Revised Nomenclature and Stratigraphic Relationships of the Fredericksburg Complex and Quantico Formation of the Virginia Piedmont

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By LOUIS PAVLIDES

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A stratigraphic study of the polydeformed and metamorphosed crystalline rocks of the northeast Virginia Piedmont

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CONVERSION FACTORS

Metric unit		Inch-Pound equivalent	
Length			
millimeter (mm)	=	0.03937	inch (in)
meter (m)	=	3.28	feet (ft)
kilometer (km)	=	.62	mile (mi)
Area			
square meter (m^2)	=	10.76	square feet (ft^2)
square kilometer (km^2)	=	.386	square mile (mi^2)
hectare (ha)	=	2.47	acres
Volume			
cubic centimeter (cm^3)	=	0.061	cubic inch (in^3)
liter (L)	=	61.03	cubic inches
cubic meter (m^3)	=	35.31	cubic feet (ft^3)
cubic meter	=	.00081	acre-foot (acre-ft)
cubic hectometer (hm^3)	=	810.7	acre-feet
liter	=	2.113	pints (pt)
liter	=	1.06	quarts (qt)
liter	=	.26	gallon (gal)
cubic meter	=	.00026	million gallons (Mgal or 10^6 gal)
cubic meter	=	6.290	barrels (bbl) (1 bbl=42 gal)
Weight			
gram (g)	=	0.035	ounce, avoirdupois (oz avdp)
gram	=	.0022	pound, avoirdupois (lb avdp)
metric tons (t)	=	1.102	tons, short (2,000 lb)
metric tons	=	0.9842	ton, long (2,240 lb)
Specific combinations			
kilogram per square centimeter (kg cm^2)	=	0.96	atmosphere (atm)
kilogram per square centimeter	=	.98	bar (0.9869 atm)
cubic meter per second (m^3/s)	=	35.3	cubic feet per second (ft^3/s)
Specific combinations—Continued			
liter per second (L/s)	=	.0353	cubic foot per second
cubic meter per second per square kilometer [$(m^3/s)/km^2$]	=	91.47	cubic feet per second per square mile [$(ft^3/s)/mi^2$]
meter per day (m/d)	=	3.28	feet per day (hydraulic conductivity) (ft/d)
meter per kilometer (m/km)	=	5.28	feet per mile (ft/mi)
kilometer per hour (km/h)	=	.9113	foot per second (ft/s)
meter per second (m/s)	=	3.28	feet per second
meter squared per day (m^2/d)	=	10.764	feet squared per day (ft^2/d) (transmissivity)
cubic meter per second (m^3/s)	=	22.826	million gallons per day (Mgal/d)
cubic meter per minute (m^3/min)	=	264.2	gallons per minute (gal/min)
liter per second (L/s)	=	15.85	gallons per minute
liter per second per meter [(L/s)/m]	=	4.83	gallons per minute per foot [(gal/min)/ft]
kilometer per hour (km/h)	=	.62	mile per hour (mi/h)
meter per second (m/s)	=	2.237	miles per hour
gram per cubic centimeter (g/cm^3)	=	62.43	pounds per cubic foot (lb/ft^3)
gram per square centimeter (g/cm^2)	=	2.048	pounds per square foot (lb/ft^2)
gram per square centimeter	=	.0142	pound per square inch (lb/in^2)
Temperature			
degree Celsius (°C)	=	1.8	degrees Fahrenheit (°F)
degrees Celsius (temperature)	=	[(1.8×°C)+32]	degrees Fahrenheit

REVISED NOMENCLATURE AND STRATIGRAPHIC RELATIONSHIPS OF THE FREDERICKSBURG COMPLEX AND QUANTICO FORMATION OF THE VIRGINIA PIEDMONT

By LOUIS PAVLIDES

ABSTRACT

The Fredericksburg Complex, in part a migmatitic terrane in northeast Virginia, is subdivided on the basis of lithology, as well as aeromagnetic and aeroradiometric data, into two metamorphic suites. These suites are separated by the northeast-trending Spotsylvania lineament, a rectilinear geophysical feature that is probably the trace of an old fault zone. East of the lineament, the Po River Metamorphic Suite, of Proterozoic Z and (or) early Paleozoic age, consists dominantly of biotite gneiss, generally augen gneiss, and lesser amounts of hornblende gneiss and mica schist. West of the Spotsylvania lineament is the Ta River Metamorphic Suite, composed mostly of amphibolite and amphibole gneiss. However, to the southwest, along its strike belt, the Ta River contains abundant biotite gneiss and mica schist. Both the Ta River and Po River contain abundant foliated granitoid and pegmatoid bodies as concordant tabular masses and as crosscutting dikes; these rocks are considered part of the Ta River and Po River Metamorphic Suites. The amphibolitic Holly Corner Gneiss is interpreted to be a western allochthonous equivalent of the Ta River. Both the Ta River and Holly Corner are considered to be coeval, eastern, distal facies of the Lower Cambrian(?) Chopawamsic Formation. The Paleozoic Falls Run Granite Gneiss intrudes the Ta River Metamorphic Suite and the Holly Corner Gneiss; locally the Falls Run is interpreted to have been transported westward with the Holly Corner after intrusion.

The Quantico Formation, in the core of the Quantico-Columbia synclinorium, rests with angular unconformity along its northwest and southeast limbs, respectively, on the Chopawamsic Formation and the Ta River Metamorphic Suite. The Quantico Formation is assigned the same Late Ordovician age and similar stratigraphic position as the Arvonia Slate of the Arvonia syncline.

The youngest rocks of the area are the granitoid and pegmatoid bodies of the Falmouth Intrusive Suite. They consist of several generations of chiefly dikes and sills that are intrusive into the Fredericksburg Complex and into the Quantico Formation. Granitoid rocks also form small plutons. The Falmouth is isotopically dated as Carboniferous in age.

Some of the metavolcanic rocks of the Evington Group and part of the amphibolite gneiss and amphibolite of the Hatcher Complex, named by W. B. Brown in 1969, are probably coeval with the Chopawamsic Formation and hence equivalents of the Ta River Metamorphic Suite and the Holly Corner Gneiss. The biotitic gneiss and granitoid rocks east of the Spotsylvania lineament in the Dillwyn area are considered to be coeval with the Po River Metamorphic Suite.

INTRODUCTION

Mapping in the Piedmont of northeast Virginia has resulted in the publication of reports (Pavlides and others, 1974; Pavlides, 1976) that have used informal stratigraphic names and rock units. With the completion of additional mapping in parts of the area (fig. 1, pl. 1) we can now formalize some of the stratigraphic nomenclature and revise and better define the units.

The rocks of the area have undergone polyphase deformation and contain several generations of folds and foliations. Most of the rocks described in this report have undergone progressive metamorphism within the amphibolite facies. Locally, some of the rocks have been retrogressively metamorphosed; others have been metasomatized. These structural and metamorphic features have been described elsewhere (Pavlides, 1976, p. 17–20, 22–24) and are not discussed herein, except where the need arises for purposes of this report.

GENERAL STATEMENT

The Fredericksburg Complex was originally defined informally (Pavlides and others, 1974, p. 569–570) as an injection zone of granitoid dikes and sills and pegmatoid bodies within a block of Piedmont rocks in northeastern Virginia. This injection zone extends from the Coastal Plain contact on the east to the limit of dike, sill, and pegmatoid injection on the west (Pavlides, 1976, fig. 2). The Piedmont host rocks within this complex included schist of the Quantico Slate (Formation), as well as several types of gneiss, schist, and metaigneous rocks (Pavlides, 1976, p. 1 and fig. 2).

On the basis of recently completed mapping, the Fredericksburg Complex is redefined and subdivided lithologically and designated a formal unit. Lonsdale (1927) had originally applied the name Fredericksburg to gneiss that extended as far as 13 km southwest and 13 km northwest of Fredericksburg. In the same report Lonsdale also used the name Fredericksburg granite for the granite intrusion into the "Fredericksburg granite gneiss" (Wilmarth, 1938, p. 776). Because of this dual usage of the name, it is herein used more broadly for the Fredericksburg Complex, a more regionally extensive terrane that includes the Fredericksburg granite and

Fredericksburg gneiss of Lonsdale (1927) and excludes rocks of the Quantico Formation. Because the rocks of the Fredericksburg Complex are structurally complex, are metamorphosed, and include a variety of metaigneous rocks, the suggested amendment to the Stratigraphic Code (Sohl, 1977, p. 248-251) is adopted herein as a guideline for stratigraphic nomenclature, and the term *metamorphic suite*, rather than formation, is used for rock units within the newly defined Fredericksburg Complex.

Gneiss, schist, amphibolite and metaigneous rocks of the Fredericksburg Complex stratigraphically below and along the east flank of the Quantico belt of rocks are assigned to the Ta River and Po River Metamorphic Suites. Both the Ta River and Po River Metamorphic Suites of the Fredericksburg Complex have tabular granitoid[1] bodies that in many places are conformably layered with the gneiss and schist of these suites. Locally, these conformable granitoid bodies are crosscut by foliated granitoid dikes also assigned to the Ta River and Po River. The conformable granitoid bodies commonly have the same foliation as the enclosing country rocks. The granitoid bodies of the Ta River and Po River are crosscut by generally weakly to imperceptably foliated granitoid bodies of the Falmouth Intrusive Suite that also intrude the Quantico Formation. The Po River Metamorphic Suite of the Fredericksburg Complex is locally migmatitic in that it consists of deformed metamorphic country rock that in places resembles restite in bulk composition and also has granitoid rocks that may be leucosomatic in origin.

The schist of the Quantico Slate (Formation) within the injected zone of the Fredericksburg Complex of former usage (Pavlides, 1976, fig. 2) are retained within the Quantico. In addition, the Quantico Slate of former usage is herein designated the Quantico Formation because this unit in most places is a schist that locally contains quartzitic layers and can seldom be classified as a slate.

The term Berea as applied to "quartz monzonite" (Neuschel and others, 1971, p. 307) and to the pluton containing microcline gneissic granite (quartz monzonite of Neuschel, 1970) within a refolded synform in the northeast part of the Salem Church Quadrangle (Pavlides, 1976, p. 4, 17, and fig. 2) is discontinued in this report. The term Berea had been applied earlier to the Berea Sandstone (Wilmarth, 1938, p. 165) and is thus preempted. In place of Berea, the gneissic granite in the Salem Church Quadrangle and similar rocks

[1] Granitoid as used in this report includes rocks in the granite to tonalite composition range. Pegmatoid is similarly used for the pegmatitic-textured rocks. Nomenclature for granitoid rocks is based on the International Union of Geological Sciences (IUGS) system published by Streckeisen (1973).

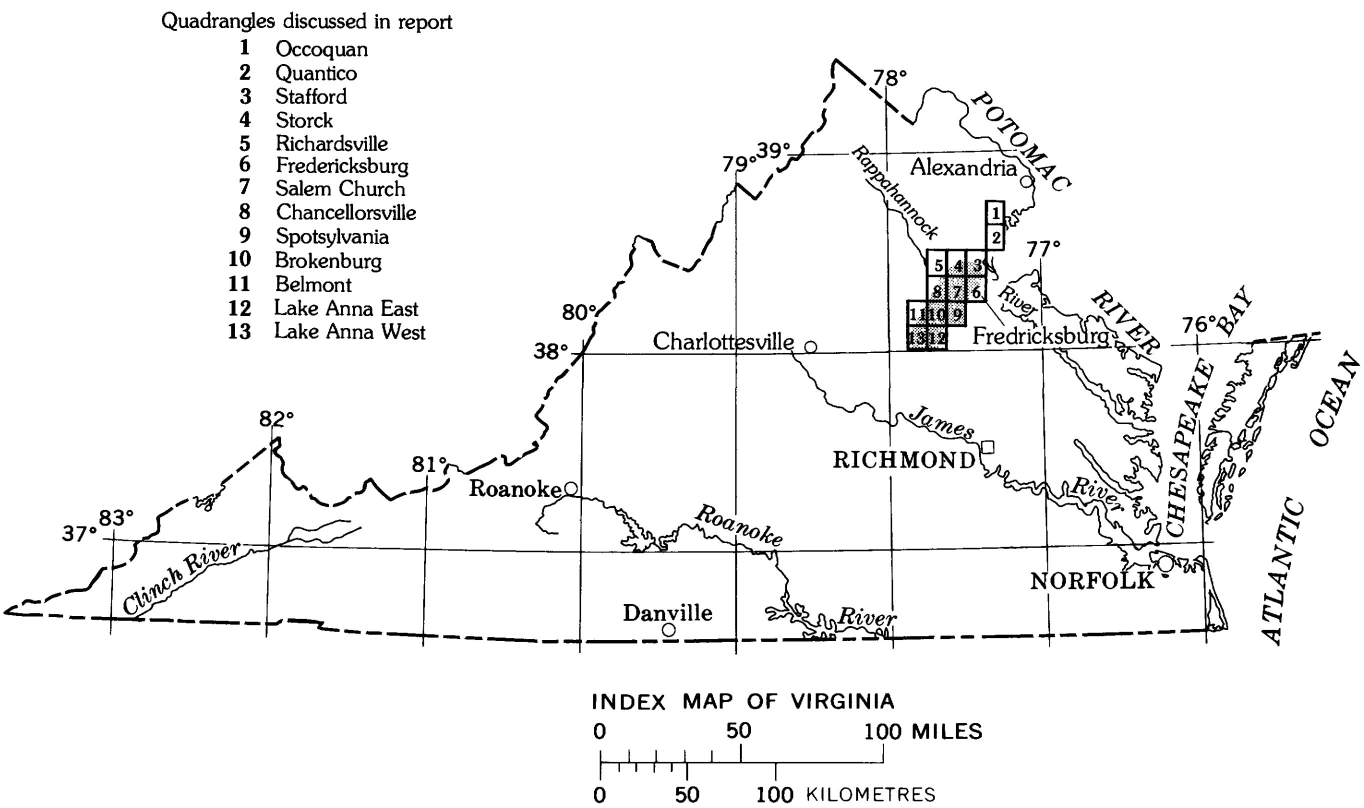

FIGURE 1.–Index map of Virginia, showing the topographic quadrangles referred to in this report and the area of plate 1 (shaded).

elsewhere to the east in the Po River Metamorphic Suite are now named the Falls Run Granite Gneiss.

Under the stratigraphic usage adopted herein, the granitoid dikes, sills, and irregular intrusions and pegmatoid bodies that constituted the injection zone that previously defined the Fredericksburg Complex are considered part of the Falmouth Intrusive Suite. They represent several late plutonic events in the region. They are removed from the Fredericksburg Complex as now defined and are discussed separately with the lithologies in which they are emplaced.

The rocks of the Piedmont have been altered to saprolite and clay residuum through weathering. Fresh bedrock, however, is found locally along stream and river courses, particularly near the Fall Line. East of the Fall Line, the Coastal Plain deposits cover Piedmont bedrock. West of the Fall Line patches of Coastal Plain deposits and upland sand and gravel also locally cover the bedrock on the interfluves. The information on Piedmont bedrock, therefore, is incomplete, being good to excellent in local stream and river beds, absent in places of younger cover sediments, and obscure where rocks are extensively weathered. Estimates as to proportions of different rock types within any stratigraphic unit, therefore, are difficult to make and may be subject to bias because of the weathering characteristics of different rocks. Some types of rocks form better exposures because of their resistance to weathering. These rocks would be more abundantly exposed than other types that are readily weathered but that perhaps are more representative of a stratigraphic unit. For this reason, and because of the complex regional deformation, quantitative estimates of rock types in stratigraphic units are avoided.

FREDERICKSBURG COMPLEX

The Fredericksburg Complex is named after Fredericksburg, Va., which is situated at the Fall Line along the Rappahannock River (pl. 1). Some of the gneiss and metaigneous rocks of the complex are well exposed along the Rappahannock River upstream from Fredericksburg to a point where the Quantico Formation is first exposed (pl. 1). The gneiss of the Fredericksburg Complex in this area is characterized by steep- to vertical-dipping foliation. Compositional layering locally defines tight isoclinal folds. Such folds can be seen in some exposures of gneiss upstream from the Fall Line at Fredericksburg along the Rappahannock River. In most places, however, folds are not readily discernible, and the unit has the deceiving appearance of being a homoclinal sequence. The Ta River and Po River Metamorphic Suites of the Fredericksburg Complex, although broadly distinguishable on lithologic differences, are generally more markedly separable by their aeromagnetic and aeroradiometric signatures, as recognized earlier by Neuschel (1970, figs. 2, 3, and 4). The Ta River Metamorphic Suite of this report had been designated by Neuschel as a hornblende gneiss unit, and the Po River Metamorphic Suite, as a granite gneiss unit. Neuschel (1970, p. 3578) considered the contact between these two units to be a fault. This presumed fault was placed along a rectilinear boundary that is practically coincident with both the aeromagnetic and aeroradiometric features that distinguish the two terranes.

Where the Ta River and Po River Metamorphic Suites are not in fault contact, as in the Salem Church and Fredericksburg Quadrangles (pl. 1), the nature of the boundary between these two units is not readily definable. Specifically, because of metamorphism and abundant granitoid dike and sill intrusion in this terrane, it is uncertain if the two suites have a conformable, gradational contact or are separated by an unconformity.

SPOTSYLVANIA LINEAMENT

The major fault postulated by Neuschel (1970) at the contact between the presently defined Ta River and Po River metamorphic terranes is difficult to document on the ground north of the James River. During hearings conducted by the former Atomic Energy Commission concerning the construction of the nuclear reactor plant at Lake Anna by the Virginia Electric Power Co., this lineament was informally referred to as "Neuschel's Lineament." In this report, this linear geophysical boundary is designated the Spotsylvania lineament after Spotsylvania Court House near which the trace of the lineament passes.

Although the Spotsylvania lineament appears as a markedly linear feature of considerable regional extent on small-scale aeromagnetic maps (Zietz and others, 1978a, 1978b), the lineament appears to be more diffuse on large-scale aeromagnetic maps, such as those at a scale of 1:24,000, and to encompass a zone as wide as 2.3 km. A broad zone of discontinuous en-echelon faults or shear zones seems a better interpretation of this magnetic lineament than is a single fault. En-echelon faults of Cretaceous to middle Tertiary(?) age have been mapped at and near the Fall Line immediately on strike and northeast of the Spotsylvania lineament by Mixon and Newell (1977) and may represent reactivation of possible old faults along this lineament.

AEROMAGNETIC AND AERORADIOMETRIC FEATURES

The Ta River Metamorphic Suite is characterized by parallel, northeast-trending positive anomalies and by local crescent-shaped anomalies convex to the northeast (Neuschel, 1970, fig. 2). Although the crescent-shaped anomalies were not explained by Neuschel, my mapping demonstrates that they reflect areas of antiformal folds. One of these is the described refolded fold along the Rappahannock River in the Salem Church Quadrangle (Pavlides, 1976, p. 18-19, fig. 2) near the north end of the Ta River Metamorphic Suite (pl. 1). The aeroradiometric intensity of the Ta River is low and produces a pattern of subdued irregular anomalies, except in one area where large anomalies are present and are attributed to the presence of a granite mass (Neuschel, 1970; compare fig. 3 with fig. 4).

The geophysical features of the Po River Metamorphic Suite contrast with those of the Ta River by showing a combination of low magnetic and high aeroradiometric properties. The Po River terrane is characterized by a subdued magnetic pattern having only a few local highs that trend north, northeast, and northwest. In contrast, it has a relatively high aeroradioactive character adjacent to the contact with the Ta River, as shown in a broad zone about 8 km wide. This zone is characterized by northeast-trending high aeroradiometric anomalies. North and east of these aeroradiometric anomalies the Coastal Plain sediments blanket the Po River terrane, and the subdued aeroradiometric pattern over these sediments is unrelated to the bedrock beneath them (Neuschel, 1970, compare fig. 2 with fig. 4).

PO RIVER METAMORPHIC SUITE

The Po River Metamorphic Suite is named after the Po River, which flows southeasterly across the Fredericksburg Complex in Virginia. Composite type areas of this suite that include saprolite as well as rock outcrops are in the Spotsylvania 7½ minute Quadrangle and include (1) the segment along the Po River between the Spotsylvania lineament and U.S. Route 1 and (2) along the Ni River, between the Spotsylvania lineament and U.S. Route 1 (pl. 1). In general, the Po River section has more exposures than does the Ni River section. Excellent fresh-rock exposures of the Po River Metamorphic Suite can be seen along the Rappahannock River from the Fall Line, at U.S. Route 1 in Fredericksburg and Falmouth, upstream to the dam.

GNEISS[2]

Biotite-bearing gneiss is the most common rock in the Po River Metamorphic Suite. Characteristically the gneiss is a dark-colored, layered, and foliated rock; micaceous minerals are concentrated in the dark layers, and quartz and feldspar, in the light layers. However, all gradations in the relative proportions of mica, quartz, and feldspar are found in the various layers that constitute a gneiss. Feldspar occurs as a groundmass constituent, very commonly in large augen-shaped grains (fig. 2).

