and is at biotite ± garnet grade.

INTRUSIVE ROCKS

The metasedimentary and metavolcanic rocks in the Annandale quadrangle are intruded by small bodies of unnamed muscovite monzogranite, Occoquan Granite, and Falls Church Tonalite. Muscovite monzogranite is a light-gray to pink, fine- to medium-grained, locally pegmatitic rock composed of about 40 percent quartz, 24 percent plagioclase, 20 percent microcline, and 25 percent muscovite. In most exposures, the monzogranite is well foliated, but at places it is massive. The largest body mapped is in Holmes Run east of Glasgow Intermediate School. The unit intrudes the Annandale Group and the Indian Run Formation, but appears to be intruded by the Falls Church Tonalite and the Occoquan Granite.

Occoquan Granite.—The largest body of intrusive rocks in the Annandale quadrangle is the northern part of the Occoquan batholith, the major intrusive body in northern Virginia. The batholith consists of the Occoquan Granite, a monzogranite that has lesser granodiorite and tonalite phases (Seiders and others, 1975; Seiders and Mixon, 1981). In the Annandale quadrangle, the Occoquan Granite is well exposed along Pohick Creek, Accotink Creek, and the lower reaches of Backlick, Indian, Turkeycock, and Holmes Runs where it is mostly light-gray, medium- to coarse-grained monzogranite (fig. 2). Some of the rock along the northern border of the batholith, such as along Backlick, Indian, and Holmes Runs is tonalite. The tonalites from the Occoquan batholith plot on the quartz-plagioclase tieline of the quartz-alkali-plagioclase plot (fig. 2) and could belong to the plagiogranite suite of Coleman and Peterman (1975). This factor distinguishes these tonalites from another mode of tonalite from the Occoquan batholith, presented by Seiders and others (1975), that contains 2-9 percent potassium feldspar. The tonalites, however, compositionally resemble those of the Falls Church Tonalite (see below) and the plagiogranitic metatonalites of the central Virginia volcanic-plutonic belt (Pavlides, 1981).

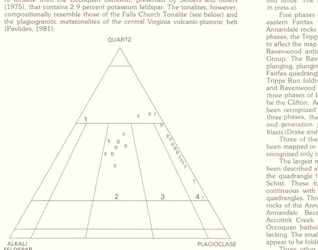


FIGURE 2.—Quartz-alkali-feldspar-plagioclase (Streckeisen, 1976) plot comparing granitoid rocks of the Annandale quadrangle with those of the Occoquan batholith (Seiders and others, 1975) and plutonic rocks of the central Virginia volcanic-plutonic belt (Pavlides, 1981). In the Annandale quadrangle: Occoquan batholith B, and Falls Church Tonalite F. In other areas: Occoquan batholith in other quadrangles X; trondhjemite metatonalite from central Virginia, T, and plagiogranitic metatonalite from central Virginia, P. Represented fields are: 1, quartz-rich granitoid; 2, monzogranite; 3, granodiorite; and 4, tonalite.

Chemical analyses were obtained from two samples of rock from the northern part of the Occoquan batholith (table 1). Sample 2 was taken from within 1800 ft (549 m) of the contact of the batholith with the Indian Run Formation. This rock, a well-foliated, garnetiferous muscovite-biotite monzogranite, is chemically a granite and plots with granites from other places within the Occoquan batholith (fig. 3). Sample 1 was taken about 1.4 mi (2.3 km) from the contact of the batholith with the Indian Run Formation. The rock here is a biotite tonalite and plots near the granodiorite field on figure 2 and not with the plagiogranite-tonalites from the central Virginia volcanic-plutonic belt. There appears to be no consistency in rock type along the north border of the batholith. As was shown above, the rock along the north border in Holmes Run is granite (sample 2). In Turkeycock Run to the west, the rock at the batholith border is granite but the final 600 ft (183 m) of section exposed along the creek adjacent to the Coastal Plain overlap is tonalite. In the west drainage to the west, Indian Run, the intrusive rock is a tonalite similar to that exposed in Backlick Run (sample 1). The rock along the north border of the batholith near Lake Accotink and along the Southern Railroad near the Rivanna's gas storage area is also tonalite. The relation of granite to tonalite could not be determined and the Occoquan batholith may well be a composite intrusion.

