The Chopawamsic Formation— A New Stratigraphic Unit in the Piedmont of Northeastern Virginia

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CONTRIBUTIONS TO STRATIGRAPHY

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Description of a sequence of felsic, intermediate, and mafic metavolcanic and metasedimentary rocks

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By D. L. Southwick, John C. Reed, Jr., and R. B. Mixon

ABSTRACT

The name Chopawamsic Formation is introduced for a sequence of felsic, intermediate, and mafic metavolcanic and metasedimentary rocks in northeastern Virginia. No fossils have been found in the Chopawamsic, but it conformably underlies the Quantico Slate of Ordovician age and conformably overlies and interfingers with mica gneiss of the Wissahickon Formation of late Precambrian(?) age. The unit is estimated to be 6,000-10,000 feet thick. It is very likely correlative with the volcanic rocks beneath the Arvonia Slate in central Virginia and with the James Run Gneiss and volcanic complex of Cecil County, Md. It may also be correlative with parts of the sedimentary and volcanic sequence of the Carolina slate belt.

INTRODUCTION

The name Chopawamsic Formation is here introduced for a sequence of interbedded metavolcanic and metasedimentary rocks that conformably underlies the Quantico Slate of Ordovician age (Watson and Powell, 1911) on the northwestern limb of the Quantico syncline in the Occoquan, Quantico, Joplin, and Stafford 7½-minute quadrangles, Prince William and Stafford Counties, Va. The formation rests on and interfingers with pebbly mica gneiss of the Wissahickon Formation of late Precambrian(?) age. The formation can be divided into three principal lithologic units: (1) metamorphosed medium- to thick-bedded mafic to intermediate volcanic rocks derived from andesitic to basaltic flows, coarse breccias, and finer tuffaceous clastic rocks; (2) metamorphosed medium- to thick-bedded felsic volcanic rocks derived from flows and associated volcaniclastic accumulations; and (3) metamorphosed thin- to medium-bedded volcaniclastic rocks of felsic to mafic composition, locally containing beds of nonvolcanic quartzose metagraywacke, green to gray phyllite, and felsic to mafic flows. Units 1 and 2 grade vertically and laterally into unit 3 and appear to be tongues or lenses within a complex volcanic-sedimentary pile.

The geologic structure of the northwestern limb of the Quantico syncline is relatively simple. Bedding strikes N. 25°-35° E., and dips are generally vertical but range from 70° NW. to 60° SE. Slaty cleavage in the Quantico Slate and schistosity in the Chopawamsic Formation are parallel or subparallel to bedding. Graded bedding is recognizable in only a few places but indicates tops of beds are consistently to the southeast. There is no evidence in either individual outcrops or in map patterns of any large-scale repetition of stratigraphic units. If one assumes that the average dip is about vertical, the thickness of the Chopawamsic Formation is estimated to range from 6,000 to 10,000 feet.

The rocks here referred to the Chopawamsic Formation were mentioned briefly by Watson and Powell (1911, p. 39) as "phyllites and schists." They recognized the tuffaceous character of some beds near the base of the Quantico Slate but did not mention the volcanic rocks beneath the slate. Lonsdale (1927) recognized and described the following rock types among those we include in the Chopawamsic Formation: greenstone schist, quartz schist with biotite and feldspar, hornblende quartz schists often with chlorite, sericite quartz schists often with epidote and chlorite, and arkosic quartzite. He suggested that the greenstone schist was of volcanic origin and noted the occurrence (p. 61) of "* * * areas which resemble amygdaloidal cavities of basalt." On the 1928 geologic map of Virginia (Virginia Geol. Survey, 1928), the bulk of the rocks of the Chopawamsic Formation are mapped as "Peters Creek quartzite," but some bodies of greenstone are mapped separately. The contacts shown are from Lonsdale (1927). On the later State geologic map (Virginia Div. Mineral Resources, 1963), the contacts are virtually the same as on the 1928 map, but the Chopawamsic Formation is correctly mapped as "metamorphosed volcanic and sedimentary rocks."

TYPE SECTION AND REFERENCE SECTIONS

The Chopawamsic Formation is named for its exposures along Chopawamsic Creek on the Quantico Marine Base in the Joplin 7½-minute quadrangle (Ⓣ on fig. 1). The unit crops out along the creek from a point 1.13 miles S. 45° W. of the crossroads of Joplin to a point 2.46 miles S. 6° E. of Joplin. These exposures are designated as the type section. Outcrops of the lower half of the formation are very few because the valley has been flooded by Breckenridge Reservoir, but the upper half of the formation is well exposed in semicontinuous slabs along the stream below the dam. Neither the upper (southeastern) or lower (northwestern) contact are exposed in the type section, but both can be located within a few feet, on the basis of float and scattered outcrops. The lower contact is placed at the abrupt change from medium-grained feldspathic mica gneiss of the Wissahickon Formation to fine-grained thinly interlayered amphibole schist, amphibolite, and feldspathic schists of the Chopawamsic. The upper contact is placed at the first occurrence of dark-gray to black graphitic slate typical of the Quantico Slate. The thickness of the formation in the type section is estimated to be about 10,000 feet.