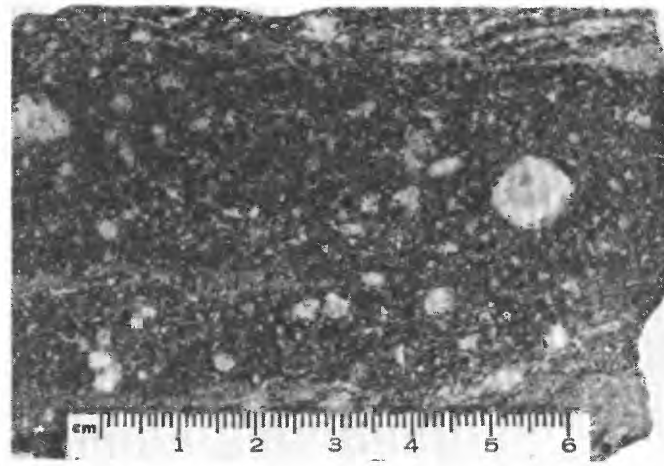

FIGURE 2.—Biotitic augen gneiss of the Po River Metamorphic Suite of the Fredericksburg Complex in the Spotsylvania Quadrangle (sawed surface).

Table 1, analyses 1–6, lists the modal composition of some representative biotite gneisses and indicates their general range in composition. Among the major mineral constituents, plagioclase (twinned and untwinned) is almost invariably the most abundant mineral and is followed in decreasing order of abundance by the characterizing biotite and then by quartz. Microcline is generally a minor constituent, and epidote and myrmekite also are common minor constituents.

Hornblende-bearing gneiss is also present in the Po River Metamorphic Suite but in subordinate amounts as compared with the biotite gneiss. Physically, it resembles the biotite gneiss in color and texture but contains varying amounts of hornblende, as well as biotite.

Modal analyses of hornblende gneiss are listed under columns 7 and 8 of table 1. These analyses are of thin sections cut from different parts of the same block of rock. The analysis under column 9 represents the arithmetic average of 7 and 8. Figure 3 is of the biotite-hornblende gneiss whose modal analyses are listed in columns 7, 8, and 9 of table 1. These analyses suggest the rock is a restite depleted of its leucosome.

SCHIST

Garnetiferous two-mica schist is found locally in the Po River Metamorphic Suite and has a foliation conformable with the adjacent gneisses.

GRANITOID AND PEGMATOID BODIES

Numerous foliated gneissic granitoid rocks, including pegmatoid, are found as tabular bodies, as well as nontabular masses, in the Po River. The tabular granitoid

[2] Metamorphic-rock nomenclature in this report lists the characterizing minerals in order of increasing abundance, irrespective of whether the protolith was sedimentary or igneous.

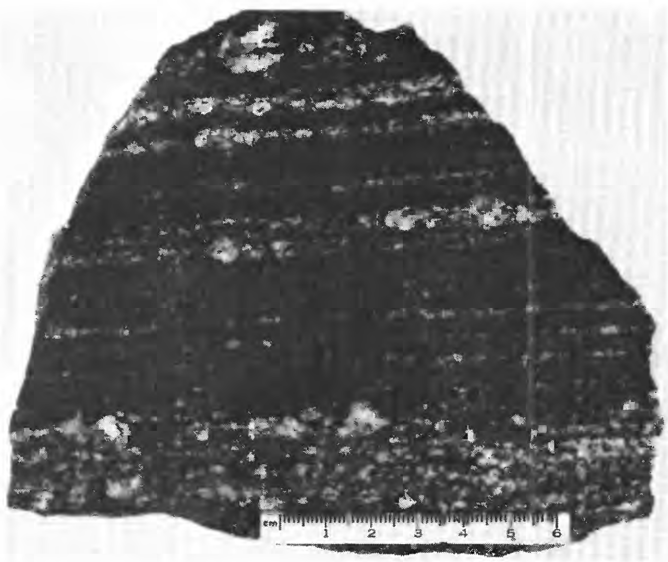

FIGURE 3. – Biotite-hornblende gneiss from the Po River Metamorphic Suite of the Fredericksburg Complex in the Spotsylvania Quadrangle (sawed surface). Note plagioclase augen in certain layers. Modal analyses of this rock are samples numbered 7, 8, 9 in table 1. This rock may be a restite depleted in leucosome.

and pegmatoid bodies form concordant, sill-like layers within the gneiss. They range from less than 2.5 cm wide to as much as about 7.6 m wide. The nontabular irregularly shaped granitoid bodies generally form relatively large masses that may be parts of plugs and plutons of various sizes. Locally, thinner granitoid layers about 0.5–1.0 cm wide are conformable with the foliation in the gneiss (fig. 4).

The lack of restite selvages of biotite or hornblende in these layers suggests that if the granitoid layers are leucosomes they are arterites; they probably formed elsewhere, migrated, and consolidated in their present position in the gneiss. Modal analyses of granitoid rocks of the Po River Metamorphic Suite are listed in table 2.

In general these granitoid rocks are two-mica gneissic monzogranite, granodiorite, and tonalite, as seen on the quartz, alkali-feldspar, and plagioclase (QAP) plot (fig. 5).

Biotite is invariably the more abundant of the micas and is alined along foliation. The quartz and feldspar have weak to marked dimensional orientation within foliation in most rocks. In thin section bulbous and rim myrmekite is a ubiquitous minor constituent. Clear, more sodic rims on plagioclase grains also are found locally at plagioclase-microcline contacts.

Within the Po River Metamorphic Suite, granitoid dikes and sills of the Falmouth Intrusive Suite have the same general compositional range as do the Po River granitoid rocks (compare fig. 6 with fig. 12). They are recognized in the field on the basis of weak to moderately defined mica foliation that locally may be absent in some of these granitoid rocks and by the fact that Falmouth granitoid rocks, where suitable exposure exists, crosscut the foliated granitoid rocks of the Po River. Mineralogically the Falmouth granitoid rocks contain somewhat more quartz than do the granitoid rocks of the Po River.

AGE

The age of the Po River Metamorphic Suite is uncertain, but may be considered Proterozoic Z and (or) early Paleozoic based on its stratigraphic position underlying the Ta River Metamorphic Suite and the Holly Corner Gneiss, both correlated with the Lower Cambrian(?) Chopawamsic Formation (fig. 14).

HOLLY CORNER GNEISS

The Holly Corner Gneiss is named after Holly Corner, a crossroads within this gneiss terrane in the north-central part of the Salem Church Quadrangle. Immediately south of Holly Corner are two small intermittent streams that flow southward and empty into the Rappahannock River. Good exposures of saprolite and fresh bedrock of the Holly Corner are visible along the courses of the streams.

The Holly Corner Gneiss is only present in the Salem Church Quadrangle in a refolded synform (pl. 1) and was earlier informally described as a hornblende-biotite quartzofeldspathic gneiss (Pavlides, 1976, fig. 2 and p. 7–8).

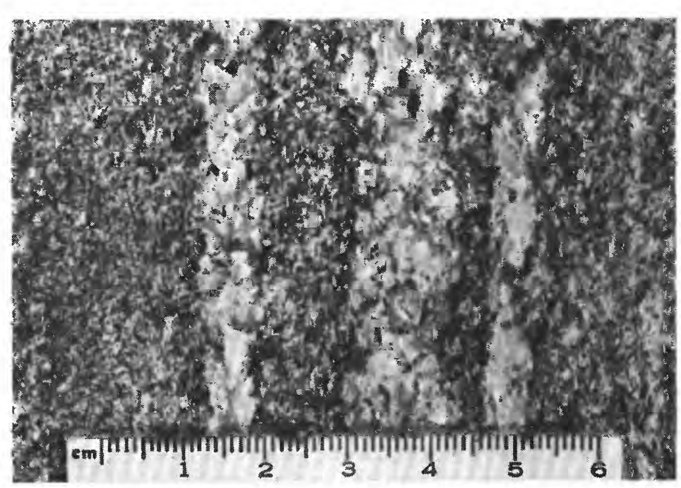

FIGURE 4. – Hornblende-biotite-quartz-plagioclase gneiss containing thin conformable granitoid layers, along Ni River in Spotsylvania Quadrangle (sawed surface). Granitoid layers are probably arteritic leucosomes.

TABLE 1.—*Modal analyses, in percent, of gneiss and schist of*

[Modal analyses by S. Linda Cranford (U.S. Geological

Mineral	Sample number (top) and field number, P– (bottom)								
	1	2	3	4	5	6	7	8	9
	76–7[1]	76–8[1]	76–9[1]	76–20[1]	76–21[1]	76–22[1]	76–24A[1]	76–24B[1]	76–24
Quartz	23.0	15.2	20.0	17.1	12.4	8.5	6.4	5.0	5.7
Plagioclase	43.9	52.7	43.3	53.8	56.7	68.3	43.3	38.4	40.8
Microcline	8.0	----	.3	8.5	4.4	2.1	----	----	----
Biotite	21.4	31.3	12.1	18.9	25.0	18.0	10.3	1.1	5.7
Muscovite	2.3	.1	20.5	----	----	1.4	----	----	----
Hornblende	----	----	----	----	----	----	35.2	55.2	45.2
Myrmekite	1.2	----	3.5	.4	1.0	1.3	----	----	----
Garnet	----	----	.2	----	----	----	----	----	----
Apatite	----	.2	----	.2	.1	.3	.2	----	.1
Epidote	.1	.1	--	.7	.1	1.5	----	----	----
Sphene	----	----	----	.3	.2	.4	.7	.4	.5
Zircon	----	----	----	----	----	----	----	----	----
Opaque minerals	----	.2	.1	.2	----	.1	4.0	----	2.0
Other	----	.2	----	----	----	.2	----	----	----

[1] Petrography by Karen Wier and Louis Pavlides.

NOTES:

P–76–7.—Muscovite-microcline-biotite-quartz-plagioclase augen gneiss. Augen are dominantly plagioclase, but microcline forms the largest augen and is in groundmass. Brown biotite has zircon inclusions with halos. Plagioclase is twinned and untwinned and is myrmekitic where in contact with microcline. Spotsylvania Quadrangle, Va., at lat 38°14′35″ N. and long 77°32′17″ W.; 2,254 points counted.

P–76–8.—Quartz-biotite-plagioclase augen gneiss. Plagioclase augen are as much as 5 mm long and also as smaller sized constituents. Dimensionally alined brown biotite defines rock foliation. Some euhedral epidote grains have allanite cores. Spotsylvania Quadrangle, Va., at lat 38°14′35″ N. and long 77°32′17″ W.; 1,800 points counted.

P–76–9.—Garnetiferous biotite-quartz-muscovite-plagioclase augen gneiss. Plagioclase augen 3–5 mm are common; plagioclase forms twinned and untwinned grains and is myrmekitic adjacent to microcline grains. Brown biotite is found in folia; muscovite in places wraps around garnet that forms equidimensional subhedral grains about 1 mm in size. Spotsylvania Quadrangle, Va., at lat 38°14′32″ N. and long 77°32′24″ W.; 2,398 points counted.

P–76–20.—Microcline-quartz-biotite-plagioclase augen gneiss. Plagioclase and microcline form augen and ground mass constituents. Dimensionally alined brown biotite imparts strong foliation to rock. Sphene is in subhedral grains. Spotsylvania Quadrangle, Va., at lat 38°12′11″ N. and long 77°33′14″ W.; 2,519 points counted.

P–76–21.—Microcline-quartz-biotite-plagioclase augen gneiss. Feldspars form augen and groundmass constituents, and plagioclase is myrmekitic at contact with microcline grains. Dimensionally alined red-brown biotite imparts foliation to rock. Epidote is euhedral to anhedral, and some grains have allanite cores. Spotsylvania Quadrangle, Va., at lat 38°12′11″ N. and long 77°33′14″ W.; 2,476 points counted.

P–76–22.—Microcline-quartz-biotite-plagioclase gneiss. Dimensionally alined greenish-brown biotite imparts foliation to rock. Epidote is found in well-formed grains and in places has allanite cores. Spotsylvania Quadrangle, Va., at lat 38°11′52″ N. and long 77°32′39″ W.; 2,577 points counted.

P–76–24A.—Quartz-biotite-hornblende-plagioclase gneiss. Plagioclase forms augen. Hornblende is green, and biotite is greenish brown. Spotsylvania Quadrangle, Va., at lat 38°12′27″ N. and long 77°33′35″ W.; 2,532 points counted.

P–76–24B.—Biotite-quartz-plagioclase-hornblende gneiss. Plagioclase forms augen and is a groundmass constituent. Green hornblende is dimensionally alined in foliation plane. Spotsylvania Quadrangle, Va., at lat 38°12′27″ N. and long 77°33′35″ W.; 2,420 points counted.

P–76–24.—Quartz-biotite-plagioclase-hornblende gneiss. Modal analysis is arithmetic mean of modal analyses P–76–24A and P–76–24B.

P–76–109.—Hornblende-biotite-quartz-plagioclase gneiss. Red-brown biotite with minor poikilitic, green, calciferous hornblende and fine-grained quartz and feldspar grains form irregular streaky folia interleaved with coarser grained quartz and plagioclase-rich layers containing sparse amounts of biotite. Biotite has crystallographic and dimensional orientation, whereas quartz and feldspar generally are dimensionally alined along foliation direction. Lake Anna East Quadrangle, Va., at lat 38°00′36″ N. and long 77°43′44″ W.; 2,820 points counted.

P–72–105.—Microline-biotite-quartz-plagioclase augen gneiss. Rock is well foliated and contains quartz and feldspar having dimensional orientation and brown biotite having dimensional and lattice orientation. Biotite generally wraps around large leucocratic grains and is not arranged in a precise folial manner. Microcline is distinctly concentrated in a few layers, suggesting emplacement as an arteritic leucosome. Plagioclase forms augen and is generally untwinned. Patch antiperthite and symplectite of patch plagioclase within plagioclase are present locally. Myrmekite in plagioclase is formed at contact with microcline. Fredericksburg Quadrangle, Va., at lat 38°19′20″ N. and long 77°28′49″ W.; 2,240 points counted.

P–74–63A.—Biotite-microcline-quartz-plagioclase augen gneiss. Large microcline augen are found with sparse garnet in a foliated biotitic quartz-plagioclase-microcline groundmass. Augen are laterally bounded by lensoid aggregates of microcline and quartz intergrowths. Some sphene forms inclusions in microcline augen. Myrmekite is locally abundant within plagioclase at contact with microcline grains. Fredericksburg Quadrangle, Va., at lat 38°17′16″ N. and long 77°29′19″ W.; 2,594 points counted.

P–75–33.—Biotite-hornblende-plagioclase-muscovite-quartz augen gneiss. Plagioclase, both untwinned and twinned and approximately andesine in composition, forms augen and is in groundmass. Foliation is defined by dimensionally and crystallographically alined reddish-brown biotite. Pale-green hornblende is also in biotite folia. Some quartz and small amounts of plagioclase form thin streaks or "ribbons." Fredericksburg Quadrangle, Va., at lat 38°17′17″ N. and long 77°29′23″ W.; 2,288 points counted.

P–74–78.—Biotite-plagioclase-muscovite-quartz schist. Rock is foliated and contains sparse amounts of garnet. Some plagioclase is myrmekitic. Fredericksburg Quadrangle, Va., at lat 38°19′05″ N. and long 77°28′40″ W.; 2,151 points counted.

P–75–35.—Garnetiferous muscovite-quartz-biotite-plagioclase gneiss. Rock is foliated, consisting of braided folia of biotite and muscovite that wrap around quartz and plagioclase grains. Porphyroblastic muscovite differs from other muscovite in crystallographic direction and contains inclusions that have a persistent alinement within and amongst different porphyroblasts. Plagioclase is poikilitic, and euhedral to subhedral garnet is abundant. Fredericksburg Quadrangle, Va., at lat 38°19′20″ N. and long 77°28′24″ W.; 2,179 points counted.

P–75–36.—Plagioclase-quartz-biotite-muscovite schist. Muscovite and biotite are found in thick folia associated with interstitial granoblastic quartz. Leucocratic lenticular masses are composed of plagioclase, quartz, and minor amounts of muscovite and biotite. These lenses are alined in foliation plane, the mica folia wrapped around them. Garnet forms sparse, nonpoikilitic porphyroblasts. Fredericksburg Quadrangle, Va., at lat 28°19′20″ N. and long 77°28′24″ W.; 2,247 points counted.

P–75–34.—Hornblende-biotite-plagioclase-quartz augen gneiss. Rock is well foliated; in the rock, quartz and plagioclase have dimensional orientation, and brown biotite and pale-green amphibole have lattice and dimensional orientation. Augen consist of single-crystal and multicrystal aggregates of andesitic plagioclase. Some of the folia containing biotite and amphibole also have streaks of very fine grained felsic minerals suggesting recrystallized cataclastic zones. Fine-grained sphene is an accessory. Fredericksburg Quadrangle, Va., at lat 38°17′17″ N. and long 77°29′23″ W.; 2,352 points counted.

P–77–6.—Biotite-hornblende-quartz-plagioclase gneiss. Foliation is streaky, consisting of crystallographically and dimensionally alined brown biotite and dimensionally oriented coarser grained green calciferous amphibole. Epidote-zoisite is found in well-formed grains. Some epidote has core of allanite, and some has marginal symplectic intergrowth with vermicular quartz. Fredricksburg Quadrangle. Va., at lat 38°19′39″ N. and long 77°29′59″ W.; 2,967 points counted.

the Po River Metamorphic Suite of the Fredericksburg Complex

Survey); ___, absent or present in amounts <0.1 percent]

	Sample number (top) and field number, P- (bottom)								
	10	11	12	13	14	15	16	17	18
	76–109	72–105	74–63A	75–33	74–78	75–35	75–36	75–34	77–6
	27.6	24.9	29.2	38.5	41.7	20.3	13.8	38.9	22.0
	37.9	49.3	30.8	35.7	15.1	44.9	7.0	35.9	55.7
	----	11.0	22.2	.9	----	----	----	----	----
	25.5	12.2	15.4	9.0	6.1	27.5	37.9	19.4	5.9
	----	2.0	.1	----	36.5	3.8	41.0	----	----
	7.5	----	----	14.2	----	----	----	5.2	14.9
	----	.7	1.4	----	----	----	----	.1	----
	----	----	.1	----	.3	2.2	.3	----	----
	.2	----	.4	.1	.2	----	----	----	----
	.4	----	----	.4	----	----	----	----	1.2
	.1	----	.3	1.1	----	----	----	.5	----
	----	----	----	.1	----	----	----	----	----
	.7	----	----	----	----	1.3	----	----	----
	----	----	----	----	----	----	----	----	.2

GNEISS

The characterizing lithology of the Holly Corner is dark-gray to black, fine- to medium-grained, well-foliated hornblende- and biotite-rich gneiss. Compositional layering is rare and where present generally consists of thin calcsilicate layers (described in the next section). Modal analyses of the Holly Corner Gneiss are given in table 3.

Typically the Holly Corner is an amphibole gneiss containing varying amounts of biotite. Locally, biotite, may be the dominant dark mineral. Generally the amphibole is a green hornblende, and the plagioclase is andesine in composition, reflecting the amphibolite-grade metamorphism the gneiss has undergone. Biotite is reddish brown, and epidote is common, as is sphene, in lesser amounts. Locally, the Holly Corner contains potassic feldspar near large granitoid intrusions, as between the area of the Falls Run Granite Gneiss and the pluton composed of Falmouth Intrusive Suite rocks in the northwest part of the Salem Church Quadrangle. In places, potassic feldspar porphyroblasts are present in thin zones within the Holly Corner at the contact with the Falls Run. Potassic feldspar in the Holly Corner, therefore, is attributed to potassium metasomatism at the time of the intrusion of the Falls Run or the adjacent pluton of the Falmouth. Pyroxene, marginally altered to hornblende, is present locally in the Holly Corner within the synform that overlies the Falls Run north of the Rappahannock River in the northeast part of the Salem Church Quadrangle. This pyroxene may have formed through contact metamorphism of the Holly Corner by the intrusion of the Falls Run, or it may be relict original pyroxene. It apparently was marginally retrogressed to hornblende when amphibolite facies assemblages were formed through later regional metamorphism. Locally, hornblendite (table 3, sample 9) is present within the Holly Corner. It is considered to be a product of contact metamorphism related either to the Falls Run or to the pluton composed of the Falmouth granitoid rocks, or both. This hornblendite also may have been pyroxene rich prior to regional metamorphism.

CALCSILICATE LAYERS

Sparse, thin (generally less than 10 cm thick), gray- to pale-green calcsilicate layers are present in parts of the Holly Corner Gneiss. In some places they outline small-scale early folds (fig. 6). In thin section the calcsilicate layers of granoblastic quartz and plagioclase (andesine) contain epidote and diopsidic pyroxene. Abundances of green hornblende and biotite are variable in different layers. Calcite is present locally in small amounts.

AGE

As described in the section entitled "Regional Relationships," the Holly Corner Gneiss is considered to be possibly an eastern distal facies of the Chopawamsic Formation, which is provisionally considered to be of Early Cambrian age on the basis of discordant zircon ages (Pavlides, 1976, p. 9). The Early Cambrian age for the Holly Corner, therefore, is only valid if the stratigraphic correlation with the Chopawamsic is correct and if the zircon ages from the Chopawamsic represent real ages (see Higgins, Sinha, Zartman, and Kirk, 1977).