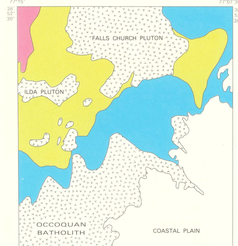


FIGURE 3.—Normative feldspar (O'Connor, 1965) plot comparing granitoid rocks of the Annandale quadrangle with the Occoquan Granite (Seiders and others, 1975) and plutonic rocks of the central Virginia volcanic-plutonic belt (Pavlides, 1981). Numbered points are analyses presented in table 1. Occoquan Granite, X; central Virginia volcanic-plutonic belt: plagiogranite metatonalite, O; and trondhjemite metatonalite, T. Fields are: trondhjemite, 1; granite, 2; tonalite, 3; granodiorite, 4; and quartz monzonite, 5.

The Occoquan Granite intrudes the Lake Barcroft Metasandstone in outcrops along Holmes Run about 3.77 ft (1.15 m) northwest of Interstate 95 where it contains many small to large septaria of that unit. The Occoquan intrudes the Popes Head Formation in the Independent Hill quadrangle to the west (Drake, 1984). The map pattern strongly suggests that the Occoquan intrudes the Indian Run Formation, but this has not been directly observed. Seiders and others (1975) obtained both concordant and discordant U-Pb zircon ages of about 560 Ma from the Occoquan Granite, suggesting an early Cambrian age. Higgins and others (1977) questioned the zircon ages and suggested that the zircons may have inherited a component of older radiogenic lead in seed crystals derived from Proterozoic basement rocks. Seiders (1978) pointed out that there was neither analytical nor textural evidence for xenocrystic zircons in the Occoquan Granite and there is no direct evidence that Occoquan magma ever passed through zircon-bearing Proterozoic basement rocks. More recently, Mose and Nagel (1982) determined a Rb-Sr whole rock isochron age for the Occoquan of 494 ± 14 Ma, suggesting a Late Cambrian age. In spite of the difference in age dates, the Occoquan almost certainly is of Cambrian age.

Falls Church Tonalite (here named).—Watson (1910) recognized two suites of intrusive rocks in the general area of Falls Church and Annandale: 1) muscovite-biotite granite and 2) coarse-grained, siliceous hornblende-biotite-quartz diorite. Suite 1 crops out in the southern part of the area and is the Occoquan Granite of current usage. Suite 2 crops out in the northern part of the area and in modern terminology is tonalite. In the Annandale quadrangle, tonalite and related rocks form the large Falls Church pluton, the Idla pluton, several smaller plutons in and west of Annandale, and two small plutons in the Holmes Run area south of Lake Barcroft. This suite of rocks is here named the Falls Church Tonalite for the city of that name in the Falls Church quadrangle adjacent to the north. The Falls Church Tonalite consists of biotite-hornblende tonalite, biotite tonalite, muscovite-biotite tonalite, garnetiferous muscovite-biotite tonalite, lesser muscovite-biotite granodiorite, and much lesser muscovite-biotite monzogranite. The tonalites and related rocks are medium- to coarse-grained, medium- to dark-gray and typically contain small xenoliths of mafic igneous rock. Locally, such as along Tripps Run near the Congressional School, the tonalite is choked with mafic xenoliths. Outcrops of the suite are massive in appearance but most are foliated and many have quartz rod lineation. The tonalites plot along the quartz-plagioclase tieline of the quartz-alkite-plagioclase plot (fig. 1). Their petrographic characteristics place them in the plagiogranite suite of Coleman and Peterman (1975). The granodiorite and monzogranite are quite siliceous, more so than the rocks of the Occoquan batholith. Some are quartz-rich granitoids in the classification of Streckeisen (1976).