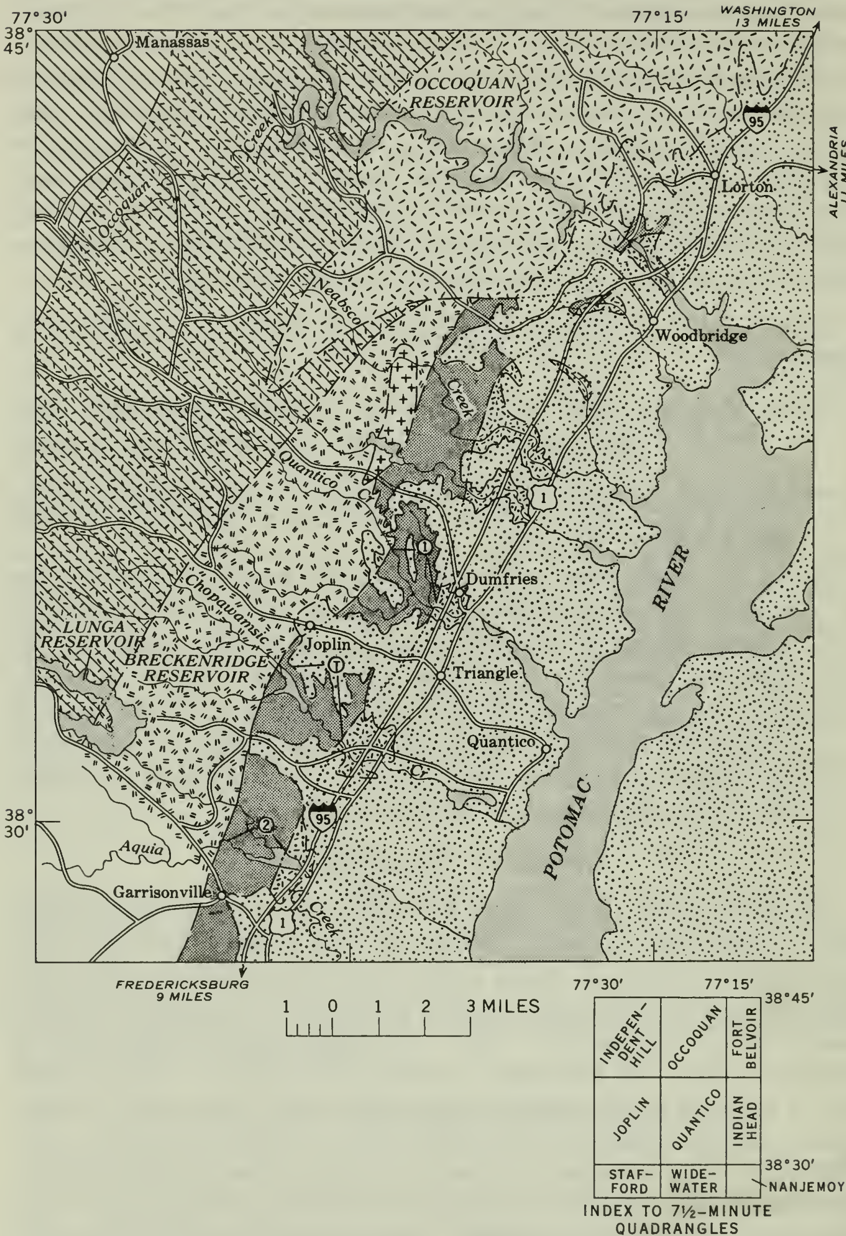
Reference sections of the Chopawamsic Formation are designated as follows:

1. Along Quantico Creek in the Quantico 7½-minute quadrangle from a point 0.19 mile upstream (west) from Interstate Highway 95 to a point 400 feet downstream from the dam near Camp No. 4 in Prince William Forest Park. The thickness of the formation in this section is about 8,000 feet.
2. Along the north shore of the new reservoir on Aquia Creek in the Stafford 7½-minute quadrangle and along Aquia Creek above the reservoir for about 0.76 mile upstream. The lower contact of the formation crosses the creek about 1.3 miles N. 5° E. of Garrisonville; the upper contact is well exposed along the north shore of the reservoir about 0.75 mile N. 52° E. of the bridge on which Interstate Highway 95 crosses Aquia Creek. The thickness of the formation in this section is about 6,000 feet.