TA RIVER METAMORPHIC SUITE

The Ta River Metamorphic Suite is crossed by the Ta River, for which it is named. Good saprolite and some fresh outcrops of the Ta River Metamorphic Suite are

TABLE 2. –*Modal analyses, in percent, of granitoid rocks of the Po River Metamorphic Suite of the Fredericksburg Complex*

[Modal analyses by S. Linda Cranford (U.S. Geological Survey); ____, absent or present in amounts < 0.1 percent]

Mineral	Sample number (top) and field number, P- (bottom)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	76-1[1]	76-2[1]	76-3[1]	76-4[1]	76-5[1]	76-6[1]	76-10[1]	76-17[1]	72-106	72-108	74-60	74-62	74-65	75-32
Quartz	30.4	26.0	23.1	21.5	25.1	21.8	17.8	21.5	22.8	29.2	24.5	22.9	20.4	30.4
Plagioclase	31.8	48.8	57.0	31.3	37.6	48.3	62.9	41.9	55.2	56.4	25.7	35.2	39.0	22.0
Microcline	20.5	18.4	8.4	27.4	18.2	18.4	6.8	[2]28.8	12.4	6.7	[2]46.6	32.9	36.1	42.3
Biotite	.4	2.2	8.0	10.6	8.0	6.4	9.1	2.5	6.6	6.5	1.6	1.0	1.4	4.0
Muscovite	14.5	1.7	1.4	6.1	9.2	2.5	1.8	2.0	2.5	1.1	1.2	6.6	2.6	____
Myrmekite	2.1	2.5	1.5	.3	.8	1.8	.8	2.9	.1	.2	.4	1.2	.2	1.2
Garnet	.3	____	____	____	____	____	____	____	____	____	____	____	.1	____
Apatite	.1	.1	.4	.4	.3	____	.1	.2	____	____	____	____	____	____
Epidote	____	.1	.3	1.2	.7	.4	.1	.2	.2	____	____	____	____	____
Chlorite	____	.3	____	.1	____	.2	.1	.1	.1	____	____	.2	.4	____
Sphene	____	____	____	.4	____	____	____	____	____	____	____	____	____	____
Calcite	____	____	____	.8	____	____	____	____	____	____	____	____	____	____
Zircon	____	____	____	____	.1	____	____	____	.1	____	____	____	____	____
Opaque minerals	____	____	.1	.1	____	.4	____	____	____	____	____	____	____	.1
	Normalized values used in ternary diagrams													
Quartz	36	27	27	27	31	24	20	23	26	31	25	25	21	32
Plagioclase	40	54	64	39	47	56	72	46	61	61	27	39	41	24
Alkali feldspar	24	19	9	34	22	20	8	31	13	8	48	36	38	44

[1] Petrography by Karen Wier and Louis Pavlides.
[2] Includes orthoclase.

NOTES:

P-76-1.–Gneissic muscovite monzogranite. Rock is weakly foliated and allotriomorphic inequigranular; the foliation is defined by dimensionally and lattice-oriented muscovite and red-brown biotite. Plagioclase is myrmekitic at contacts with microcline. One grain of patch antiperthite is present. Garnet is in subhedral partial grains and is locally poikilitic. Spotsylvania Quadrangle, Va., at lat 38°14′12″ N. and long 77°31′43″ W.; 2,326 points counted.

P-76-2.–Gneissic muscovite-biotite granodiorite. Rock is foliated and allotriomorphic inequigranular; foliation is defined by dimensionally and lattice-oriented muscovite and red-brown biotite. Plagioclase has sericitic alteration in core of crystals. Locally chlorite has replaced biotite. Epidote is commonly associated in replacement clots with biotite, muscovite, and chlorite. Spotsylvania Quadrangle, Va., at lat 38°14′14″ N. and long 77°31′55″ W.; 2,915 points counted.

P-76-3.–Gneissic muscovite-biotite granodiorite. Rock is foliated and allotriomorphic inequigranular; foliation is defined by dimensionally and lattice-oriented red biotite. Some quartz and feldspar also have dimensional orientation. Plagioclase is twinned as well as untwinned and in places shows sericitically altered interiors. Myrmekite is more common in untwinned than twinned plagioclase. Spotsylvania Quadrangle, Va., at lat 38°14′27″ N. and long 77°32′09″ W.; 1,506 points counted.

P-76-4.–Gneissic muscovite-biotite monzogranite. Rock is strongly foliated and allotriomorphic inequigranular; it contains dimensionally and lattice-oriented muscovite and green biotite defining rock foliation. Plagioclase is mostly untwinned and has sericitically altered interior; some grains have exsolved rims of more albitic and unaltered plagioclase. Some muscovite symplectically intergrown with quartz. Spotsylvania Quadrangle, Va., at lat 38°14′32″ N. and long 77°32′16″ W.; 3,314 points counted.

P-76-5.–Gneissic biotite-muscovite granodiorite. Rock is allotriomorphic inequigranular and well foliated; foliation is defined by dimensionally and lattice-oriented muscovite and green biotite. Dimensional orientation of quartz and feldspar also well defined. Plagioclase is twinned and untwinned. Spotsylvania Quadrangle, Va., at lat 38°14′35″ N. and long 77°32′18″ W.; 1,781 points counted.

P-76-6.–Gneissic muscovite biotite-granodiorite. Rock is allotriomorphic inequigranular and has wavy foliation caused by entrained dimensionally and lattice-oriented red biotite that commonly is deflected around megacrysts. Some feldspars are surrounded by finer grained feldspar aggregates, suggesting recrystallized mortar structure of an originally cataclastic rock. Myrmekite characteristically is formed at margin of plagioclase in contact with microcline. Spotsylvania Quadrangle, Va., at lat 38°14′35″ N. and long 77°32′18″ W.; 2,286 points counted.

P-76-10.–Gneissic muscovite-biotite tonalite. Rock is allotriomorphic inequigranular and well foliated; it contains dimensionally and lattice- oriented red-brown biotite conspicuously alined; quartz and feldspar have well-formed dimensional orientations. Twinned and untwinned plagioclase is present, and myrmekite is present mostly in untwinned plagioclase. Some plagioclase has exsolved, more sodic rims. Spotsylvania Quadrangle, Va., at lat 38°14′43″ N. and long 77°32′30″ W.; 1,608 points counted.

P-76-17.–Muscovite-biotite monzogranite. Rock is allotriomorphic granular and composed of large quartz and feldspar grains separated from each other by finer grained quartz and by a feldspar groundmass that may be recrystallized mortar structure of an original cataclastic rock. Myrmekite is found in plagioclase along contacts with microline or as inclusions within large grains of microcline. Biotite is green and locally intergrown with muscovite; in places it is replaced by chlorite. Spotsylvania Quadrangle, Va., at lat 38°13′10″ N. and long 77°34′48″ W.; 2,577 points counted.

P-72-106.–Foliated dike of muscovite-biotite-granodiorite that crosscuts gneiss. Rock is allotriomorphic granular and contains brown biotite that is strongly alined along foliation and that is locally retrograded to chlorite. Where plagioclase is in contact with microcline, a clear albitic rim is present in plagioclase. Muscovite is not persistently alined in foliation direction. Fredericksburg Quadrangle, Va., at lat 38°19′20″ N. and long 77°28′49″ W.; 1,696 points counted.

P-72-108.–Foliated, hypidiomorphic granular, muscovite-biotite granodiorite, intrusive into gneiss. Brown biotite, sphene, and muscovite are alined in foliation direction. Some quartz has dimensional orientation along foliation direction. Fredericksburg Quadrangle, Va., at lat 38°19′11″ N. and long 77°28′22″ W.; 1,594 points counted.

P-74-60.–Leucocratic muscovite-biotite, strongly foliate mylonitic monzogranite. Dark-red biotite is dimensionally and lattice oriented along foliation direction; muscovite is sparsely oriented. Quartz and plagioclase show strong dimensional orientation, with the quartz having an aggregate habit in discontinuous ribbons. Plagioclase is myrmekitic where in contact with microcline. Fredericksburg Quadrangle, Va., at lat 38°17′23″ N. and long 77°29′36″ W.; 2,507 points counted.

P-74-62.–Weakly foliated allotriomorphic-granular biotite-muscovite monzogranite. Plagioclase is crowded with sericitic alteration. Garnet is a minor accessory. Plagioclase is myrmekitic where in contact with microcline. Some feldspar is poikilitic. Fredericksburg Quadrangle, Va., at lat 38°17′18″ N. and long 77°29′27″ W.; 2,622 points counted.

P-74-65.–Foliated sill of biotite-muscovite monzogranite. Rock is allotriomorphic granular and contains brown biotite having strong dimensional and lattice orientation. Some biotite is altered to chlorite. Plagioclase is clouded with sericitic alteration and contains lattice-oriented muscovite flakes. Garnet is a minor accessory. Fredericksburg Quadrangle, Va., at lat 38°17′16″ N. and long 77°29′19″ W.; 1,943 points counted.

P-75-32.–Foliated fine-grained sill of biotite syenogranite in biotite gneiss. Leucocratic minerals are dimensionally alined or flattened. Microporphyritic texture is imparted by larger grains of quartz and feldspar inset in finer grained groundmass. Reddish-brown biotite is dimensionally and lattice oriented along foliation. Some of the groundmass quartz has granoblastic texture. Myrmekite is present where plagioclase is in contact with microcline. Fredericksburg Quadrangle, Va., at lat 38°17′17″ N. and long 77°29′23″ W.; 2,387 points counted.

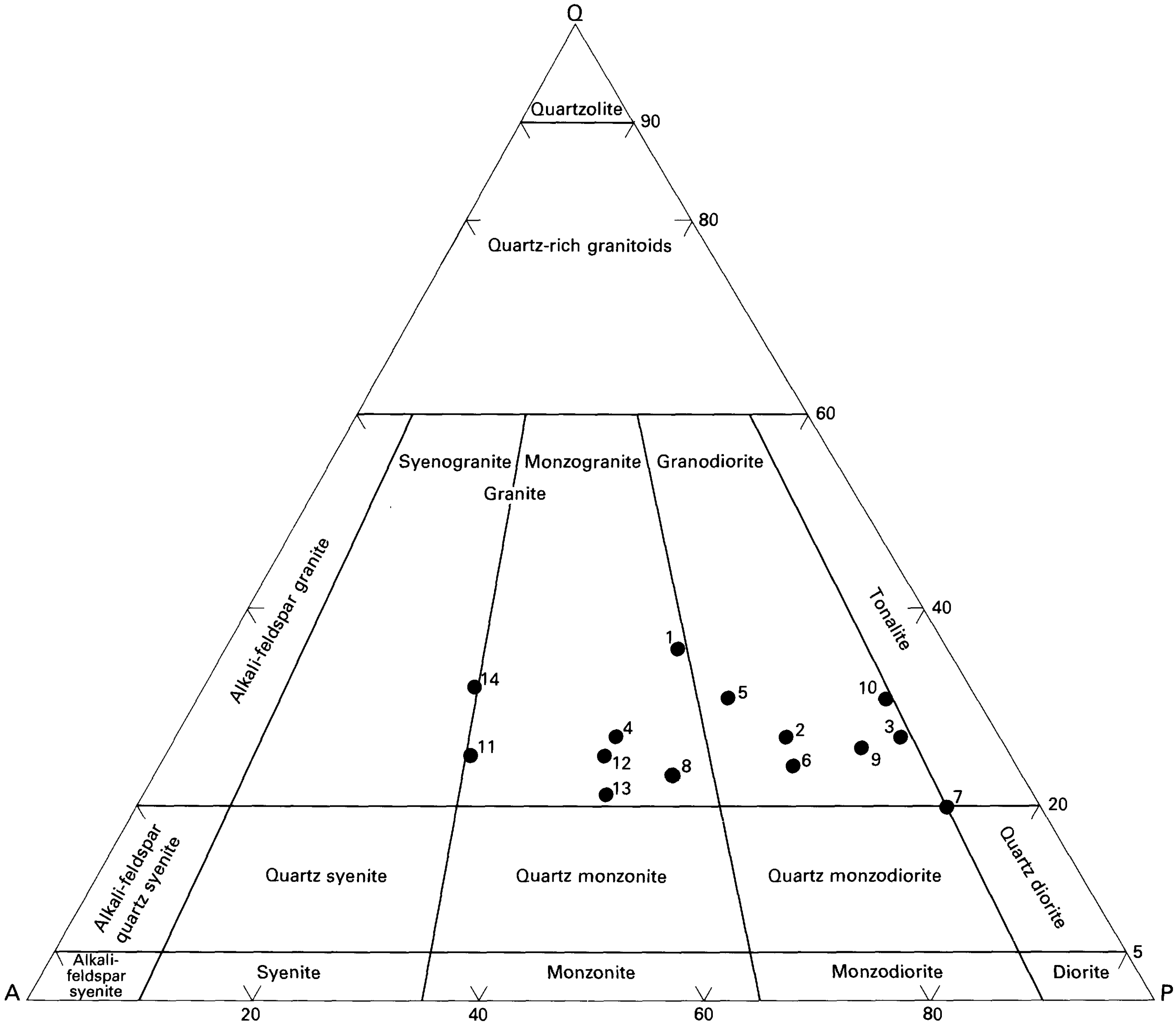

FIGURE 5.–Compositional range of granitoid rocks of the Po River Metamorphic Suite of the Fredericksburg Complex. Q, quartz; A, alkali feldspar; P, plagioclase. Sample numbers refer to those on table 2.

exposed along Route 656 in the southeast corner of the Brokenburg Quadrangle. Route 656 is a connecting road between Route 208 in the Brokenburg Quadrangle and Route 614, to the south in the Lake Anna East Quadrangle.

REGIONAL LITHOLOGIC VARIATIONS

In the northern part of the Ta River Metamorphic Suite terrane (Salem Church and Brokenburg Quadrangles) the lithology is chiefly amphibolitic gneiss associated with conformable granitoid rocks and smaller amounts of biotite gneiss and schist. To the southwest along strike, in the Lake Anna West Quadrangle the Ta River contains more biotite gneiss and schist and smaller amounts of amphibolite gneiss. An increase in regional metamorphic grade also occurs in the southwest part of the Ta River, and the associated granitoid bodies include more felsic types than does the northeast part of the Ta River Metamorphic Suite.

TABLE 3.—*Modal analysis, in percent, of the Holly Corner Gneiss of the Fredericksburg Complex*

[Modal analyses by S. Linda Cranford (U.S. Geological Survey); ____, absent or present in amounts < 0.1 percent]

Mineral	Sample number (top) and field number, P- (bottom)								
	1	2	3	4	5	6	7	8	9
	72–138	72–140	73–58A	73–22	73–39	73–24	70–101	73–59	70–103
Quartz	23.6	34.2	19.8	29.5	28.1	32.4	6.4	19.8	0.7
Plagioclase	34.5	31.0	38.0	29.8	33.0	24.3	18.5	12.1	12.0
Biotite	10.4	.8	8.8	19.4	21.1	23.1	4.8	____	2.1
Hornblende	29.6	25.8	26.6	17.9	10.4	12.2	29.8	27.4	84.8
Sphene	.6	.6	.2	.5	.2	.8	1.1	1.1	____
Zircon	.1	____	____	____	____	____	____	____	____
Epidote	1.2	2.2	3.6	1.7	6.2	3.5	5.2	____	____
Microcline	____	4.9	2.4	1.0	____	3.0	33.7	38.7	____
Mymekite	____	.2	.2	____	____	____	.1	____	____
Chlorite	____	.1	____	____	____	____	____	____	____
Apatite	____	____	.2	.1	.2	.1	.1	1.0	____
Calcite	____	____	____	____	.9	.5	____	____	____
Muscovite	____	____	____	____	____	____	.2	____	____
Opaque minerals	.1	.1	____	____	____	____	____	____	.3

NOTES:

P-72-138.—Biotite-quartz-hornblende-plagioclase gneiss. Rock is foliated and quartzofeldspathic, having biotite-bearing hornblende-rich folia. Quartzofeldspathic layers contain minor amounts of biotite and hornblende. Green hornblende poikilitically encloses small grains of quartz. Reddish-brown biotite has rigorous dimensional and lattice orientation in foliation plane. Prismatic hornblende has mostly nematoblastic texture, but some of the hornblende is at various orientations to the foliation plane. Plagioclase is oligoclase, and the larger grains are poikilitic. Salem Church Quadrangle, Va., at lat 38°18′40″ N. and long 77°32′23″ W.; 1,767 points counted.

P-72-140.—Horneblende-plagioclase-quartz gneiss. Rock is lineated and foliated. Granoblastic quartz-feldspar groundmass contains coarse-grained green hornblende that is dispersed throughout rock as dimensionally oriented grains but not in distinct folia. Minor reddish-brown biotite is lattice and dimensionally oriented in foliation plane. Epidote is generally associated with hornblende, commonly as inclusions within the hornblende. Sphene also is locally enclosed poikilitically by hornblende. Andesine is generally broadly twinned. Salem Church Quadrangle, Va., at lat 38°19′37″ N. and long 77°32′26″ W.; 1,943 points counted.

P-73-58A.—Biotite-quartz-hornblende-plagioclase gneiss. Plagioclase is twinned (andesine) and untwinned. Potassic feldspar is generally in contact with myrmekitic untwinned plagioclase. Green hornblende is locally poikilitic. Accessory epidote is more closely associated with biotite than with hornblende. Salem Church Quadrangle, Va., at lat 38°21′27″ N. and long 77°34′16″ W.; 1,672 points counted.

P-73-22.—Hornblende-biotite-quartz-plagioclase gneiss. Rock is fine grained and foliated and lineated. Biotitic and hornblendic folia also contain some feldspar. Some folia are dominantly biotitic, whereas others are dominantly hornblendic. Commonly epidote is poikilitically enclosed by biotite or hornblende. Quartzose layers are granoblastic. Salem Church Quadrangle, Va., at lat 38°20′29″ N. and long 77°35′43″ W.; 2,185 points counted.

P-73-39.—Hornblende-biotite-quartz-plagioclase gneiss. Reddish-brown biotite and green hornblende have lattice and dimensional orientation and form discontinuous streaky folia between the granoblastic-textured quartz and feldspar layers. Biotite and hornblende are locally poikilitic and enclose epidote and finer grained groundmass minerals. Hornblende also encloses fine-grained biotite, suggesting that it started forming after biotite had begun to form. Salem Church Quadrangle, Va., at lat 38°20′42″ N. and long 77°35′08″ W.; 1,964 points counted.

P-73-24.—Hornblende-biotite-plagioclase-quartz gneiss. Rock is medium grained and foliated with irregular wavy folia of brown biotite and green hornblende and quartz-feldspar layers in which are dispersed fine-grained biotite and hornblende grains. Epidote is found mostly in the hornblende-biotite folia. Quartz-feldspar layers are composed of fine-grained granoblastic groundmass enclosing larger quartz grains, as well as mosaic-textured quartz aggregates. Plagioclase is close to andesine in composition. Salem Church Quadrangle, Va., at lat 38°20′32″ N. and long 77°35′33″ W.; 2,059 points counted.

P-70-101.—Biotite-quartz-plagioclase-hornblende-microcline gneiss. Rock is medium grained and composed of coarse-grained green hornblende that is generally helicitic and encloses trains of microcline, quartz, and biotite. Fine-grained brown biotite is strongly alined along foliation planes. Sphene is well formed, and epidote is subhedral to euhedral. Abundance of microcline in this rock is attributed to proximity to intrusive of microcline-rich Falls Run Granite Gneiss and hence is believed to be largely metasomatic. Large hornblende may represent contact metamorphism also related to the Falls Run intrusion. Salem Church Quadrangle, Va., at lat 38°20′50″ N. and long 77°34′57″ W.; 2,277 points counted.

P-73-59.—Plagioclase-quartz-hornblende-microcline gneiss. Rock is rudely foliated, the foliation being imparted by partial dimensional orientation of green hornblende. Texture and abundant potassic feldspar in this gneiss, as in P-70-101, is attributed to thermal recystallization and potassic metasomatism related to the intrusion of the nearby Falls Run Granite Gneiss. Salem Church Quadrangle, Va. at lat 38°21′25″ N. and long 77°34′10″ W.; 2,521 points counted.

P-70-103.—Biotite-plagioclase hornblendite. Gneiss is black and fine grained and contains fine- and coarse-grained crystals of green hornblende, which constitute most of the rock. Granoblastic plagioclase is poorly twinned to untwinned and is found mostly as aggregate patches within the hornblende framework. Sparse brown biotite is found mostly as well-formed fine grains between hornblende, as well as being enclosed by it. This hornblendite is between the Falls Run Granite Gneiss and the pluton of the Falmouth Intrusive Suite; it may have been thermally metamorphosed at two different times, when each of these granitoid plutons was separately emplaced. Salem Church Quadrangle, Va., at lat 38°20′51″ N. and 77°34′10″ W.; 1,793 points counted.

The contact between the Ta River and the Holly Corner Gneiss is gradational and difficult to establish, especially where abundant granitoid intrusions and increase in metamorphic grade have obscured the lithologies. This is particularly true of this contact in the northeast part of the Salem Church Quadrangle and the northwest part of the Fredericksburg Quadrangle.

GNEISS

The characterizing amphibolitic rocks of the Ta River are generally dark-gray to black, well-foliated gneiss units that are rarely layered. Table 4 lists modal analyses of gneiss representative of the Ta River. The gneiss ranges from amphibolite (table 4, samples 3–7) through various types of amphibolite gneiss (table 4, samples 1, 2, and 8) to biotite gneiss. Some of the amphibolite (table 4, sample 6) in the Lake Anna East and West Quadrangles contains pyroxene, which may reflect higher grade regional metamorphism here than in the Ta River terrane to the northwest.