Four samples of the Falls Church Tonalite were analyzed chemically (table 1, samples 3, 4, 5, and 6); three of the four are granodiorite and the fourth a mafic tonalite. Three of the samples are corundum normative, although they contain less than 15 percent Al_2O_3. These rocks also contain 1.4 to 2.8 percent K_2O. The granodiorites contain modal potassium feldspar so it appears that much of the K_2O, at least, is an original component and not the result of post-emplacement alteration. This conclusion is supported by the lack of evidence for such alteration in thin section, although plagioclase shows the effects of metamorphism where andesine is altered to mixtures of more sodic feldspar, epidote, and clinozoisite. The rocks of the Falls Church Tonalite, therefore, appear to differ from the plagiogranite metatonalites of the central Virginia volcanic-plutonic belt that have original K_2O contents of 0.20–0.38 percent (Pavlides, 1981). This chemical difference is clearly shown in figure 3.

An entirely different type of rock occurs within the mapped limits of the Falls Church pluton. This rock, a trondhjemite, is exposed in the Falls Church quarry about 1312 ft (400 m) north of the boundary between the Annandale and Falls Church quadrangles near the east margin of the Falls Church pluton (Drake and others, 1979). The trondhjemite is a light-gray, granular, massive rock that consists of about equal parts of quartz and oligoclase and 16 percent muscovite. It is quite strongly deformed and recrystallized and the oligoclase is typically choked with tiny muscovite flakes. The trondhjemite (table 1, sample 7) is quite siliceous and very corundum normative although it contains less than 15 percent Al_2O_3. It also contains 1.9 percent K_2O. The normative corundum and K_2O content must result from post-emplacement alteration as evidenced from the extensive growth of muscovite in the plagioclase. The trondhjemite plots on the right of the trondhjemite field (fig. 3) because of the alteration effect. It also plots almost on the albite-orthoclase tieline (fig. 3) because of its low content of CaO, and as such, differs from the trondhjemitic metatonalites of the central Virginia volcanic-plutonic belt (fig. 3). The relation of the trondhjemite to the other rocks within the Falls Church pluton cannot be determined so it is uncertain as to whether it is a part of the Falls Church Tonalite or of no genetic relation to these rocks.

Rocks of the Falls Church Tonalite have not been isotopically dated, but the suite is thought to be of Cambrian age because the other intrusive rocks in this part of the Piedmont were emplaced during the Cambrian. The relation of the Falls Church Tonalite to the Occoquan Granite is uncertain as is the relation of the major granite phase of the Occoquan to the lesser tonalite phase. Perhaps the granitoid rocks of this area constitute a large, incompletely unroofed, composite intrusion as has been suggested before (Drake and others, 1979). If this is so, the tonalites within the mapped Occoquan batholith would likely belong to the Falls Church Tonalite.

The Ages of Metasedimentary and Metavolcanic Rocks

The ages of metasedimentary and metavolcanic rocks cannot be directly determined and relative ages depend on the Cambrian age of the Occoquan Granite. The Occoquan does intrude the Popes Head Formation and rocks of the Annandale Group (Drake and Lyttle, 1981). Map relations clearly show that it intrudes the Indian Run Formation in the Annandale quadrangle and the Sykesville Formation elsewhere in Fairfax County (Drake and others, 1979). All these rocks are older than the Occoquan Granite and thus must be of Cambrian or older age. The Popes Head Formation was originally defined as being of Late Proterozoic and(or) Early Cambrian age (Drake and Lyttle, 1981). It is now believed to be of Cambrian age because of its unconformable relation to the other lithotectonic units, and, because of the Sr-Rb dating, the Occoquan Granite may be younger than Early Cambrian age as originally believed (Drake, 1983, in press a).