Amphibole in these rocks is a green hornblende (commonly poikiloblastic), and the plagioclase, both twinned and untwinned, ranges from andesine to bytownite. In general, textures in thin section range from

TABLE 4.—*Modal analyses, in percent, of the Ta River Metamorphic Suite of the Fredericksburg Complex*

[Modal analyses by S. Linda Cranford (U.S. Geological Survey); ____, absent or present in amounts <0.1 percent]

Mineral	Sample number (top) and field number, P- (bottom)										
	1	2	3	4	5	6	7	8	9	10	11
	70-51	74-39	75-76	76-80	76-71	76-61	76-78	76-175	76-120	76-121	76-143
Quartz	13.3	27.4	____	12.3	2.8	____	7.7	18.9	29.5	3.3	9.1
Plagioclase	17.0	43.1	46.9	____	50.9	33.5	45.0	54.8	50.4	49.4	42.4
Biotite	____	____	____	____	____	____	____	____	14.7	17.5	28.0
Muscovite	____	____	.6	____	____	____	____	____	____	____	____
Hornblende	66.8	29.1	47.5	68.7	44.2	58.3	45.7	25.7	____	20.9	7.1
Myrmekite	____	____	____	____	____	____	____	____	____	.3	.1
Garnet	____	____	____	____	____	____	____	____	2.1	.1	.1
Apatite	.1	____	____	____	____	____	____	____	.1	.2	.5
Epidote	____	____	5.0	18.4	1.8	1.2	.1	____	3.1	7.4	12.1
Sphene	____	____	____	.6	____	____	1.5	____	____	.6	.6
Pyroxene	____	____	____	____	____	7.9	____	____	____	____	____
Opaque minerals	2.9	.4	____	____	.2	____	____	.6	____	.2	.1
Other	____	____	____	.1	____	____	____	____	____	____	____

NOTES:

P-70-51.—Dark-green to black amphibolite. Rock has thin, folded quartz-feldspar layers and local feldspathic gash veinlets.Green hornblende ranges from euhedral to subhedral. Stafford Quadrangle, Va., at lat 38°23'39" N. and long 77°29'52" W.; 1,626 points counted.

P-74-39.—Quartz-hornblende-plagioclase gneiss. Rock is foliated and has strong dimensional orientation of green hornblende that is subhedral to euhedral. Plagioclase is andesine. Salem Church Quadrangle, Va., at lat 38°18'26" N. and long 77°35'08" W.; 2,708 points counted.

P-75-56.—Epidote amphibolite. Rock is medium grained and nonfoliated and contains well-formed bytownitic plagioclase, some having good polysynthetic twinning and some characterized by partial and partial-wedge twins. Hornblende is green. Salem Church Quadrangle, Va., at lat 38°15'25" N. and long 77°33'05" W.; 3,007 points counted.

P-76-80.—Quartz-epidote-amphibolite. Lake Anna West Quadrangle, Va., at lat 38°02'20" N. and long 77°46'12" W.; 2,318 points counted.

P-76-71.—Amphibolite. Rock consists of green amphibole and twinned and untwinned plagioclase, some of which is sericitically and (or) kaolinitically altered. Lake Anna East Quadrangle, Va., at lat 38°03'27" N. and long 77°43'51" W.; 2,811 points counted.

P-76-61.—Amphibolite. Rock contains pyroxene, which may be relict. Lake Anna East Quadrangle, Va., at lat 38°05'08" N. and long 77°43'51" W.; 2,240 points counted.

P-76-78.—Amphibolite. Lake Anna West Quadrangle, Va., at lat 38°02'37" N. and long 77°47'23" W.; 2,210 points counted.

P-76-175.—Quartz-hornblende-plagioclase gneiss. Brokenburg Quadrangle, Va., at lat 38°11'10" N. and long 77°38'42" W.; 2,107 points counted.

P-76-120.—Garnet-biotite-quartz-plagioclase gneiss. Lake Anna West Quadrangle, Va., at lat 38°05'20" N. and long 77°46'58" W.; 2,373 points counted.

P-76-121.—Quartz-epidite-biotite-hornblende-plagioclase gneiss. Lake Anna West Quadrangle, Va., at lat 38°05'20" N. and long 77°46'58" W.; 2,310 points counted.

P-76-143.—Hornblende-quartz-epidote-plagioclase gneiss. Lake Anna West Quadrangle, Va., at lat 38°03'40" N. and long 77°47'35" W.; 2,344 points counted.

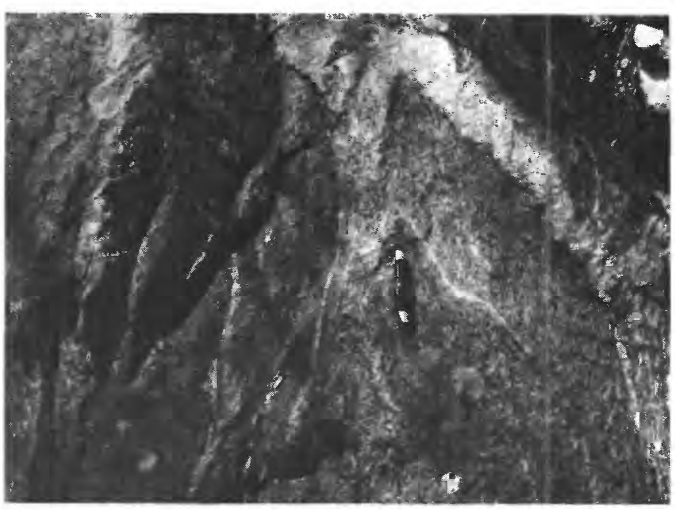

FIGURE 6.—Early folds outlined by calcsilicate layers in the Holly Corner Gneiss of the Fredericksburg Complex. Foliation in the gneiss is axial planar to the early fold.

granoblastic to foliated by dimensionally alined grains. Epidote is present generally in subhedral grains, and in some gneiss it is abundant. The biotite-rich gneiss in the Ta River (table 4, samples 9 and 10) is similar to biotite-rich amphibolite gneiss in the Po River Metamorphic Suite.

SCHIST

Biotitic schist is found chiefly as saprolite in the Ta River. It can generally be recognized by the abundant bronzy to tarnished-looking flakes of oxidized biotite in the saprolite.

METAGABBRO

Coarse-grained metagabbro resembling "metagabbro" within the Chopawamsic Formation along Long Branch (Pavlides, 1976, fig. 1 and p. 34-35) is present in the north-central part of the Brokenburg Quadrangle. Although poorly exposed, it appears to consist of coarse-grained amphibole and altered plagioclase in a ground-mass of fine-grained plagioclase. Epidote is generally abundant.

TABLE 5.—*Modal analyses, in percent, of the granitoid rocks of the Ta River Metamorphic Suite of the Fredericksburg Complex*

[Modal analyses by S. Linda Cranford (U.S. Geological Survey); ____, absent or present in amounts <0.1 percent]

Mineral	Sample number (top) and field number (bottom)												
	1	2	3	4	5	6	7	8	9	10	11	12	13
	P-73-80[1]	P-73-81[1]	P-73-83[1]	P-73-84[1]	P-73-85[1]	P-76-13[1]	P-76-14[1]	P-76-15[1]	P-76-92	P-76-93	P-76-95	NA-1	P-76-142
Quartz	22.7	28.8	32.9	40.9	32.9	19.6	12.9	26.8	31.6	28.0	29.6	38.0	27.6
Plagioclase	43.3	65.8	58.6	54.5	63.3	70.6	73.1	65.7	43.6	36.4	34.1	28.3	33.5
Microcline	[2]23.1	----	----	----	----	----	----	1.7	12.0	24.7	26.0	[2]30.9	36.2
Biotite	6.4	2.9	7.8	.8	1.9	1.5	----	4.6	9.8	6.4	5.2	1.7	1.3
Muscovite	1.2	----	.2	2.3	1.1	----	----	----	1.0	1.0	3.9	.3	.9
Hornblende	----	.8	----	----	----	6.6	12.8	----	----	----	----	----	----
Myrmekite	2.7	.3	----	----	----	----	----	----	.3	2.1	.3	.5	.1
Garnet	----	----	----	.1	.1	----	----	----	----	----	----	----	----
Apatite	.4	----	----	----	----	.1	.1	----	----	----	----	----	----
Epidote	----	----	----	----	----	.6	.3	.2	1.8	1.1	.5	----	----
Chlorite	----	----	.4	.5	.2	----	----	.1	----	----	----	.3	----
Sphene	----	----	----	----	.1	.9	.8	----	----	----	----	----	----
Opaque minerals	.2	1.1	----	.9	.5	----	----	.6	.1	----	.4	.1	.4
Other	----	.2	----	----	----	.1	----	.2	----	.3	----	----	----
	Normalized values used for ternary diagrams												
Quartz	25	30	36	43	34	22	15	28	36	31	33	39	28
Plagioclase	50	70	64	57	66	78	85	70	50	42	38	30	35
Alkali feldspar	25	----	----	----	----	----	----	2	14	27	29	31	37

[1] Petrography by Karen Wier and Louis Pavlides.
[2] Microcline plus orthoclase.

NOTES:

P-73-80.—Muscovite-biotite granodiorite. Rock is weakly foliated, fine grained, and allotriomorphic granular and contains dark-brown biotite as the chief accessory. Spotsylvania Quadrangle, Va., at lat 38°14′54″N. and long 77°36′42″ W.; 2,258 points counted.

P-73-81.—Gneissic hornblende-biotite tonalite. Rock is foliated and allotriomorphic granular. Dimensionally alined brownish-green biotite is alined along foliation. Spotsylvania Quadrangle, Va., at lat 38°14′48″ N. and long 77°35′50″ W.; 2,153 points counted.

P-73-83.—Gneissic biotite tonalite. Rock is weakly foliated and allotriomorphic granular and contains green biotite as the chief accessory. Spotsylvania Quadrangle, Va., at lat 38°15′00″ N. and long 77°37′18″ W.; 2,154 points counted.

P-73-84.—Gneissic muscovite tonalite. Spotsylvania Quadrangle, Va., at lat 38°14′49″ N. and long 77°37′29″ W.; 1,970 points counted.

P-73-85.—Gneissic muscovite-biotite tonalite. Rock is foliated and allotriomorphic granular. Spotsylvania Quadrangle, Va., at lat 38°14′48″ N. and long 77°37′22″ W.; 2,553 points counted.

P-76-13.—Gneissic biotite-hornblende tonalite. Rock is foliated and allotriomorphic granular and contains green hornblende. Spotsylvania Quadrangle, Va., at lat 38°14′27″N. and long 77°35′29″ W.; 2,449 points counted.

P-76-14.—Hornblende diorite gneiss. Rock is foliated and allotriomorphic granular and contains green hornblende. Some of the plagioclase is zoned. Spotsylvania Quadrangle, Va., at lat 38°14′19″ N. and long 77°35′26″ W.; 2,482 points counted.

P-76-15.—Biotite tonalite gneiss. Rock is foliated and allotriomorphic granular; elongate grains are dimensionally oriented. Spotsylvania Quadrangle, Va., at lat 38°13′45″N. and long 77°34′59″ W.; 2,544 points counted.

P-76-92.—Biotite granodiorite gneiss. Rock is foliated and allotriomorphic granular. Lake Anna West Quadrangle, Va., at lat 38°01′33″ N. and long 77°46′53″W.; 2,110 points counted.

P-76-93.—Biotite monzogranite gneiss. Lake Anna West Quadrangle, Va., at lat 38°01′18″ N. and long 77°50′27″ W.; 2,128 points counted.

P-76-95.—Muscovite-biotite monzogranite gneiss. Lake Anna West Quadrangle, Va., at lat 38°39′33″ N. and long 77°50′46″ W.; 2,138 points counted.

NA-1.—Biotite monzogranite gneiss. Lake Anna West Quadrangle, Va., at lat 38°03′36″ N. and long 77°47′29″ W.; 1,853 points counted.

P-76-142.—Muscovite-biotite monzogranite gneiss. Lake Anna West Quadrangle, Va., at lat 38°03′30″ N. and long 77°47′31″ W.; 2,461 points counted.

GRANITOID ROCKS

Foliated, granitoid rocks are found in tabular masses conformable with the amphibolitic gneiss, as well as in irregular masses, in the Ta River Metamorphic Suite (table 5). In the northern terrane of the Ta River, these granitoid rocks are predominantly tonalitic and less frequently quartz dioritic to granodioritic in composition (fig. 7). The presence of tonalitic gneiss here contrasts with its absence in the Po River Metamorphic Suite to the southeast. In the southern part of the Ta River, where more biotite gneiss and schist are present in the section, the associated granitoid rocks are mostly monzogranitic (table 5, samples 10–13) and, less commonly, granodioritic (table 5, sample 9) in composition. Biotite is ubiquitous in the Ta River granitoid rocks, but hornblende is present only in the more mafic granitoid bodies of the northern terrane.

AGE

For reasons described in the section entitled "Regional relationships," the Ta River Metamorphic Suite is possibly a more eastern, less felsic, and more highly metamorphosed temporal equivalent of the Chopawamsic Formation. Therefore, it is provisionally considered to be of Early Cambrian age.

FALLS RUN GRANITE GNEISS

This granite gneiss is named for Falls Run that flows southeastward across the northeast part of the Salem

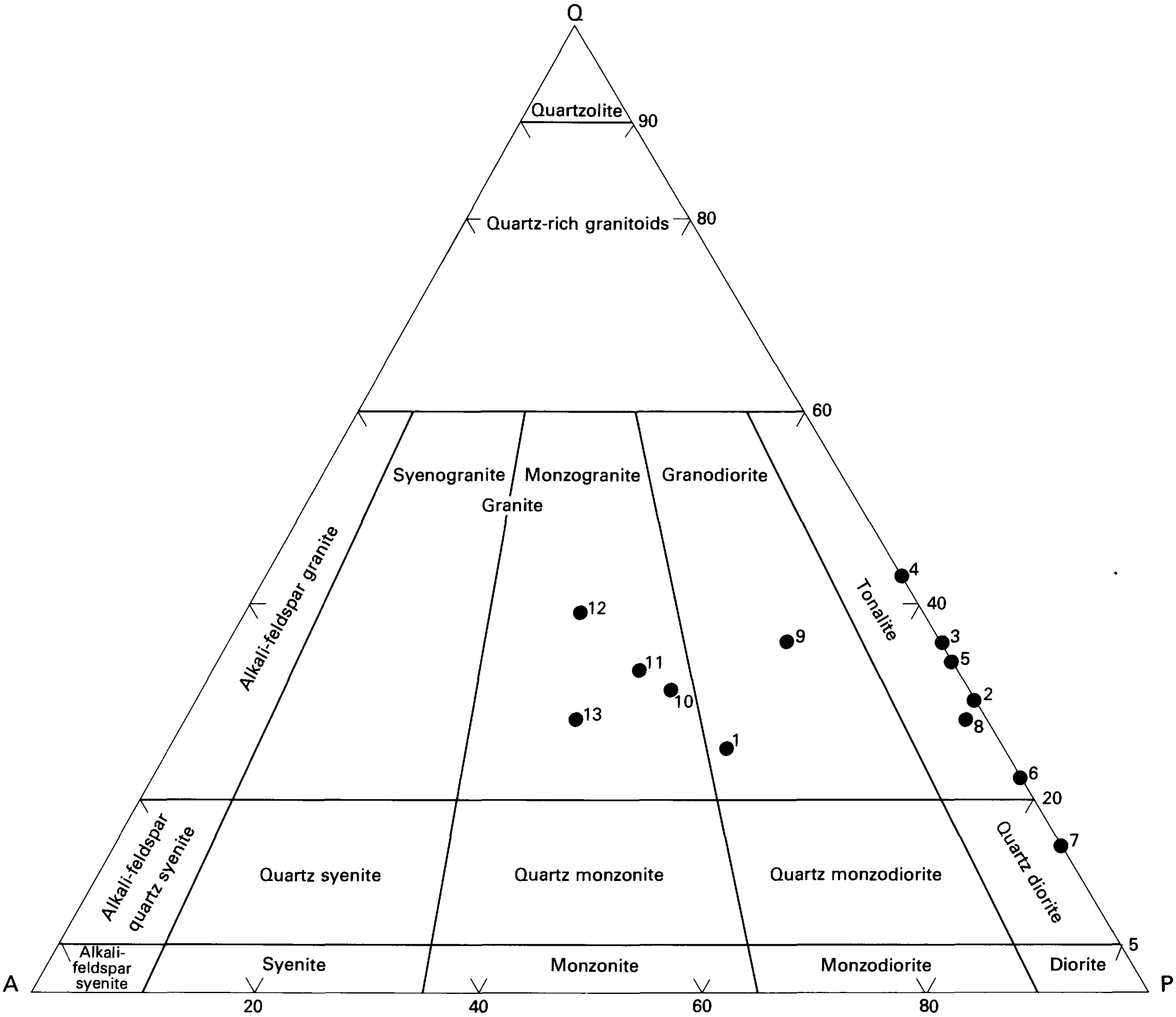

FIGURE 7.–Compositional range of granitoid rocks of the Ta River Metamorphic Suite of the Fredericksburg Complex. Q, quartz; A, alkali feldspar; P, plagioclase. Sample numbers refer to those on table 5.

Church Quadrangle. Some of the most extensive bedrock and saprolite exposures of this gneiss that are available in the area are downstream from the intersection of Falls Run and Route 654 (pl. 1). The Falls Run Granite Gneiss in the Salem Church Quadrangle is in a refolded fold (Pavlides, 1976, p. 18–19 and fig. 2) that is on the inverted limb of a recumbent fold (Pavlides, 1978, p. 51). The Falls Run Granite Gneiss and the Holly Corner Gneiss, within which the Falls Run was emplaced, are considered to be allochthonous where they are found in the Salem Church and Storck Quadrangles. The rocks in the Spotsylvania Quadrangle (pl. 1) that are assigned to the Falls Run probably are autochthonous and have been emplaced originally as an intrusion into the Po River Metamorphic Suite.

Typically the Falls Run Granite Gneiss in the Salem Church Quadrangle is a pale-pink to nearly white coarse-grained strongly foliated rock (fig. 8). The microcline is generally found in elongate grains, commonly as much as several centimeters long, whose long axes lie in the same direction as the rock foliation (dimensional orientation). Irregular streaky patches composed dominantly

TABLE 6.—*Modal analyses, in percent, of the Falls Run Granite Gneiss of the Fredericksburg Complex*

[Modal analyses by S. Linda Cranford (U.S. Geological Survey); ____, absent or present in amounts <0.1 percent]

Mineral	Sample number (top) and field number, P- (bottom)												
	1	2	3	4	5	1A	6	7	8	9	10	11	12
	70–118	70–120	72–168	72–169	77–X[1]	70–118[1]	72–130[1]	73–71[1]	74–52[1]	74–55[1]	75–13[1]	76–18[2]	76–23[2]
Quartz	23.0	13.2	27.1	31.7	18.6	20.6	30.1	22.8	2.4	21.1	16.0	3.5	9.9
Plagioclase	26.4	25.6	26.3	33.9	26.2	30.6	32.2	28.6	37.9	41.3	24.6	29.5	47.8
Microcline	37.2	41.3	[3]23.9	[3]21.5	[3]46.9	[3]38.8	[3]33.8	[3]37.3	[3]46.6	[3]21.6	[3]49.3	44.1	32.5
Biotite	2.4	6.5	5.9	3.2	____	____	____	____	____	____	____	8.2	5.4
Muscovite	____	____	____	9.0	____	____	____	____	____	____	____	____	____
Hornblende	5.8	9.2	1.7	____	____	____	____	____	____	____	____	8.4	2.3
Myrmekite	2.6	1.8	2.5	.7	____	____	____	____	____	____	____	2.6	.9
Apatite	.6	.2	.3	____	____	____	____	____	____	____	____	.5	.2
Epidote	1.6	1.5	1.4	____	____	____	____	____	____	____	____	1.8	.4
Sphene	.5	.6	.6	____	____	____	____	____	____	____	____	.1	.3
Opaque minerals	____	.3	.4	____	____	____	____	____	____	____	____	.2	.3
Other	____	____	____	____	____	____	____	____	____	____	____	1.1	.2
Dark minerals	____	____	____	____	8.2	10.1	3.9	11.3	13.1	16.0	10.2	____	____
	Normalized values used in ternary diagrams												
Quartz	26	16	30	36	20	23	31	26	3	25	18	4	11
Plagioclase	32	34	32	39	29	34	34	32	44	49	27	41	53
Alkali Feldspar	42	50	38	25	51	43	35	42	53	26	55	55	36

[1] Analysis of stained slab.
[2] Petrography by Karen Wier and Louis Pavlides.
[3] Microcline plus orthoclase.

NOTES:

P-70-118.—Monzogranite gneiss. Rock is coarse grained and strongly foliated; foliation consists of discontinuous folia of green hornblende, greenish-brown biotite, sphene, and epidote. Myrmekite very common, especially where plagioclase is in contact with microcline. Large microcline grains are poikilitic. Salem Church Quadrangle, Va., at lat 38°18′36″ N. and long 77°31′52″ W.; 1,869 points counted.

P-70-120.—Quartz monzonite gneiss. Rock is coarse grained and strongly foliated; foliation is defined by dimensionally oriented biotite and hornblende. Myrmekite is very common, especially where plagioclase is in contact with microcline; in places myrmekite forms cauliflower-like growths protruding into microcline. Some plagioclase has clear albitic rims at contacts with microcline. Greenish-brown biotite is locally intergrown with hornblende. Salem Church Quadrangle, Va., at lat 38°18′40″ N. and long 77°31′39″ W.; 2,052 points counted.

P-72-168.—Monzogranite gneiss. Rock is coarse grained and foliated and contains greenish-brown biotite in dimensional orientation along foliation. Salem Church Quadrangle, Va., at lat 38°21′04″ N. and long 77°35′00″ W.; 2,185 points counted.

P-72-169.—Muscovite-monzogranite gneiss. Rock is coarse grained and foliated. Salem Church Quadrangle, Va., at lat 38°21′02″ N. and long 77°34′56″ W.; 2,224 points counted.

P-77-X.—Monzogranite gneiss. Salem Church Quadrangle, Va., at lat 38°20′22″ N. and long 77°32′51″ W.; 1,745 points counted.

P-72-130.—Monzogranite gneiss. Salem Church Quadrangle, Va., at lat 38°22′03″ N. and long 77°30′22″ W.; 1,696 points counted.

P-73-71.—Monzogranite gneiss. Salem Church Quadrangle, Va., at lat 38°20′22″ N. and long 77°32′52″ W.; 823 points counted.

P-74-52.—Monzonite gneiss. Salem Church Quadrangle, Va., at lat 38°18′13″ N. and long 77°31′38″ W.; 831 points counted.

P-74-55.—Granodiorite gneiss. Salem Church Quadrangle, Va., at lat 38°18′17″ N. and long 77°31′52″ W.; 901 points counted.

P-75-13.—Quartz syenite gneiss. Salem Church Quadrangle, Va., at lat 38°18′36″ N. and long 77°31′47″ W.; 765 points counted.

P-76-18.—Monzonite gneiss. Rock is coarse grained and foliated and contains dimensionally oriented greenish-brown biotite and green hornblende alined along foliation. Some felsic grains also have dimensional orientation. Spotsylvania Quadrangle, Va., at lat 38°13′14″ N. and long 77°34′22″ W.; 2,645 points counted.

P-76-23.—Quartz monzonite gneiss. Rock is coarse grained and foliated and contains irregular folia of green hornblende and brownish-green biotite that wrap around large quartz and feldspar aggregates. Twinned and untwinned plagioclase is commonly myrmekitic at contacts with microcline. Spotsylvania Quadrangle, Va., at lat 38°13′04″ N. and long 77°34′13″ W.; 2,334 points counted.

of mica and hornblende are dimensionally and crystallographically oriented in the foliation. The folia wrap around the large feldspar grains rather than break through them (fig. 8) as a strong planar foliation. Modal analyses of the Falls Run rocks are listed in table 6, and their composition range is shown on fig. 9. Most of the Falls Run in the Salem Church Quadrangle is a monzogranite or beta granite (adamellite) and for brevity has been designated simply a granite gneiss. Some of it has the composition of quartz monzonite and monzonite. The Falls Run in the Spotsylvania Quadrangle, on the basis of very limited sampling, is determined to lie in the monzonite to quartz monzonite fields (fig. 9).

In thin section, potassic feldspar, mostly microcline, occurs in coarse grains that are commonly poikilitic, whereas the generally subordinate plagioclase occurs as a finer grained groundmass constituent. Myrmekite is ubiquitous and is found in plagioclase where the latter is in contact with potassic feldspar. Also clear, more albitic rims are found locally in plagioclase where it is in contact with potassic feldspar. Generally, greenish-brown biotite is the characterizing mica although locally muscovite is present and may be more abundant than biotite. Green hornblende is also an abundant accessory and, along with the micas, is found in folia. Sphene and epidote, generally in well-formed grains, are common within the folia.

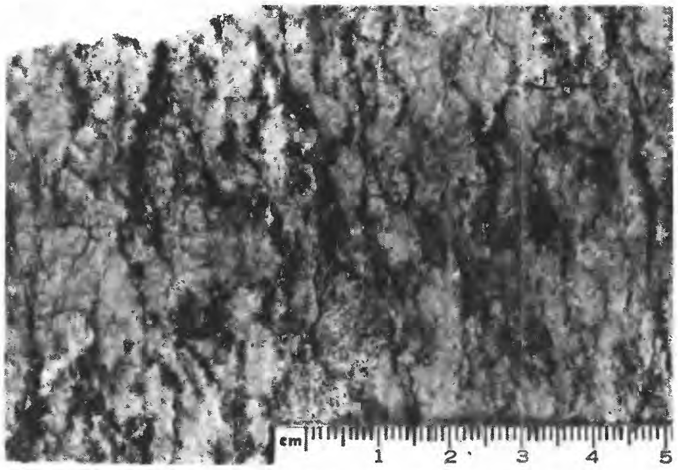

FIGURE 8.–A hand specimen of the Falls Run Granite Gneiss of the Fredericksburg Complex (sawed surface). The large leucocratic grains are mostly microcline dimensionally alined along the rock foliation. The dark irregular layers contain mostly biotite and hornblende.

AGE

U/Pb and Rb/Sr studies (Pavlides and others, 1979) indicate that the Falls Run is 385–415 million years old (Early Devonian to Middle Silurian).

QUANTICO FORMATION

The Quantico Slate was named by Darton (1894) for exposures along Quantico Creek in northeastern Virginia. The formation there is a narrow belt of black slate overlying the crystalline rocks of the Piedmont and lying beneath the Cretaceous Potomac Formation (Group) of the Coastal Plain. Watson and Powell (1911) described the Quantico Slate as composed of dark-gray and black slate, beds of green and maroon slate, and dense homogeneous black graphitic slate. They considered the Quantico to be of Late Ordovician age on the basis of fossils that they found along Powells Creek and that were examined and dated by R. S. Bassler of the U.S. National Museum. In 1916, in the explanation accompanying the Geological Map of Virginia by the Virginia Geological Survey, T. L. Watson lumped the Quantico and Arvonia Slates as Cincinnatian slates of the Piedmont province. Lonsdale (1927) recognized that the Quantico varied from black graphitic slate to gray phyllite along its strike belt southwest from Dumfries, Va. Mixon, Southwick, and Reed (1972) described the Quantico as a gray-to-black slate that is commonly very graphitic and pyritic and locally contains layers of graywacke, which in places are graded. They also included near the base of the Quantico a horizon composed of felsic tuff, thin felsic flows, quartzite, and silty slate and a second horizon composed of chlorite-actinolite greenschist. My mapping to the southwest of the area mapped by Mixon, Southwick, and Reed indicates that the metavolcanic horizons they recognized are of only local importance, as they have not been found in comparable positions in the Quantico to the southwest. Rather, the Quantico to the southwest appears to enclose various metasandstone beds at various horizons. The metamorphic grade also increases to the southwest, and rather than being a slate, the Quantico is actually a garnetiferous schist that contains staurolite, chloritoid, fibrolitic sillimanite, or kyanite at different places. The rock name Quantico Slate, therefore, is deemed lithologically inappropriate for this unit, and it is herein modified to Quantico Formation. Because the northern strike belt of the Quantico has been described by other investigators, only the Quantico Formation south of the Quantico Quadrangle is discussed here.

SCHIST

The Quantico Formation continues as a black graphitic slate and phyllite southwest from the Quantico Quadrangle (fig. 1; pl. 1) to near the southern part of the Stafford Quadrangle, where it changes over a very short distance to a dark-gray biotite-muscovite schist. Southwest from this point, degree of metamorphism generally increases, producing fine- to medium-grained staurolitic schist (Pavlides, 1976, fig. 8) and biotite-muscovite garnetiferous schist that locally contains fibrolitic sillimanite or kyanite. Table 7 contains modal analyses of schist in the garnet and staurolite grade from the Quantico Formation. Muscovite is more abundant than biotite. Chlorite is mostly a retrograde mineral after biotite or, less commonly, marginal alteration on garnet. In general, graphitic schist within the Quantico is sparse and irregularly distributed south of the Stafford Quadrangle.

QUARTZITE

Quartzite forms thin discontinuous lenses within the formation and locally at the base of the Quantico. Some of these have been mapped out and individually designated as lenses I–V (pl. 1). Locally, along the contact with the underlying Chopawamsic Formation, the basal quartzite of the Quantico is a mylonite (Pavlides, 1976, fig. 3). Table 7 lists modal analyses of quartzite lenses from several horizons within the Quantico Formation. As can be seen from figure 10, most of these are quartz or feldspathic metaarenite and metawacke. In places sillimanite is found in some of this quartzite.

Quartzite lens V (samples 22, 23, table 7) contains potassic feldspar probably introduced from the abundant granitoid rocks of the Falmouth Intrusive Suite emplaced within this quartzite lens. Therefore these modes are not plotted on figure 10.

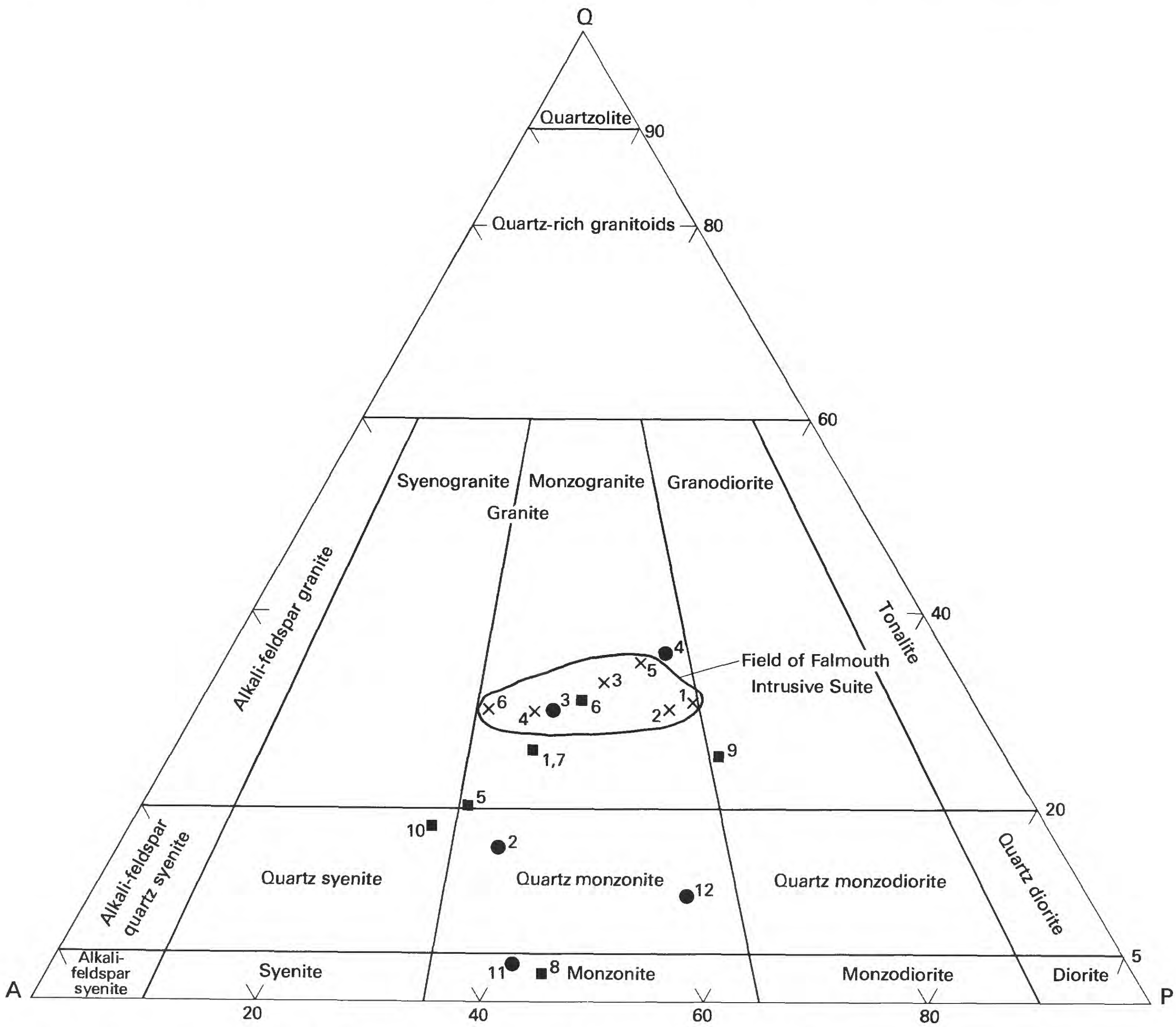

FIGURE 9.–Compositional range of the Falls Run Granite Gneiss of the Fredericksburg Complex (dots) and range of the Falmouth Intrusive Suite granitoid rocks (crosses) emplaced in the Falls Run. Squares are point counts of polished slabs of the Falls Run. Q, quartz; A, alkali feldspar; P, plagioclase. As shown in table 6, analysis of sample 1A is a slab count of the same rock modally analyzed in thin section (sample 1). Analysis of sample 7 is a slab count that has an analysis identical with that of sample 1.

CALCSILICATE LAYERS

Thin diopsidic calcsilicate layers are found locally in the lower part of the Quantico Formation. These layers are generally several centimeters thick and are pale green in places because of the diopside.

AGE

Considerable controversy exists as to the age of the Quantico Formation since it was dated as Late Ordovician through the field work of Watson and Powell (1911) and the paleontologic determination by R. S. Bassler. The controversy concerning the age of the Quantico is summarized as follows (Pavlides, 1976):

> The original fossil collection [of Watson and Powell] has been lost, and the fossil locality is now beneath roadfill of U.S. Interstate Highway 95 so that additional collections from the locality can no longer be made. Seiders and others (1975, p. 507–508) reported that fossil-like inorganic impressions were found in the Quantico [Formation] 4.8 km north of Powells Creek. On the unstated inference that similar inorganic objects may have been incorrectly identified as fossils, they felt that Bassler's determinations of the Quantico fossils may be erroneous and should not be a "* * * factor bearing on the age of the Quantico" (Seiders and others, 1975, p. 508). On the basis of the fact that a body of quartz monzonite which cuts the Quantico has

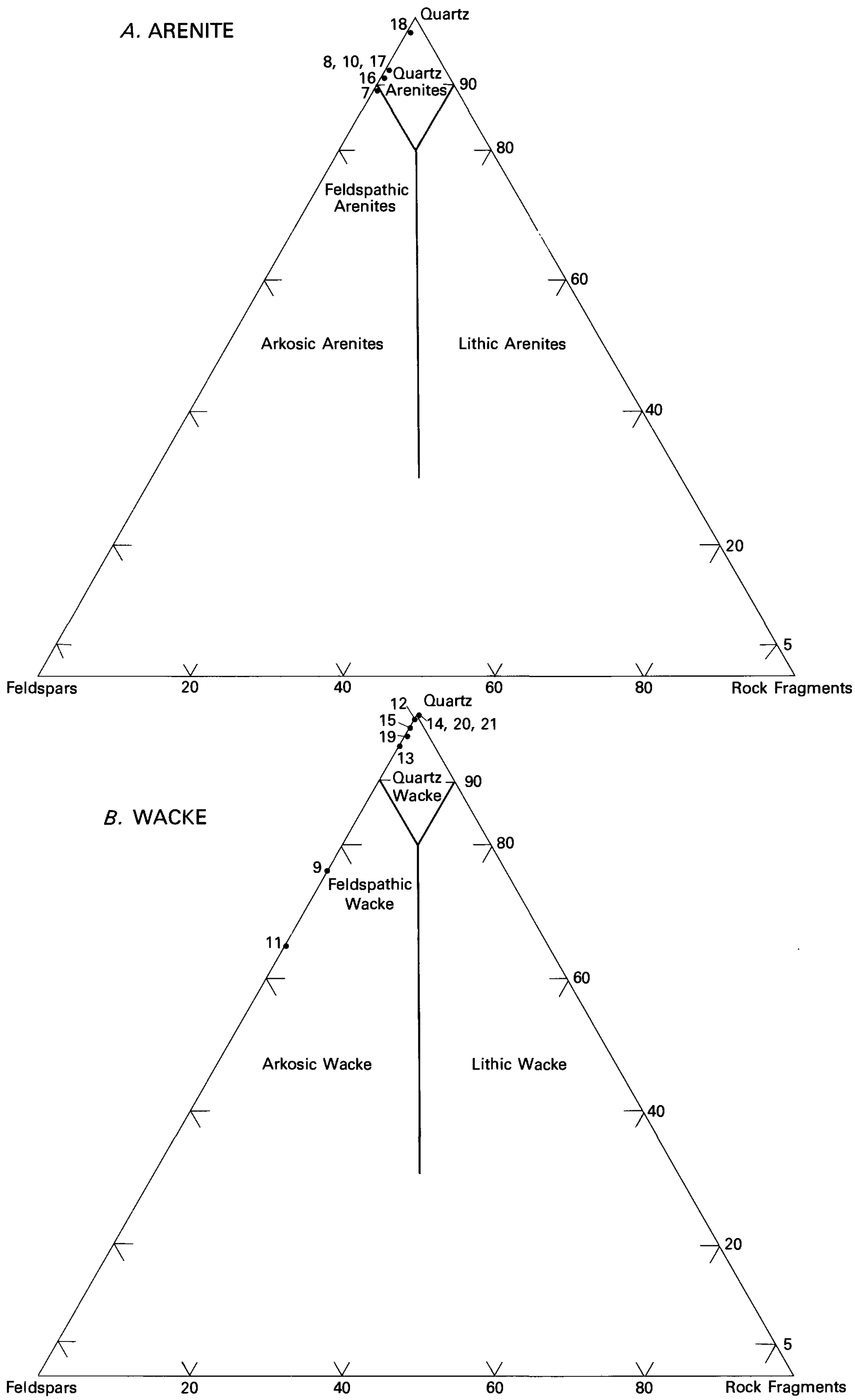

FIGURE 10.–Classification of quartzite lenses from the Quantico Formation: ***A,*** Arenite; ***B,*** Wacke. Triangular diagrams are modified from Williams, Turner, and Gilbert (1954, figs. 96, 97). Sample numbers on diagram are from table 7. Rocks containing less than 10 percent micaceous minerals, including chlorite, are considered metaarenite, whereas those containing more than 10 percent of these minerals are considered metawacke (metagraywacke).

TABLE 7.–*Modal analysis, in percent, of schist and*

[Modal analysis by S. Linda Cranford (U.S. Geological Survey) ----, absent

Mineral	Sample number (top) and field number, P- (bottom)									
	Schist						Quartzite lens I			
	1	2	3	4	5	6	7	8	9	10
	70-30A	70-32	70-32B	71-5	74-15	73-20	70-80A	70-83	74-43	75-11
Quartz	44.2	49.0	40.6	67.5	45.3	47.5	82.3	84.9	64.9	83.8
Muscovite	39.3	38.0	41.5	17.1	33.9	37.3	4.0	4.6	7.5	7.3
Biotite	11.1	5.5	11.3	3.9	16.4	10.0	4.0	3.2	5.7	2.2
Chlorite	3.0	.4	.4	9.2	.2	.4	.1	----	.5	----
Garnet	1.0	3.6	2.6	.1	1.9	1.5	----	.1	----	----
Staurolite	----	1.4	1.9	1.4	1.4	1.0	----	----	----	----
Plagioclase	----	.1	----	----	----	----	3.9	6.8	21.4	6.6
Microcline	----	----	----	----	----	----	5.5	----	----	----
Tourmaline	----	----	----	.8	----	----	----	----	----	----
Apatite	----	----	----	----	----	----	----	.1	----	----
Total mica	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	8.1	7.8	13.7	9.5
Opaque minerals	[1]1.4	[1]1.9	[1]1.6	----	[1]1.0	[1]2.2	----	.2	----	.1
	Normalized values used in ternary diagrams									
Quartz	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	89	92	76	92
Feldspar	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	11	8	24	8
Rock fragments	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	----	----	----	----

[1] Contains graphite.

NOTES:

P-70-30A.–Garnet-chlorite-biotite-muscovite schist. Quartz, in mosaic habit with interspersed fine-grained muscovite and biotite in random orientation, is found in lensoid or lozenge-shaped alined masses separated by thin muscovite-biotite folia that impart schistosity to the rock. Larger biotite porphyroblasts are in both quartzose and micaceous folia, commonly having their mineral cleavage at an angle to the rock foliation. Such biotite porphyroblasts are commonly altered to chlorite or chlorite and white mica. Graphite imparts black dusty appearance in thin section. Stafford Quadrangle, Va., at lat 38°24′25″ N. and long 77°29′35″ W.; 2,093 points counted.

P-70-32.–Staurolite-garnet-biotite-muscovite schist. Staurolite locally encloses garnet, and some staurolite has "pressure shadow" eyes of biotite and muscovite. Quartz is locally recrystallized into thin elongated plates. Stafford Quadrangle, Va., at lat 38°24′19″ N. and long 77°29′29″ W.; 1,538 points counted.

P-70-32B.–Staurolite-garnet-biotite-muscovite schist. Sample similar to sample P-70-32. Stafford Quadrangle, Va., at lat 38°24′19″ N. and long 77°29′29″ W.; 1,368 points counted.

P-71-5.–Staurolite-biotite-chlorite-muscovite-quartz schist. Rock is a two-foliation schist containing coarse-grained quartz forming seams along early foliation (S_1). Staurolite is commonly altered peripherally to shimmer aggregate of muscovite. In places, shimmer aggregate of mica pseudomorphously replaces staurolite. Helicitic texture is common in staurolite. Muscovite having helicitic texture is found along early foliation (S_1) that is kinked into chevron folds by a later foliation (S_2). Brown biotite, free of helicitic texture, is also alined along S_1; it has been extensively replaced pseudomorphously by chlorite. Some biotite (early?) is helicitic. Stafford Quadrangle, Va., at lat 38°24′36″ N. and long 77°28′17″ W.; 2,039 points counted.