The Annandale Group has had a much more complicated geologic history than the younger Popes Head Formation and the precursory mélanges—the Sykesville and the Indian Run Formations. This suggests that the Annandale Group is older and may be of Late Proterozoic age. There is probably a better chance that the Sykesville and Indian Run are of Early Cambrian rather than of Late Proterozoic age but that remains uncertain. In any case, the Sykesville and Indian Run Formations and Annandale Group must be considered as Late Proterozoic and(or) Early Cambrian in age.

STRUCTURAL GEOLOGY

The structural geology of the Annandale quadrangle results from the assemblage of tectonic motifs that contain already folded rocks and the subsequent folding of the assemblage and the overlying Popes Head Formation.

Three fold phases are recognized in the Popes Head Formation. The oldest of these phases, the Clifton, is named for the major syncline that contains the Popes Head Formation (Drake and Lyttle, 1981; Drake, in press a). Clifton folds there are close to tight, have a strong schistosity parallel to their axial surfaces, trend northeast, and are overturned to the east. The Clifton folds are refolded by north-northeast- to north-northwest-trending Accotink Creek folds, which are also close to tight, have a strain-slip cleavage parallel to their axial surfaces, and are overturned to the east. Because they are nearly coaxial, it is believed that Clifton and Accotink Creek folds resulted from progressive deformation within a stress continuum rather than from separate periods of deformation. In the same area, a third phase of north-northwest- to northeast-trending Fairfax folds deforms the axial surfaces of Clifton and Accotink Creek folds. Fairfax folds plunge steeply northwest because of the steep dip of earlier fold limbs. The folds may result from right-lateral tangential stress (Drake, in press a).

Five phases of folds are recognized in rocks of the Annandale Group in eastern Fairfax County, two of which predate the emplacement of the Annandale rocks above the Indian Run Formation. Folds of the oldest of these phases, the Tripps Run, are recognized only mesoscopically and do not appear to affect the map pattern. The second phase, the Ravenwood, is named for the Ravenwood anticline that controls the structural geometry of the Annandale Group. The Ravenwood anticline is overturned to the south and is doubly plunging, plunging east in the Annandale quadrangle and west in the adjacent Fairfax quadrangle. Ravenwood folds deform transposition foliation formed by Tripps Run folding and do not have an axial-surface schistosity. Tripps Run and Ravenwood folds may have formed during a stress continuum. The other three phases of folds recognized within the Annandale Group are thought to be the Clifton, Accotink Creek, and Fairfax folds. Fairfax folds have only been recognized in outcrop and have not been mapped. The oldest of these three phases, the Clifton, has an axial-surface schistosity that contains second-generation phyllosilicates, and rotated garnet and chlorite porphyroblasts (Drake and Lyttle, 1981).

Three of the five fold phases recognized in eastern Fairfax County have been mapped in the Annandale quadrangle. The other two phases have been recognized only in outcrop.

The largest mapped fold in the quadrangle, the Ravenwood anticline, has been described above. An anticline-syncline pair in the northwestern corner of the quadrangle fold rocks of the Popes Head Formation and the Accotink Schist. These folds are clearly Accotink Creek phase because they are continuous with a train of such folds in the adjacent Fairfax and Vienna quadrangles. Three folds, including two synforms and an antiform, deform the rocks of the Annandale Group and Indian Run Formation in the area west of Annandale. Because of their nearly north trend, they are thought to be Accotink Creek phase folds. The map pattern suggests that rocks of the Occoquan batholith may be involved in this folding, but direct evidence is lacking. The small plutons are foliated parallel with these fold trends but do not appear to be folded as such.

Three other folds, which deform rocks of the Annandale Group, were mapped in the Lake Barcroft area. The largest of these folds, a synform, overprints the Red Fox thrust fault and folds the Indian Run Formation. Two of these folds also deform the axial surface of the Ravenwood anticline. These folds are thought to be of the Clifton fold phase because they have an axial-surface strain-slip schistosity that contains second-generation phyllosilicates and rotated garnet and chlorite porphyroblasts.