P-74-15.–Staurolite-garnet-biotite-chlorite-muscovite schist having two foliations. Sample is similar to sample P-71-5, except that staurolite is unaltered and locally encloses garnet. Salem Church Quadrangle, Va., at lat 38°19′35″ N. and long 77°36′37″ W.; 2,123 points counted.

P-73-20.–Staurolite-garnet-biotite-muscovite schist having two foliations, as does sample P-71-5. Staurolite shows rotational helicitic texture. Salem Church Quadrangle, Va., at lat 38°20′36″ N. and long 77°36′11″ W.; 2,423 points counted.

P-70-80A.–Micaceous quartzite; protolith probably a feldspathic arenite. Rock is foliated, containing reddish-brown biotite and coarser grained muscovite that have dimensional and lattice orientation, which impart the foliation to the rock. Locally, potassic feldspar poikilitically encloses rounded quartz grains; elsewhere groundmass quartz is granoblastic. Untwinned plagioclase is characterized by fine "dusty" alteration. Salem Church Quadrangle, Va., at lat 38°18′47″ N. and long 77°32′30″ W.; 2,063 points counted.

P-70-83.–Micaceous quartzite; protolith probably a quartz arenite. Rock is heteroblastic textured and fine grained and contains reddish-brown biotite and coarser grained muscovite that have dimensional and lattice orientation, which imparts rock foliation. Twinned and untwinned plagioclase is clouded with sericitic alteration. Salem Church Quadrangle, Va., at lat 38°18′46″ N. and long 77°32′31″ W.; 2,247 points counted.

P-74-43.–Biotite-muscovite quartzite; protolith probably a feldspathic wacke. Salem Church Quadrangle, Va., at lat 38°17′25″ N. and long 77°32′07″ W.; 1,694 points counted.

P-75-11.–Biotite-muscovite quartzite; protolith probably a quartz arenite. Salem Church Quadrangle, Va., at lat 38°19′02″ N. and long 77°32′28″ W.; 2,428 points counted.

zircons that yielded discordant Pb-U ages interpreted by them as 560 m.y., and because they accepted the Quantico as conformable with the underlying Chopawamsic that is dated by zircons interpreted as 550 m.y. old, Seiders and others (1975) believe the Quantico is of Cambrian rather than Ordovician age. However, there are now serious discrepancies appearing in the literature concerning the absolute reliability of zircon ages in dating their host rock in particular situations. This problem has been investigated by Higgins and others (1977), who conclude that zircon ages from metavolcanic and metaplutonic rocks in this part of the central Piedmont may not represent real rock ages because (a) Piedmont zircons may have been contaminated by seed crystals derived from a Precambrian basement complex and thus may have inherited old radiogenic lead and (b) Piedmont zircons may also have lost lead and uranium during post-plutonic and volcanic Paleozoic metamorphism. Higgins and others (1977) further concluded that because the ages from Piedmont zircons are suspect and there is evidence for an unconformity between the Chopawamsic and Quantico (Pavlides, *in* U.S. Geol. Survey, 1973), the original Ordovician age of the Quantico should be reinstated on the basis of its fossil content as reported by Watson and Powell as well as its regional correlation.

Recently, along Powells Creek in the Quantico Quadrangle, I collected a loose slab of Quantico Slate within the outcrop belt on the Quantico, from along the creek bed, that contains forms I thought might be graptolites. William B. N. Berry of the University of California at Berkeley examined this slab and reported (written commun., June 13, 1975) "I have split the slate piece up and note that pyrite is pretty evenly sprinkled around through the piece and that it seems to be in cubes or near-cubes except for the few streaks that caught your eye as possible graptolites. I have looked at those streaks several times *quartzite lenses of the Quantico Formation*

or present in amounts <0.1 percent; n.d., not determined]

Sample number (top) and field number, P- (bottom)												
			Quartzite lens II				Quartzite lens III		Quartzite lens IV		Quartzite lens V	
11	12	13	14	15	16	17	18	19	20	21	22	23
74-21	74-22	74-23	70-91	70-92	70-92A	70-94	75-75	74-19	74-13	74-14	74-36	74-38
49.3	88.6	72.5	77.2	85.0	84.0	86.0	91.3	85.2	74.8	62.6	51.9	46.8
3.1	.8	17.8	16.5	7.8	2.7	3.0	2.3	7.4	.5	19.9	1.4	2.8
20.7	9.9	3.4	5.3	4.7	4.6	2.0	4.6	4.4	20.8	15.0	4.2	2.6
----	----	----	----	.1	.8	----	----	----	----	.9	----	----
----	----	----	----	----	----	----	----	----	.3	.2	----	----
----	----	----	----	----	----	----	----	----	----	----	----	----
25.6	.8	4.4	----	2.3	7.8	7.0	1.5	3.0	----	----	25.8	27.5
----	----	----	----	----	----	----	----	----	----	----	16.6	20.1
----	----	----	----	----	----	----	----	----	.2	.2	----	----
----	----	----	.1	----	----	----	----	----	----	----	----	----
23.8	10.7	21.2	21.8	12.5	7.3	5.0	6.9	11.8	21.3	35.8	5.6	5.4
1.2	----	1.9	.9	.1	----	1.0	.1	----	3.3	1.2	.1	.1
Normalized values used in ternary diagrams–Continued												
65	99	95	100	98	91	92	98	97	100	100	55	50
35	1	5	----	2	9	8	2	3	----	----	45	50
----	----	----	----	----	----	----	----	----	----	----	n.d.	n.d.

NOTES–Continued:

P-74-21.–Muscovite-biotite-plagioclase quartzite; protolith probably an arkosic wacke. Rock is granoblastic and fine grained. Plagioclase is approximately oligoclase-andesine in composition. Dimensional and lattice orientation of mica imparts foliation to the rock. A few grains of skeletal, poikiloblastic garnet are present. Salem Church Quadrangle, Va., at lat 38°18'37" N. and long 77°34'20" W.; 2,258 points counted.

P-74-22.–Biotitic quartzite; protolith probably a quartz wacke. Rock is granoblastic textured and contains dimensionally and lattice-oriented reddish-brown mica imparting foliation to the rock. Salem Church Quadrangle, Va., at lat 38°18'39" N. and long 77°34'12" W.; 2,755 points counted.

P-74-23.–Biotite-muscovite sulfidic quartzite; protolith probably a quartz wacke. Rock foliation is defined by dimensional and lattice oreintation of mica and dimensional orientation of quartz. Rock contains sulfide (pyrrhotite?) and sparse fine-grained zoisite. Salem Church Quadrangle, Va., at lat 38°18'44" N. and long 77°34'08" W.; 1,797 points counted.

P-70-91.–Biotite-muscovite quartzite; protolith probably a quartz wacke. Rock is fine grained and granoblastic textured and contains well-defined foliation imparted by dimensionally and lattice-oriented mica. Quartz is clouded with fine-grained inclusions. Muscovite and biotite are locally intergrown. Salem Church Quadrangle, Va., at lat 38°19'17" N. and long 77°33'52" W.; 2,220 points counted.

P-70-92.–Biotite-muscovite quartzite; protolith probably a quartz arenite. Rock is granoblastic and contains alined mica imparting the rock foliation. A second foliation occurs in interfolial quartzose layers containing mica alined at about 30° to the primary foliation. Plagioclase is untwinned. Salem Church Quadrangle, Va., at lat 38°19'02" N. and long 77°33'55" W.; 2,922 points counted.

P-70-92A.–Muscovite-biotite-plagioclase quartzite; protolith probably a quartz arenite. Rock is medium grained and heteroblastic and contains alined mica defining foliation; much mica also randomly oriented. Plagioclase is untwinned and twinned. Salem Church Quadrangle, Va., at lat 38°19'20" N. and long 77°33'55" W.; 2,118 points counted.

P-70-94.–Biotite-muscovite-plagioclase quartzite; protolith probably a quartz arenite. Rock is fine grained and contains strong mica alinement and weak dimensional orientation of quartz. Plagioclase is clouded with alteration. Salem Church Quadrangle, Va., at lat 38°19'25" N., and long 77°34'01" W.; 2,072 points counted.

P-75-75.–Muscovite-biotite quartzite; protolith probably a quartz arenite. Salem Church Quadrangle, Va., at lat 38°18'42" N. and long 77°35'17" W.; 2,787 points counted.

P-74-19.–Biotite-muscovite quartzite; protolith probably a quartz arenite. Rock is granoblastic textured and contains well-formed alined micas that impart the rock foliation.

P-74-13.–Biotite quartzite; protolith probably a quartz arenite. Skeletal helicitic garnet porphyroblasts enclose alined grains that have a different orientation than does the rock foliation. Salem Church Quadrangle, Va., at lat 38°19'31" N. and long 77°36'59" W.; 2,663 points counted.

P-74-14.–Biotite-muscovite quartzite; protolith probably a quartz wacke. Foliation is imparted by alined fine-grained biotite and muscovite formed by initial metamorphism (M_1). Biotite of a younger metamorphism (M_2) grows with its cleavage at a high angle to rock foliation and locally enclose M_1-biotite. M_2-biotite is locally chloritized. Skeletal, helicitic garnet poikiloblasts contain alined inclusion at an angle to rock foliation, suggesting garnet rotation after it enclosed earlier foliation. Salem Churcn Quadrangle, Va., at lat 38°19'42" N. and long 77°36'48" W.; 2,598 points counted.

P-74-36.–Biotite-feldspar quartzite; protolith probably a feldspathic arenite. Abundant microcline is probably metasomatically introduced from abundantly associated granitoid rocks of the Falmouth Intrusive Suite here. Salem Church Quadrangle, Va., at lat 38°18'25" N. and long 77°33'40" W.; 2,754 points counted.

P-74-38.–Micaceous feldspathic quartzite; protolith probably a feldspathic arenite. Rock is modified by potassic-feldspar mineralization, as is sample P-74-36. Salem Church Quadrangle, Va., at lat 38°18'47" N. and long 77°33'40" W.; 2,504 points counted.

now and think I can see a definite form in them. The forms taper and what could have been thecae do seem to be there. I have lifted the pyrite off the streaks and the shapes stay–indeed this pyrite looks different from that in the remainder of the slate piece. It is smeared out in a definite form and occurs as a thin film, whereas the pyrite on the rest of the rock is in cubes. Then, looking at the forms closely, not only do they taper, but they appear to curve at the tapered end, just as do many graptolites. So, on the basis of these observations, I am willing to say that there are some structures in the rock that have the appearance of graptolites." If this slab is indeed graptolitic, and contains graptoloids, as the thecea suggest, then it indicates an age for the Quantico no older than Ordovician.

It has been demonstrated that the Quantico syncline is continuous with the Columbia syncline; therefore, they are actually a single structurally complex syncline (Pavlides and others, 1974, fig. 8, and unpub. data) herein designated the Quantico-Columbia synclinorium. The Quantico Formation forms the core of this synclinorium. It unequivocally overlies the predominately metavolcanic Chopawamsic Formation along the northwest limb of the Quantico-Columbia synclinorium. The Ta River Metamorphic Suite, which is interpreted to be the more highly metamorphosed southeastern facies of the Chopawamsic and presumed coeval amphibolite of the "Hatcher Complex," lies along the southeast flank of the synclinorium stratigraphically beneath the Quantico. The contact between the

Quantico and Chopawamsic Formations is considered to be conformable northeastward from about the southern latitude of the Quantico Quadrangle (Southwick and others, 1971). This relationship was reported only along the northwest flank of the Quantico-Columbia synclinorium, as the southeast limb is covered by Coastal Plain sedimentary rocks at that latitude. However, evidence for an unconformity between the Quantico and the Chopawamsic south of the Quantico Quadrangle on both limbs of the Quantico-Columbia synclinorium has been found (Pavlides, 1973). In the Arvonia syncline (Brown, 1969), an unconformity also separates the Ordovician Arvonia Slate, which has close lithologic similarity to the Quantico, from the underlying metavolcanic rocks of the Chopawamsic and amphibolite of the Hatcher Complex of Brown (1969). Brown's Hatcher amphibolite is herein suggested to be a higher grade metavolcanic rock of the Chopawamsic Formation. The stratigraphic and lithologic similarity between the Arvonia syncline and Quantico-Columbia synclinorium is, therefore, striking.

The Quantico has classically been considered the same age as the fossiliferous Upper Ordovician part of the Arvonia, not only because of the fossils found by Watson and Powell (1911) within the Quantico but also because of the above cited stratigraphic and lithologic similarities. Because of the unresolved controversy as to the relevance of the zircon ages used by Seiders and others (1975) to discount the Ordovician age of the Quantico, the precise age of the Quantico cannot be unequivocally established at this time. However, the stratigraphic and lithologic criteria for a coequality of the Quantico and the Arvonia remain valid, and because of this, a Late Ordovician age for the Quantico is provisionally used in this report.

NOTE.—Since the preparations of this report, new data have been obtained by Louis Pavlides, John Pojeta, Jr., MacKenzie Gordon, Jr., R. L. Parsley, and A. R. Bobyarchick concerning the age of the Quantico Formation.

In the course of examining the Dale City pluton and its contact with the Quantico Formation in Dale City, Virginia, near the site of zircon sample 5 of Seiders and others (1975, fig. 1), fossils were discovered in the Quantico about 50 m northeast of the contact. These fossils consist primarily of crinoid stems with star-shaped lumens, a morphological development recognized at present only in Ordovician or younger age crinoids. Also an actinoceroid cephalopod, probably of Ordovician to Silurian age, is present in the collection. The age of the Dale City fossil collection therefore is probably of Ordovician or younger age. In addition, the lithologic and stratigraphic similarity of the Quantico to the Arvonia Slate of Middle to Late Ordovician age in the central Virginia Piedmont supports an Ordovician age for the Quantico.

The contact separating the Quantico Formation and Dale City pluton is in saprolitized terrane and was readily exposed at several places along one large outcrop. Sandy, fine- to medium-grained saprolite (quartzite) about 2 m thick, which is the basal unit of the Quantico, here grades upward imperceptably into slate typical of the Quantico. The quartzite (sandy saprolite) rests with sharp contact on saprolite of the plutonic rocks, which clearly lack a chill zone. Also, contact metamorphic effects are absent in the overlying sand and slate saprolite. Joints within the plutonic rock terminate abruptly at the contact. Canvas peel coats across the contact, made by Juergen Reinhardt, clearly demonstrate the local channel-like character of the sand and, in places, its well-layered to cross-bedded character. Clearly, this contact is an unconformity (nonconformity) and not an intrusive one; it is considered to be the same unconformity recognized in the Fredericksburg area (Pavlides, 1973).

There is now little reason to doubt the authenticity of the original Powells Creek collection made by Watson and Powell (1911) nor the identification by Bassler of *Pterinea demissa* of Late Ordovician age from this collection. Furthermore, because an unconformity separates the Quantico from the Dale City pluton, the approximately 560 million year discordant zircon age for the Dale City pluton is no longer inconsistent with the local geology. The Dale City pluton and its associate pre-Quantico rocks, therefore, are exposed within the strike belt of the Quantico, probably along a heretofore unrocognized anticline.

FALMOUTH INTRUSIVE SUITE

The Falmouth Intrusive Suite is named after the town of Falmouth on the north side of the Rappahannock River at the Fall Line (pl. 1). Rocks of this suite can be seen in the form of dikes and sills and of small irregular intrusions within exposures along the banks and in the stream-bed of the Rappahannock River upstream from Falmouth. Along this transect, the Falmouth Intrusive Suite intrudes, successively upstream from Falmouth, the Po River and Ta River Metamorphic Suites, the Falls Run Granite Gneiss, the Holly Corner Gneiss, and the Quantico Formation. The Falmouth includes chiefly strongly foliated to imperceptibly foliated granitoid and, less abundantly, nonfoliated pegmatoid rocks.

GRANITOID ROCKS

Some of the granitoid dikes have fine-grained selvages that grade inward to pegmatoid cores. Several generations of granitoid rocks are included in the Falmouth Intrusive Suite. This is readily apparent where some dikes are seen to crosscut others. Also some dikes are folded and crosscut by younger nonfolded dikes. In general, pegmatoid bodies are the youngest intrusions of the Falmouth in this terrane, as they invariably crosscut the granitoid dikes of the suite. Tables 8, 9, 10, and 11 include modal analyses of granitoid rocks of the Falmouth Intrusive Suite emplaced respectively in the Ta River and Po River Metamorphic Suites, the Falls Run Granite Gneiss, the Holly Corner Gneiss, and the Quantico Formation. The compositional ranges of the Falmouth granitoid rocks are shown in figures 9, 11, 12 and 13.

The Falmouth granitoid rocks range chiefly from monzogranite (adamellite) to granodiorite and less commonly to tonalite, and rarely, to quartz-rich granitoid rock (in terms of the classification scheme used). However, the Falmouth granitoid dikes emplaced in the Falls Run Granite Gneiss show the most restricted compositional

TABLE 8.—*Modal analyses, in percent, of granitoid rocks of the Falmouth Intrusive Suite emplaced in the Ta River and Po River Metamorphic Suites of the Fredericksburg Complex*

[Modal analyses by S. Linda Cranford (U.S. Geological Survey); __, absent or present in amounts <0.1 percent]

Mineral	Sample numbers (top) and field numbers, P–(bottom)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	75–62	75–60	75–59	75–58	75–55	75–54	75–53	75–52	75–39[1]	75–38[1]	75–3[1]	75–2[1]	75–1[1]	75–57	75–48	72–110
Quartz	24.9	23.8	31.0	31.4	40.2	32.3	33.6	37.7	30.2	37.6	30.4	36.4	37.7	21.3	28.8	30.4
Plagioclase	54.7	40.8	55.0	32.3	40.4	35.8	37.8	18.4	[2]39.4	47.5	43.8	36.6	36.0	39.4	32.7	40.4
Microcline	[3]10.2	24.4	[4]1.6	19.0	[3]15.9	[3]18.7	[3]17.4	31.0	17.1	----	10.4	5.5	18.0	[3]27.9	31.1	14.1
Biotite	1.3	1.9	11.4	----	1.7	10.7	7.4	7.8	10.7	7.0	13.3	7.6	5.2	1.8	1.8	10.0
Muscovite	8.0	4.0	----	17.1	.2	.3	1.8	2.4	----	----	.2	----	.8	7.2	3.6	.6
Hornblende	----	----	----	----	----	----	----	----	.2	6.0	----	1.5	----	----	----	----
Myrmekite	.9	5.1	----	.2	----	1.1	1.9	2.4	1.1	----	.5	.7	2.0	2.3	1.8	4.3
Garnet	----	----	.3	----	----	----	----	----	----	----	----	----	.1	----	----	----
Epidote	----	----	----	----	.6	1.1	.1	.2	1.2	1.4	1.0	1.6	----	----	----	----
Apatite	----	----	----	----	----	----	----	.1	.1	.2	.3	----	----	----	----	----
Sphene	----	----	----	----	.2	----	----	----	----	----	----	----	----	----	----	----
Opaque minerals	----	----	[5].6	----	[5].3	----	.1	----	.1	[5].2	----	[5].2	[5].3	----	----	.2
	Normalized values used in ternary diagrams															
Quartz	28	25	35	33	42	37	37	42	34	44	36	41	40	23	30	34
Plagioclase	61	49	63	39	42	42	44	23	46	56	52	53	41	46	37	50
Alkali feldspar	11	26	2	23	16	21	19	35	20	--	12	6	19	31	33	16

[1] From pluton at north edge of Salem Church Quadrangle, Va.

[2] Plagioclase is oligoclase-andesine in composition.

[3] Microcline plus orthoclase.

[4] Potassic feldspar is orthoclase.

[5] Opaque mineral is magnetite.

NOTES:

P-75-62.—Biotite-muscovite granodiorite. Rock is fine grained and allotriomorphic granular and has foliation defined by mica alinement. Salem Church Quadrangle, Va., at lat 38°16′50″ N. and long 77°35′32″ W.; 1,869 points counted.

P-75-60.—Biotite-muscovite granodiorite. Rock is fine grained and allotriomorphic granular and has weak foliation imparted by alined micas. Salem Church Quadrangle, Va., at lat 38°16′49″ N. and long 77°35′07″ W.; 2,572 points counted.

P-75-59.—Biotite tonalite. Rock is fine grained and allotriomorphic granular and has well-formed foliation imparted by alined green biotite. Poikilitic and nonpoikilitic garnet in anhedral to subhedral grains is a common accessory. This rock is crosscut by biotite-muscovite granodiorite (P-75-60). Salem Church Quadrangle, Va., at lat 38°16′49″ N. and long 77°35′07″ W.; 2,077 points counted.

P-75-58.—Muscovite granodiorite. Rock is allotriomorphic granular and contains alined muscovite imparting a strong foliation to the rock. Plagioclase is in twinned and untwinned grains that are commonly clouded. Myrmekite has a bulbous habit, and sparse nonpoikilitic garnet is accessory. Salem Church Quadrangle, Va., at lat 38°16′48″ N. and long 77°34′49″ W.; 2,884 points counted.

P-75-55.—Biotite granodiorite. Rock is fine grained and allotriomorphic granular and contains biotite and hornblende (sparse) in rude alinement that imparts foliation to the rock. Biotite is found as individual grains or intergrown with hornblende or epidote or both. Salem Church Quadrangle, Va., at lat 38°15′25″ N. and long 77°33′05″ W.; 2,317 points counted.