METAMORPHISM

The rocks within the Annandale quadrangle have had different metamorphic histories (fig. 4). Those of the Popes Head Formation are at biotite grade and have experienced only one metamorphic event. The rocks of the Indian Run and Sykesville Formations are at biotite ± garnet grade and have apparently undergone only one metamorphic event. It is uncertain whether the Popes Head is at lower grade than the Indian Run and Sykesville or if the lack of garnet in the Popes Head is a result of composition.

FIGURE 4.—Metamorphic map of the Annandale quadrangle.

Rocks of the Annandale Group are polymetamorphic (Drake and Lyttle, 1981). The first schistosity in these rocks, which is axial surface to Tripps Run folds, contains both muscovite and biotite. A second schistosity, which is axial surface to Clifton folds, contains second generation phyllosilicate minerals and rotated garnet and chlorite porphyroblasts that had begun to grow before deformation (Drake and Lyttle, 1981). The second metamorphic event is thought to have been synchronous with the emplacement of the Occoquan Granite and Falls Church Tonalite. The recrystallization of andesine in the plutonic rocks into mixtures of more sodic plagioclase, epidote, and clinozoisite indicates that metamorphism outlasted plutonism.

Time of Deformation

Because deformation recognized in the rocks in the Annandale quadrangle is either synchronous with or predates the emplacement of the Occoquan batholith among Cambrian time, it is thought to predate the Taconic orogeny (Drake, 1983, in press a). The Occoquan was probably emplaced synkinematically during Clifton folding if the Occoquan is of Late Cambrian age (the favored interpretation), then the Clifton folding resulted from the Penobscotian orogeny (Drake, 1983 in press a). If the Occoquan is of Early Cambrian age, then the Clifton folding dates from the Cadomian orogeny (Drake, 1983, in press a). Rocks of the Annandale Group have had a much more complex geologic history than those of the Popes Head Formation. The Tripps Run and Ravenwood folds in these rocks are thought to date from the Cadomian orogeny (Drake, in press a). These fold phases clearly predate the emplacement of the Falls Church and Idla plutons that are approximately synchronous with the Occoquan Granite.