P-75-54.—Biotite granodiorite. Rock is allotriomorphic granular and contains alined biotite that imparts foliation to the rock. Salem Church Quadrangle, Va., at lat 38°16′09″ N. and long 77°33′40″ W.; 2,256 points counted.

P-75-53.—Muscovite-biotite granodiorite. Rock is allotriomorphic granular and contains alined mica imparting foliation to the rock. Salem Church Quadrangle, Va., at lat 38°16′15″ N. and long 77°33′40″ W.; 2,787 points counted.

P-75-52.—Muscovite-biotite monzogranite. Rock is allotriomorphic granular and contains alined micas imparting foliation to the rock. Quartz and some feldspar are also dimensionally alined along foliation. Garnet is present in poikilitic subhedral grains. Salem Church Quadrangle, Va., at lat 38°16′17″ N. and long 77°33′40″ W.; 2,793 points counted.

P-75-39.—Biotite granodiorite. Rock is foliated and contains dimensionally oriented quartz, oligoclase-andesine, microcline, and dimensionally and lattice-oriented dark-green biotite and green amphibole. Well-formed epidote, in part, has dimensional orientation. Myrmekite is always found in plagioclase at its contact boundary with microcline. Salem Church Quadrangle, Va., at lat 38°20′10″ N. and long 77°30′50″ W.; 2,340 points counted.

P-75-38.—Hornblende-biotite tonalite. Rock is fine grained and allotriomorphic granular and contains a superimposed foliation composed of dimensionally and lattice-oriented brown biotite and green hornblende and dimensionally oriented epidote in well-formed grains. Sparse cataclasis is present. Salem Church Quadrangle, Va., at lat 38°20′10″ N. and long 77°30′05″ W.; 2,291 points counted.

P-75-3.—Biotite granodiorite. Rock is fine grained and allotriomorphic granular and contains alined brown biotite imparting foliation to the rock. Myrmekite in plagioclase is characteristically at contacts with microcline. Salem Church Quadrangle, Va., at lat 38°19′47″ N. and long 77°30′30″ W.; 2,408 points counted.

P-75-2.—Hornblende-biotite tonalite. Rock is fine grained and allotriomorphic granular and has poorly formed foliation. Well-crystallized epidote is commonly in clots of brown biotite or green hornblende or both. Magnetite is in the form of euhedral and subhedral grains. Salem Church Quadrangle, Va., at lat 38°19′47″ N. and long 77°30′33″ W.; 2,371 points counted.

P-75-1.—Biotite granodiorite. Rock is fine grained and allotriomorphic granular and has foliation imparted by alined reddish-brown biotite. Plagioclase is both twinned and untwinned. Myrmekite in plagioclase is invariably present at contacts with microcline. Accessory garnet is in the form of nonpoikilitic subhedral to euhedral grains. Salem Church Quadrangle, Va., at lat 38°19′51″ N. and long 77°30′25″ W.; 2,303 points counted.

P-75-57.—Biotite-muscovite monzogranite. Rock is medium grained and allotriomorphic granular and contains alined micas imparting a moderate foliation to the rock. Micaceous folia also appear to define zones of cataclasis. Salem Church Quadrangle, Va., at lat 38°16′44″ N. and long 77°30′06″ W.; 2,785 points counted.

P-75-48.—Biotite-muscovite monzogranite. Rock is foliated and contains dimensionally oriented quartz and feldspar and dimensionally and lattice-oriented mica. Plagioclase is cloudy with very fine inclusions. Bulbous myrmekite is enclosed by microcline. Salem Church Quadrangle, Va., at lat 38°16′20″ N. and long 77°31′35″ W.; 2,029 points counted.

P-72-110.—Biotite granodiorite. Rock is fine grained and allotriomorphic granular and contains randomly oriented brown biotite. Some plagioclase is zoned. Salem Church Quadrangle, Va., at lat 38°19′32″ N. and long 77°30′16″ W.; 1,936 points counted.

range, being entirely monzogranite (adamellite) in composition (fig. 9) and having a quartz content that ranges from 30 to 36 percent. These rocks are also exceptionally myrmekitic, containing from 2 to 5 percent of this symplectite. The Falmouth granitoid rocks emplaced in the Ta River and Po River Metamorphic Suites are predominantly granodioritic in composition (fig. 11). Also, the Falmouth granitoid intrusions in the Holly Corner Gneiss and Quantico Formation are dominantly granodioritic or monzogranitic (adamellitic) in composition, although a few are tonalitic (figs. 12 and 13). Samples of Falmouth granitoid rocks in the Ta River and Po River Metamorphic Suites and in the granitoid plutons of Falmouth rocks are too few to show any discernible compositional characteristics.

PEGMATOID ROCKS

Dikes and irregular masses of pegmatoid rocks are the youngest rocks of the Falmouth Intrusive Suite. These rocks have not been studied extensively petrographically because their coarse grain size makes it difficult to determine their exact composition in thin section. Some of the finer grained pegmatoid rocks have graphic texture. In general, pegmatoid rocks range from muscovite-quartz-feldspar rocks to those in which muscovite is absent. Some appear to lack potassic feldspar and are tonalitic in composition.

AGE

Concordant zircon ages and two whole-rock Rb/Sr isochrons indicate that the Falmouth Intrusive Suite granitoid rocks are 300–340 million years old (Carboniferous) (Pavlides and others, 1979).

REGIONAL RELATIONSHIPS

The Quantico Formation probably everywhere overlies the Chopawamsic Formation unconformably. In several places a discontinuous micaceous quartzite is found at the base of the Quantico (pl. 1). A quartzite also is found at the base of the Arvonia Slate in the Arvonia syncline (Smith and others, 1974, pl. 1, and Brown, 1969, pl. 1). Along the northwest limb of the Quantico-Columbia synclinorium, the Quantico overlies the Chopawamsic, whereas on the southeast limb, it rests on the Ta River Metamorphic Suite. The Ta River is mostly amphibolitic at its north end and contains more biotite gneiss and mica schist (metasedimentary rocks) at its south end. A similar decrease in percentage of metavolcanic rock and an increase in schist and gneiss (metasedimentary rock) also takes place in the Chopawamsic at about the same latitude. The stratigraphic relations of the Quantico Formation, the Chopawamsic Formation, the Ta River and Po River Metamorphic Suites, and the Holly Corner Gneiss are schematically shown in figure 14.

At the south end of the Columbia-Quantico synclinorium, a southwest-trending belt of metavolcanic rocks, the Chopawamsic Formation as described elsewhere (Pavlides and others, 1974, p. 575–577, fig. 8), merges into a belt of amphibole-chlorite schist and amphibolite (Milici and others, 1963). These latter mafic rocks I consider to be contiguous with the Chopawamsic and to wrap around the northeast plunging nose of the Columbia syncline. They then trend northeastward along the southeast limb of the Columbia syncline (Pavlides and others, 1974, fig. 8). These mafic rocks of the Chopawamsic Formation eventually strike northeast into a belt of hornblende gneiss and granite (Milici and others, 1963), which in turn is on strike immediately farther northeast with the Ta River Metamorphic Suite of this report. The magnetic signature of the Ta River is also continuous with the terrane of hornblende gneiss and granite of Milici and others (1963) and with the mafic rocks of the Chopawamsic Formation along the southeast flank of the Columbia syncline. Hence, the Chopawamsic and the Ta River are considered to be

TABLE 9.—*Modal analyses, in percent, of granitoid rocks of the Falmouth Intrusive Suite in the Falls Run Granite Gneiss of the Fredericksburg Complex*

[Modal analyses by S. Linda Cranford (U.S. Geological Survey); ____, absent or present in amounts <0.1 percent]

Mineral	Sample number (top) and field number, P- (bottom)					
	1	2	3	4	5	6
	75–7	75–4	72–131	70–124	70–123	70–119
Quartz	29.2	28.2	32.3	29.3	33.1	28.6
Plagioclase	37.1	35.7	28.9	25.4	32.3	21.9
Microcline	22.8	[1]26.4	31.7	[1]38.3	[1]26.7	42.7
Biotite	6.1	3.9	1.7	2.4	5.5	2.5
Muscovite	1.1	1.1	.5	.5	____	____
Myrmekite	3.5	4.5	4.9	3.7	2.1	3.1
Epidote and Clinozoisite	.2	____	____	____	____	____
Apatite	____	____	____	.1	____	____
Opaque minerals	____	____	____	[2].4	____	.4
Other	____	____	____	____	[3].2	.7
Normalize values used in ternary diagrams						
Quartz	31	30	33	30	35	30
Plagioclase	44	42	35	30	37	26
Alkali feldspar	25	28	32	40	28	44

[1] Microcline and orthoclase.

[2] Opaque mineral is pyrite.

[3] Includes muscovite, apatite, sphene, and opaque minerals.

NOTES:

P–75–7.—Muscovite-biotite monzogranite. Rock is fine grained and allotrimorphic granular and has well-formed foliation imparted by alined brown biotie. Abundant bulbous myrmekite is found at plagioclase-microcline contacts. Some plagioclase is zoned, having a cloudy interior and clear margins. Salem Church Quadrangle, Va., at lat 38°19′50″ N. and long 77°31′30″ W.; 2,286 points counted.

P–75–4.—Muscovite-biotite monzogranite. Rock is fine grained and allotrimorphic granular and contains alined brown biotite imparting a weak rock foliation. Some microcline has interpenetrant perthite. Myrmekite in plagioclase is invariably in contact with microcline. Locally, plagioclase in contact with microcline has a clear albitic rim. Salem Church Quadrangle, Va., at lat 38°19′44″ N. and long 77°31′04″ W.; 2,224 points counted.

P–72–131.—Biotite monzogranite. Rock is nonfoliated and allotriomorphic granular. Ribbon perthite is locally present. Myrmekite is bulbous. Plagioclase is in twinned and untwinned grains, and green biotite is accessory. Salem Church Quadrangle, Va., at lat 38°22′02″ N. and long 77°30′22″ W.; 1,793 points counted.

P–70–124.—Biotite monzogranite. Rock is fine grained and allotriomorphic granular and contains alined biotite that imparts foliation to the rock; cruder and more subtle dimensional orientation of feldspar and quartz is also present. Plagioclase is generally untwinned. Salem Church Quadrangle, Va., at lat 38°19′27″ N. and long 77°31′17″ W.; 1,966 points counted.

P–70–123.—Biotite monzogranite. Rock is fine grained and allotriomorphic granular and contains alined biotite; quartz and plagioclase also have a subtle dimensional orientation. Some plagioclase has clear albitic rims where it is in contact with microcline. Salem Church Quadrangle, Va., at lat 38°19′25″ N. and long 77°31′18″ W.; 2,177 points counted.

P–70–119.—Biotite monzogranite. Rock is fine grained and allotriomorphic granular and has weak foliation imparted by alined biotite. Some plagioclase has clear albitic rims localized at contacts with microcline. Salem Church Quadrangle, Va., at lat 38°18′10″ N. and long 77°31′39″ W.; 1,939 points counted.

TABLE 10.—*Modal analyses, in percent, of granitoid rocks of the Falmouth Intrusive Suite in the Holly Corner Gneiss of the Fredericksburg Complex*

[Modal analyses by S. Linda Cranford (U.S. Geological Survey); __, absent or present in amounts < 0.1 percent]

Mineral	Sample number (top) and field number, P- (bottom)					
	1	2	3	4	5	6
	73-23	73-62	74-41	72-139	72-137	72-194
Quartz	32.0	36.2	31.6	32.3	31.5	28.0
Plagioclase	33.1	25.1	40.9	[1]41.5	42.2	33.2
Microcline	29.0	27.7	21.7	20.2	[2]15.9	32.3
Biotite	4.1	5.3	2.6	2.4	6.0	4.6
Muscovite	1.2	----	1.2	2.9	.4	.8
Myrmekite	.6	.4	2.1	.6	4.1	1.1
Opaque mineral	----	.1	----	----	----	.2
Other	----	[3]5.2	----	.2	----	----
Normalized values used in ternary diagrams						
Quartz	34	40	33	34	34	30
Plagioclase	35	29	45	45	49	36
Alkali feldspar	31	31	22	21	17	34

[1] Plagioclase is oligoclase.
[2] Microcline plus orthoclase.
[3] Includes apatite, epidote, and sphene.

NOTES:

P-73-23.—Muscovite-biotite monzogranite. Rock is massive, medium grained, and allotrimorphic granular. Brown biotite is chief accessory; muscovite occurs as primary accessory and as alteration in feldspar. Salem Church Quadrangle, Va., at lat 38°20′31″ N. and long 77°35′33″ W.; 1,954 points counted.

P-73-62.—Biotite monzogranite. Rock is streaky lineated, medium grained, and allotriomorphic granular; the streakiness is imparted by biotite and epidote that are intergrown in elongate clots. Biotite and epidote are also found as individual grains. Other accessories include well-formed sphene and apatite. Some patch perthite also is present. Salem Church Quadrangle, Va., at lat 38°21′08″ N. and long 77°34′26″ W.; 1,982 points counted.

P-74-71.—Muscovite-biotite granodiorite. Rock is massive, medium grained, and allotriomorphic granular. Salem Church Quadrangle, Va., at lat 38°18′19″ N. and long 77°32′30″ W. 2,209 points counted.

P-72-139.—Biotite-muscovite granodiorite. Salem Church Quadrangle, Va., at lat 38°18′39″ N. and long 77°32′23″ W.; 2,010 points counted.

P-72-137.—Biotite granodiorite. Salem Church Quadrangle, Va., at lat 38°18′25″ N. and long 77°32′06″ W.; 1,894 points counted

P-72-194.—Biotite, foliated, monzogranite. Salem Church Quadrangle, Va., at lat 38°20′40″ N. and long 77°33′01″ W.; 1,698 points counted.

coeval and coextensive, the Ta River being a more mafic and more metamorphosed eastward facies of the Chopawamsic. The allochthonous Holly Corner Gneiss (Pavlides, 1978) is also interpreted to be an eastward volcaniclastic facies of the Chopawamsic. Its structural provenance is not easily established. It may have been transported from east of the Ta River but west of the Spotsylvania lineament or perhaps from an area northeast of, but on strike with, the Ta River Metamorphic Suite.

Additional evidence that the Chopawamsic wraps around the Columbia syncline is provided by Good and others (1977, fig. 2 and p. 15), who also believe that the metavolcanic rocks (Chopawamsic Formation) that wrap around the nose of the Columbia syncline are at a higher metamorphic grade and merge into migmatite, a view expressed earlier by Conley and Johnson (1975). The more highly metamorphosed Chopawamsic rocks around the nose of the Columbia syncline were placed in the Hatcher Complex of Brown (1969) by Conley and Johnson (1975, p. 30). Also, Good and others (1977, p. 15) considered the metamorphosed mafic rocks and migmatite around the nose of the Columbia syncline to be similar to Brown's Hatcher Complex.

Brown (1969, pl. 1) shows his Hatcher Complex to be cut by a northeast-trending normal fault that bounds Triassic and Jurassic rocks of the Farmville Basin on their northwest side. This fault is along the projected strike of the Spotsylvania lineament (Mixon and Newell, 1977, fig. 1), whose linear continuity southward to the Farmville Basin fault is clearly demonstrated on regional aeromagnetic maps (see sections entitled "Spotsylvania lineament"). I suggest that the granitoid rock and augen gneiss of Brown's Hatcher Complex east of the fault bounding the Farmville Basin may be the equivalent, in part, of the Po River Metamorphic Suite of this report, which is also southeast of the Spotsylvania lineament. The Po River Metamorphic Suite and this part of Brown's Hatcher Complex have the same contiguous low-magnetic signature, as indicated on the aeromagnetic map of Virginia (Zeitz and others, 1978b). Brown's Hatcher Complex terrane within the Whispering Creek anticline, northwest of the Farmville Basin boundary fault and southwest of the Arvonia Slate on the southeast limb of the Arvonia syncline (Brown, 1969, pl. 1), is considered to be largely coeval and coextensive with the Ta River Metamorphic Suite. This correlation is supported by the coextensive aeromagnetic signature of high magnetic relief between the Ta River and the Whispering Creek anticline terrane, which can be seen on the aeromagnetic map of Virginia (Zeitz and others, 1978b), as well as by certain lithologic similarities. For example, the amphibolite-rich part of Brown's Hatcher Complex along the Whispering Creek anticline has areas of schist and garnet-amphibole-quartz rock which I believe are infolds of the Arvonia Slate (Brown, 1969, p. 42, pl. 1). This is similar to the infold of the Quantico Formation within the antiformal Ta River Metamorphic Suite in the Salem Church Quadrangle (pl.1).

Brown (1969, pl. 1) considered his Hatcher Complex to be in part equivalent to and older than the Evington Group, which is below the Arvonia Slate on the northwest limb of the Arvonia syncline. I consider the volcanic rocks of the Evington immediately below the Arvonia to be the Chopawamsic equivalent of central Virginia. Also Brown's Hatcher Complex along the Whispering Creek anticline is correlated, in part, as the eastern, more metamorphosed equivalent of the Chopawamsic. This is analogous to the Chopawamsic-Ta River correlation along the flanks of the Quantico-Columbia synclinorium. Figure 14 summarizes the regional correlation.

Some major problems are involved in correlating the Chopawamsic Formation along the northwest flank of

TABLE 11.—*Modal analyses of granitoids of the Falmouth*

[Modal analyses by S. Linda Cranford (U.S. Geological Survey); ____, absent

Mineral	Sample number (top) and field number, P- (bottom)							
	1 74–17	2 74–16	3 70–98	4 70–96	5 73–21	6 73–26	7 73–18	8 73–41
Quartz	26.9	29.7	57.5	30.4	47.1	34.9	30.4	29.1
Plagioclase	39.8	42.3	4.8	53.2	[2]31.6	[3]51.5	38.4	[2]39.1
Microcline	28.4	[4]21.4	23.2	5.0	____	____	[4]22.2	25.7
Biotite	2.8	4.8	5.9	2.6	____	2.3	2.0	4.7
Muscovite	1.4	1.7	7.3	8.8	21.3	11.3	5.5	0.6
Myrmekite	.7	2.7	1.2	.1	____	____	1.4	0.6
Apatite	____	.1	____	____	____	____	.1	____
Chlorite	____	____	.1	____	____	____	____	____
Opaque minerals	____	____	____	____	____	____	____	____
Other	____	____	____	____	____	____	____	____
	Normalized values used in ternary diagrams							
Quartz	28	32	66	34	60	40	33	31
Plagioclase	42	45	7	60	40	60	43	42
Alkali feldspar	30	23	27	6	____	____	24	27

[1] From pluton in north-central part of the Salem Church Quadrangle, Va. Pluton also intrudes Holly Corner Gneiss of the Fredericksburg Complex.

[2] Plagioclase is oligoclase.

[3] Plagioclase is albite-oligoclase.

[4] Microcline plus orthoclase.

NOTES:

P-74-17.—Muscovite-biotite-monzogranite. Rock is medium grained and allotriomorphic granular. Mica alinement imparts foliation, although dimensional orientation of quartz is also present. Muscovite is coarser grained than biotite. Salem Church Quadrangle, Va., at lat 38°18′15″ N. and long 77°37′03″ W.; 2,367 points counted.

P-74-16.—Muscovite-biotite-granodiorite. Rock is medium grained and allotriomorphic granular. Alined micas impart foliation to the rock. Myrmekite is in plagioclase where it is in contact with microcline. Salem Church Quadrangle, Va., at lat 38°19′21″ N. and long 77°36′21″ W.; 2,919 points counted.

P-70-98.—Biotite-muscovite quartz-rich granitoid. Rock is porphyritic, fine grained, and locally foliated. Salem Church Quadrangle, Va., at lat 38°20′18″ N. and long 77°36′23″ W.; 1,140 points counted.

P-70-96.—Biotite-muscovite tonalite. Rock is fined grained and contains alined biotite along foliation and dispersed through groundmass. Muscovite is in coarser plates and imparts the foliation to the rock. Annealed cataclastic streaks are present and alined along foliation. Salem Church Quadrangle, Va., at lat 38°20′22″ N. and long 77°36′20″ W.; 2,218 points counted.

P-73-21.—Muscovite tonalite. Rock is medium grained and graphic textured and grades into pegmatite. Salem Church Quadrangle, Va., at lat 38°20′29″ N. and long 77°36′14″ W.; 2,762 points counted.

P-73-26.—Biotite-muscovite tonalite. Rock is medium grained and allotriomorphic granular. Alined brown biotite imparts foliation to the rock. Salem Church Quadrangle, Va., at lat 38°20′05″ N. and long 77°36′16″ W.; 2,262 points counted.

P-73-18.—Biotite-muscovite granodiorite. Rock is medium grained and allotriomorphic granular. Alined micas impart foliation to the rock. Plagioclase is clouded by alteration, whereas potassic feldspar is fresh. Salem Church Quadrangle, Va., at lat 38°20′50″ N. and long 77°36′05″ W.; 2,151 points counted.

P-73-41.—Muscovite-biotite-monzogranite. Rock is medium grained and allotriomorphic granular. Brown biotite is locally chloritized (sparse). Salem Church Quadrangle, Va., at lat 38°20′37″ N. and long 77°35′00″ W.; 2,325 points counted.

the Quantico-Columbia synclinorium and Arvonia syncline with the Ta River Metamorphic Suite and the correlative parts of Brown's Hatcher Complex. Outstanding among these are the presence of metamorphosed felsic rocks in the Chopawamsic and the almost total absence of metamorphosed felsic rocks in the more highly metamorphosed Ta River and in the correlative parts of the Brown's Hatcher Complex. Quartz keratophyre intercalated with amphibolite of the Ta River has been observed in the southwest corner of the Stafford Quadrangle (Pavlides, 1976, fig. 2, and p. 8; see caption of ga unit). The general absence of felsic rocks in the Ta River and its correlatives to the southwest may be a result of lithologic facies change over a short distance in a southeastward direction within the Chopawamsic, whereby felsic volcanic rocks decrease in abundance in the section and only mafic volcanic rocks are present. This necessitates that the lithologic change took place abruptly, somewhere beneath the Quantico-Columbia synclinorium and Arvonia syncline, an assumption that cannot be readily tested by field observations. That some of the conformable granitoid rocks in the Ta River and its equivalents in Brown's Hatcher Complex to the southwest may be metamorphosed felsic volcanic rocks is an alternative possibility, but considerable petrochemical studies will be needed to evaluate this hypothesis.

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Intrusive Suite in the Quantico Formation

or present in amount < 0.1 percent]

Sample number (top) and field number, P- (bottom)										
9	10	11	12	13	14	15	16	17	18	19
73-57	70-114	70-88	70-117	70-86	74-37	70-93	76-119A	73-58[1]	73-31	70-102[1]
20.9	33.1	36.5	37.2	39.8	29.3	36.5	24.2	24.2	32.0	31.4
50.3	[2]37.8	[2]33.7	[2]34.2	35.3	[2]43.0	38.8	36.5	[2]42.1	[2]38.7	[2]43.0
16.8	[4]13.8	[4]24.3	11.1	14.1	20.0	14.9	35.5	25.9	25.6	[4]15.4
8.5	7.2	2.5	8.6	5.1	1.8	3.4	2.4	6.5	2.5	7.1
1.5	6.9	1.6	8.4	2.1	5.3	6.0	.9	----	.7	2.7
1.8	1.3	1.3	.1	3.5	.5	----	.2	.3	.5	.4
----	----	----	.1	----	----	----	----	----	----	----
----	----	----	----	----	----	----	----	----	----	----
.1	----	----	.3	----	----	.2	----	----	----	----
.2	----	----	----	.1	----	.1	.1	.9	----	.1
Normalized values used in ternary diagrams – Continued										
23	38	38	45	43	32	40	25	26	33	35
58	46	37	42	42	47	43	38	46	40	48
19	16	25	13	15	21	17	37	28	27	17

NOTES – Continued:

P-73-57. – Muscovite-biotite-granodiorite. Rock is fine grained and allotriomorphic granular. Rude compositional "layering" is defined by microcline-rich and plagioclase-rich zones. Salem Church Quadrangle, Va., at lat 38°20'16" N. and long 77°34'24" W.; 2,403 points counted.

P-70-114. – Muscovite-biotite granodiorite. Rock is medium grained and allotriomorphic granular and sparsely sulfidic. Salem Church Quadrangle, Va., at lat 38°19'51" N. and long 77°33'13" W.; 2,197 points counted.

P-70-88. – Muscovite-biotite-monzogranite. Rock is medium grained and allotriomorphic granular. Feldspars are generally poikilitic and commonly enclose quartz grains. Myrmekite is characteristically formed in plagioclase that is in contact with potassic feldspar. Salem Church Quadrangle, Va., at lat 38°18'35" N. and long 77°33'16" W.; 2,235 points counted.

P-70-117. – Muscovite-biotite granodiorite. Rock is fine grained and allotriomorphic granular. Muscovite and microcline are poikilitic. Salem Church Quadrangle, Va., at lat 38°19'38" N. and long 77°32'55" W.; 2,347 points counted.

P-70-86. – Muscovite-biotite granodiorite. Rock is medium grained and allotriomorphic granular. Salem Church Quadrangle, Va., at lat 38°18'44" N. and long 77°32'54" W.; 1,708 points counted.

P-74-37. – Biotite-muscovite granodiorite. Rock is fine grained and allotriomorphic granular. Plagioclase is found as twinned and untwinned grains and is partly altered by fine-grained flakes of muscovite. Salem Church Quadrangle, Va., at lat 38°18'29" N. and long 77°33'20" W.; 2,332 points counted.

P-70-93. – Biotite-muscovite granodiorite. Rock is weakly foliated, medium grained, and allotriomorphic granular. Plagioclase is zoned, its core showing greater muscovitic alteration than does its rim. Alined brown biotite and muscovite impart rock foliation. Salem Church Quadrangle, Va., at lat 38°19'25" N. and long 77°34'01" W.; 2,263 points counted.

P-76-119A. – Biotite monzogranite. Lake Anna West Quadrangle, Va., at lat 38°05'14" N. and long 77°47'01" W.; 2,473 points counted.

P-73-58. – Biotite monzogranite. Rock is fine grained and allotriomorphic granular. Alined brown biotite imparts a rude foliation to the rock. Salem Church Quadrangle, Va., at lat 38°20'16" N. and long 77°34'33" W.; 2,524 points counted.

P-73-31. – Biotite monzogranite. Rock is medium grained and allotriomorphic granular. Alined reddish-brown biotite imparts a rude foliation to the rock. Salem Church Quadrangle, Va., at lat 38°20'08" N. and long 77°35'29" W.; 2,102 points counted.

P-70-102. – Biotite granodiorite. Rock is fine grained and allotriomorphic granular. Alined biotite imparts rude foliation to the rock. Salem Church Quadrangle, Va., at lat 38°20'52" N. and long 77°34'39" W.: 2,237 points counted.

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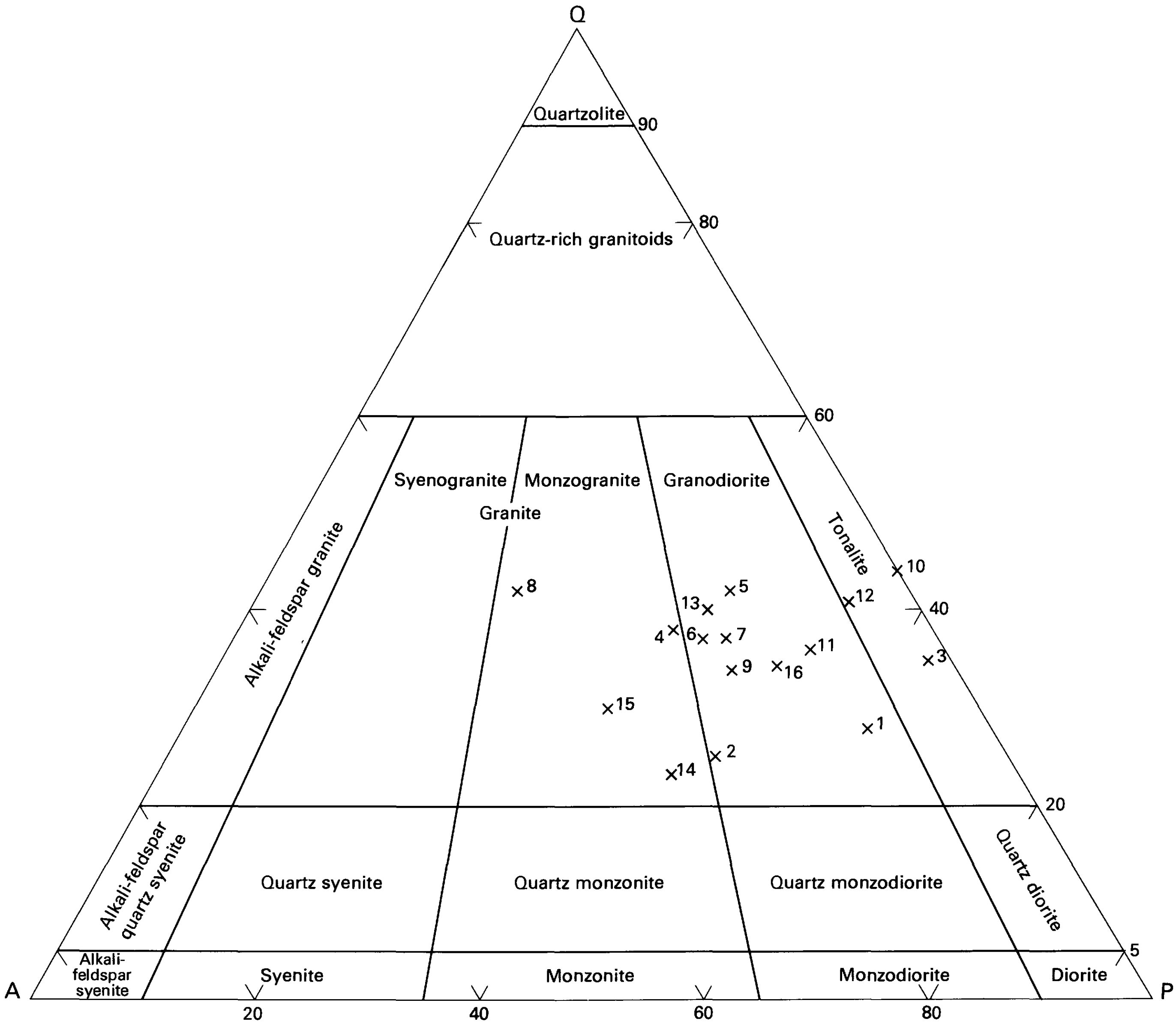

FIGURE 11.–Compositional range of the Falmouth Intrusive Suite granitoid rocks in the Ta River and Po River Metamorphic Suites of the Fredericksburg Complex. Q, quartz; A, alkali feldspars; P, plagioclase. Sample numbers refer to those on table 8.

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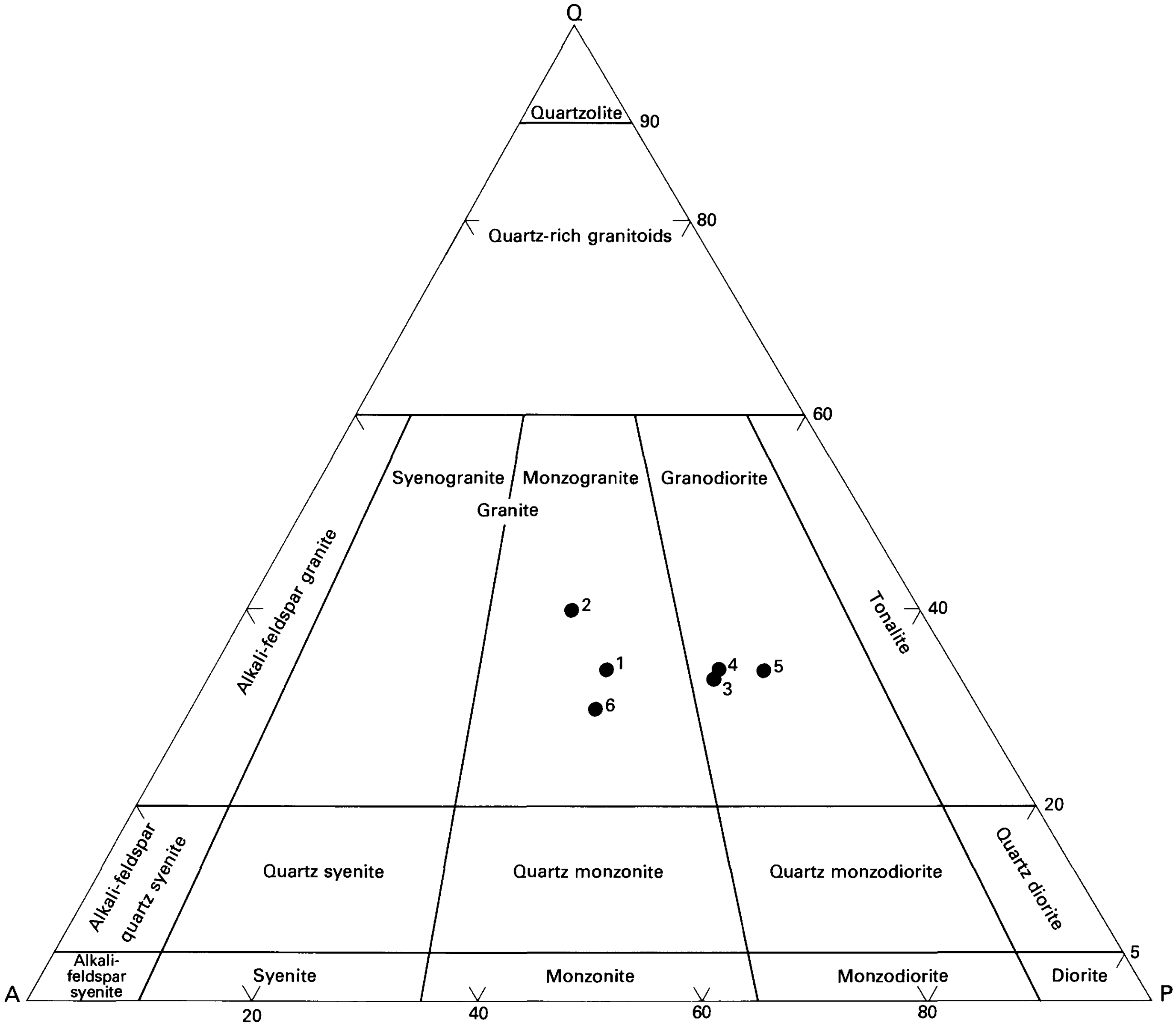

FIGURE 12. – Compositional range of the Falmouth Intrusive Suite granitoid rocks in the Holly Corner Gneiss of the Fredericksburg Complex. Q, quartz; A, alkali feldspars; P, plagioclase. Sample numbers refer to those on table 10.

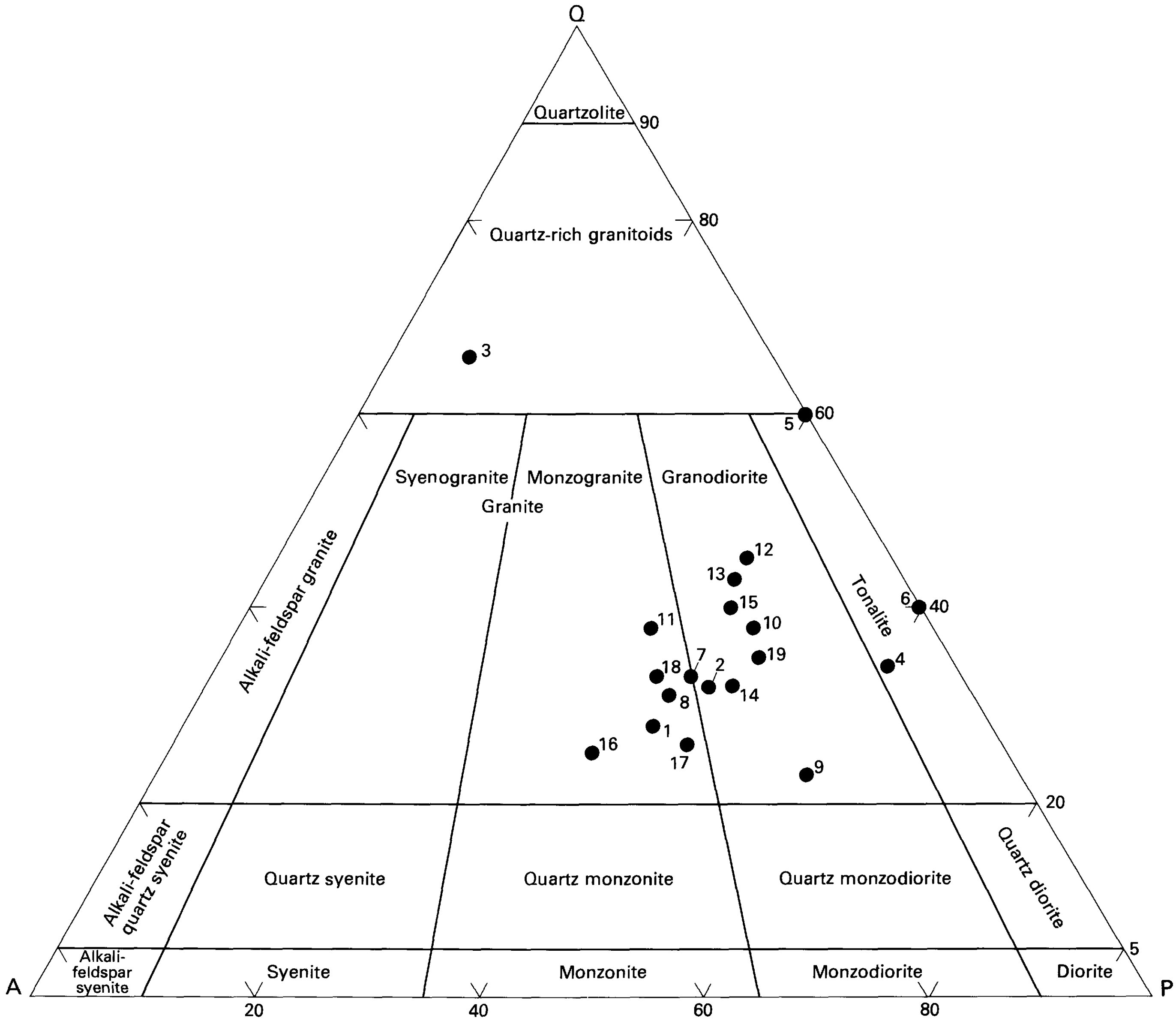

FIGURE 13.–Compositional range of the Falmouth Intrusive Suite granitoid rocks in the Quantico Formation. Q, quartz; A, alkali feldspar; P, plagioclase. Sample numbers refer to those on table 11.

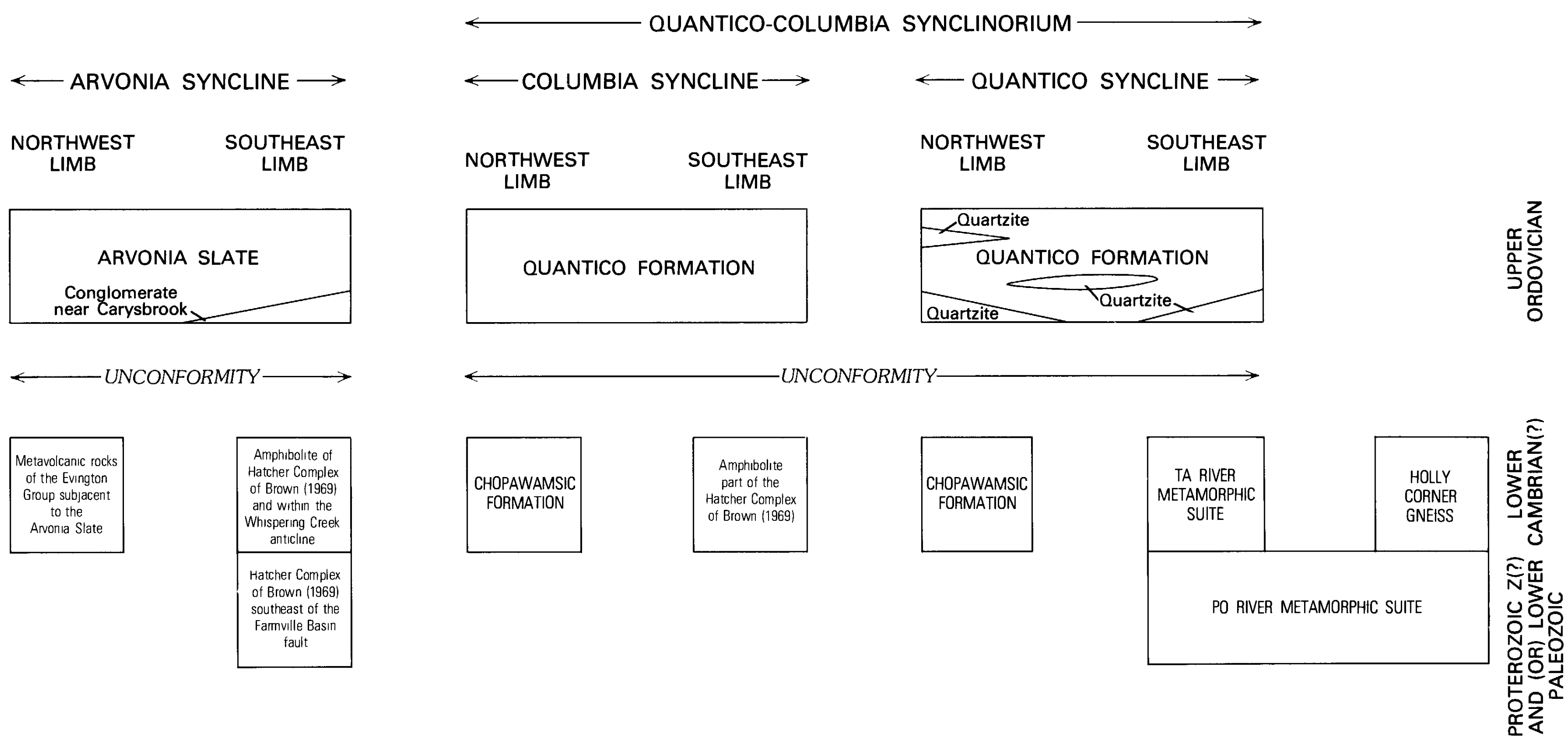

FIGURE 14.—Correlation diagram of the Fredericksburg Complex, gneiss of the Hatcher Complex of Brown (1969), and some rocks of the Quantico-Columbia synclinorium and the Arvonia syncline.