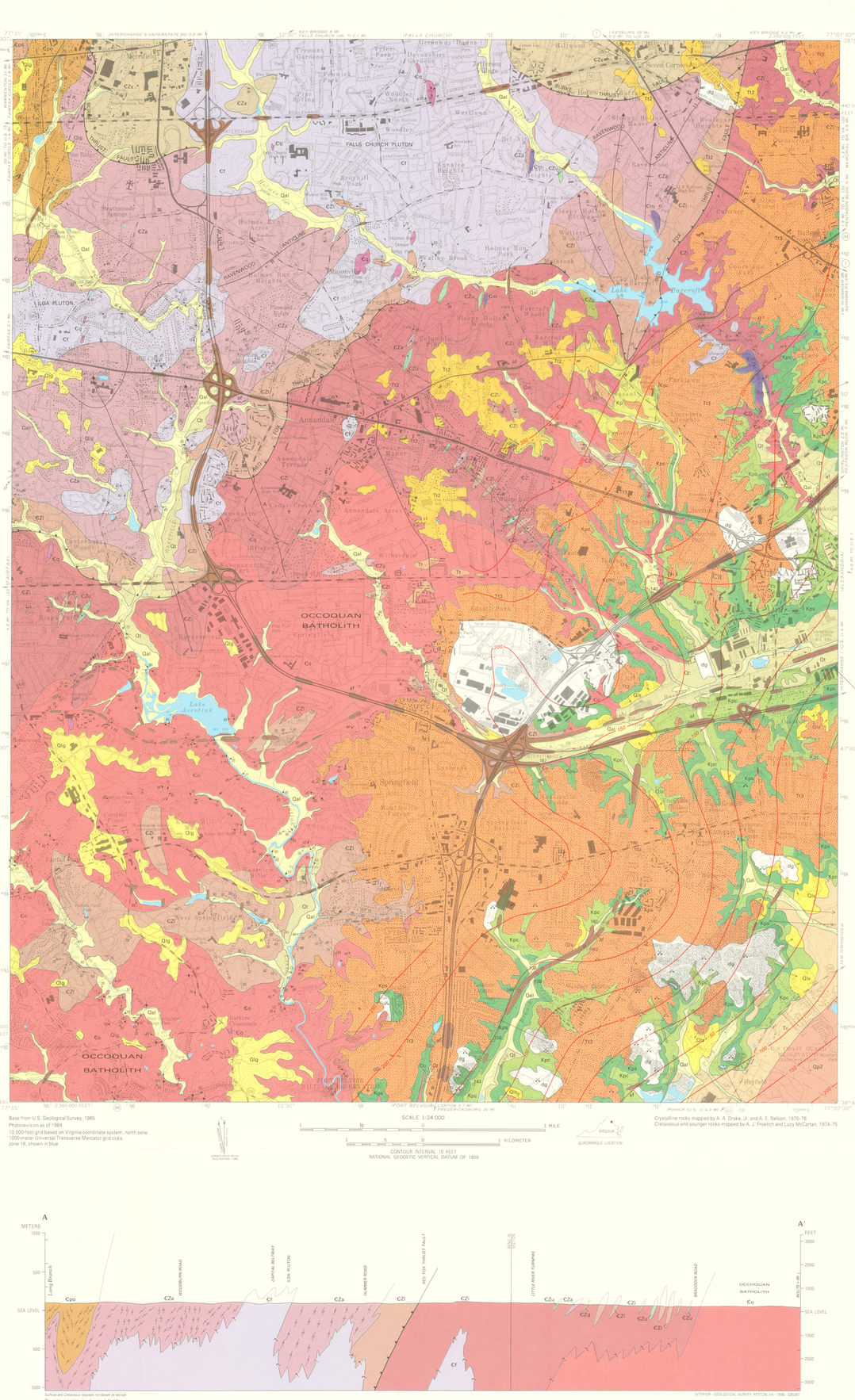
Table 1.—Chemical analyses and C.I.P.W. norms of granitoid rocks in Annandale quadrangle (weight percent)

Sample No.	1	2	3	4	5	6	7
SiO_2	71.0	71.2	75.5	74.1	58.1	69.1	78.3
Al_2O_3	13.2	14.3	14.8	14.5	14.6	13.7	14.7
Fe_2O_3	2.4	1.1	0.56	1.3	3.0	1.6	0.41
FeO	2.4	1.3	1.3	1.1	6.0	2.5	0.28
MgO	1.5	0.92	0.32	0.63	5.2	1.5	0.13
CaO	3.1	0.85	2.1	2.3	6.9	3.8	0.25
Na_2O	3.1	2.5	3.1	3.3	1.8	2.3	4.5
K_2O	1.5	4.2	2.6	2.8	1.4	2.1	1.9
H_2O+	0.79	1.1	0.63	0.02	1.2	1.0	0.73
H_2O-	0.32	0.47	0.02	0.07	0.22	0.22	0.10
TiO_2	0.49	0.33	0.20	0.35	0.73	0.61	0.03
P_2O_5	0.18	0.17	0.98	0.12	0.12	0.17	0.06
MnO	0.07	0.03	0.05	0.05	0.14	0.06	—
CO_2	0.01	0.01	0.06	0.01	0.01	0.08	0.03
Total	100.3	98.5	102.2	100.6	99.4	98.7	101.4
	C.I.P.W. Norms (weight percent)						
Quartz	39.1	40.0	41.9	36.2	18.6	38.1	45.8
Orthoclase	8.9	25.6	15.6	16.7	8.3	12.8	10.1
Albite	26.2	22.0	26.2	27.8	15.2	20.4	38.2
Anorthite	14.5	3.3	9.7	15.6	28.6	18.6	0.3
Corundum	1.3	4.5	3.3	0.3	—	0.8	5.1
$CaSiO_3$	—	—	—	—	2.4	—	—
$MgSiO_3$	3.8	2.4	0.8	1.6	13.3	3.8	0.3
$FeSiO_3$	1.3	0.9	1.4	0.5	7.9	2.4	0.1
Magnetite	3.5	1.6	0.9	1.9	4.4	2.3	0.7
Apatite	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ilmenite	1.4	0.6	0.5	0.6	1.5	1.2	—
Total	100.3	101.2	100.6	101.5	100.5	100.7	100.9

Rapid Rock Analyses by Hezekiah Smith and K. Coates

Description of samples

1. Medium-coarse-grained biotite tonalite from outcrop of Occoquan batholith in Backlick Run directly beneath trestle of Southern Railroad about 3,117 ft (950 m) northwest of Interstate 95 (lat. 38°47'48" N. and long. 77°11'01" W.). Rock is characterized by coarse protruding quartz grains (hobnails) and contains sparse inclusions of Lake Barcroft Metasandstone. Chemically, the rock is also a tonalite (fig. 3).
2. Medium-grained, well-foliated, garnetiferous muscovite-biotite monzogranite from outcrop of the Occoquan batholith in Holmes Run immediately northwest of Interstate 95 (lat. 38°49'16" N. and long. 77°07'44" W.). Chemically, the rock is a granite (fig. 3).
3. Medium-grained, garnetiferous muscovite-biotite monzogranite from a very small pluton about 1,641 ft (500 m) north-northeast of the intersection of Interstate 95 with the Little River Turnpike (lat. 38°50'14" N. and long. 75°12'48" W.). Chemically, the rock is a granodiorite (fig. 3).
4. Medium-coarse-grained, poorly foliated, muscovite-biotite granodiorite from small pluton about 984 ft (300 m) northwest of Braddock School (lat. 38°49'25" N. and long. 77°13'07" W.). Rock is characterized by elongated quartz grains (hobnails) and contains sparse inclusions of mafic igneous rock (gabbro?). Chemically, the rock is a granodiorite (fig. 3).
5. Medium-coarse-grained biotite-hornblende tonalite from an outcrop of the Falls Church pluton on northeast bank of Tripps Run about 820 ft (250 m) north of Congressional School (lat. 38°51'37" N. and long. 77°09'56" W.). Much of the rock in this immediate area is choked with gabbro inclusions and it appears as if the tonalite stoped its way into previously consolidated gabbro. Chemically, the rock is a mafic tonalite (fig. 3).
6. Medium-coarse-grained biotite granodiorite from an outcrop of the Falls Church pluton in Holmes Run about 820 ft (250 m) northwest of Annandale Road (lat. 38°51'19" N. and long. 77°11'54" W.). Rock contains abundant inclusions of Lake Barcroft Metasandstone. Chemically, the rock is a mafic granodiorite (fig. 3).
7. Medium-grained, granular, massive muscovite trondhjemite from an old quarry near the intersection of Washington Street and Tripps Run in Falls Church, Falls Church 7.5-minute quadrangle (lat. 38°52'38" N. and long. 77°10'44" W.). In 1976, the quarry was the site of a motel. Although the unit contains 1.9 percent K_2O, all the feldspar appears to be oligoclase. The rock does contain more than 16 modal percent of muscovite. Chemically, the rock is a trondhjemite (fig. 3).


FALLS CHURCH PLUTON
IDLA PLUTON
OCCOQUAN BATHOLITH
Lake Accotink
Lake Barcroft
Cpo
CZa
CZi
Cf
Qal
Qlg
Qls
Qp2
Tt2
Tt3
Kpc
Kps
Cq
Co
Cm
Cpo
CZs
CZt
Cpa
CZu
CZo
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Kp
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