CONTACT RELATIONS

The contact of the Chopawamsic Formation with the overlying Quantico Slate is gradational. Contact relations are well exposed along the north shore of the reservoir on Aquia Creek (reference section 2). There the black graphitic Quantico Slate contains scattered 1- to 6-inch-thick graded sandy and silty (tuffaceous?) layers that indicate top of beds is to the southeast. About 100 feet above the base of the slate is a 100-foot-thick unit of medium- to fine-grained schistose felsic tuff. This rock is strongly cleaved and recrystallized, but contains flattened angular fragments, probably lapilli. The schistose tuff occurs in beds as much as 20 feet thick interlayered with very finely interlaminated gray metasiltstone and black slate. The tuffaceous unit probably was deposited from submarine pyroclastic ash flows.

Below (northwest of) the schistose felsic tuff unit is another 50-100 feet of black graphitic slate, interbedded near the base with 1- to 6-inch-thick beds of metamorphosed coarse tuffaceous sandstone that contain



77°30'
77°15'
38° 45'
WASHINGTON 13 MILES
ALEXANDRIA 11 MILES
Manassas
OCCOQUAN RESERVOIR
Occoquan
Creek
95
Lorton
Neabsco
Creek
Woodbridge
Quantico
Cr
1
Dumfries
RIVER
Chopawamsic
Joplin
LUNGA RESERVOIR
BRECKENRIDGE RESERVOIR
Triangle
Quantico
Cr
38° 30'
Aquia
Garrisonville
Creek
POTOMAC
FREDERICKSBURG 9 MILES
1 0 1 2 3 MILES
77°30' 77°15'
38°45'
INDEPEN-DENT HILL
OCCOQUAN
FORT BELVOIR
JOPLIN
QUANTICO
INDIAN HEAD
38°30'
STAF-FORD
WIDE-WATER
NANJEMOY
INDEX TO 7½-MINUTE QUADRANGLES

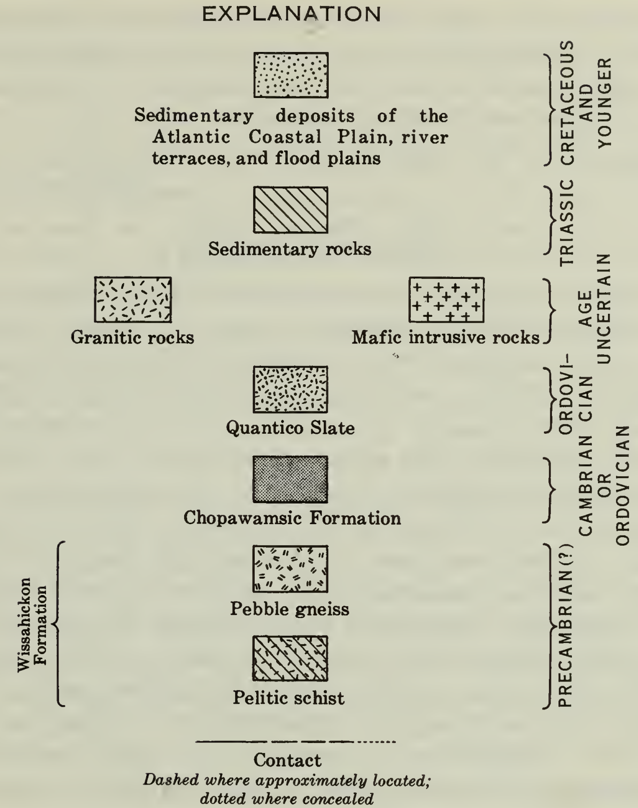


FIGURE 1.—Sketch map showing outcrop belt of the Chopawamsic Formation in the Occoquan, Quantico, and Joplin quadrangles and part of the Stafford quadrangle. Circled symbols refer to sections mentioned in text: (T), type section along Chopawamsic Creek; ①, reference section 1 along Quantico Creek; ②, reference section 2 along Aquia Creek. Geology in the Quantico and adjacent parts of Joplin and Stafford quadrangles based on detailed mapping by the authors; geology in part of the Occoquan quadrangle based on mapping by V. M. Seiders. Other geologic map details sketched from State geologic map (Virginia Div. Mineral Resources, 1963).

angular fragments of fine-grained light-colored sericite phyllite (probably pumice lapilli), granules of light-blue quartz 0.1-0.25 inch in diameter, and angular chips of black slate as much as 1 inch in diameter. The sequence of interbedded slate and tuffaceous sandstone is about 100 feet thick and is underlain by mafic volcanic breccia and amygdaloidal greenstone typical of the mafic parts of the Chopawamsic Formation. The contact between the Quantico Slate and the Chopawamsic Formation is placed at the lowest continuous bed of graphitic slate in the interbedded slate-sandstone sequence.

Nowhere else is the upper contact of the Chopawamsic Formation well exposed, but similar relations can be inferred from float and scattered outcrops along Quantico Creek (reference section 1) and Neabsco Creek, both in the Quantico 7½-minute quadrangle.

No exposures of the lower contact of the Chopawamsic Formation have been located, but its position can be inferred within a few feet in the type section and in both reference sections. In these sections the Wissahickon Formation northwest of the contact is a massive nonlayered and weakly foliated medium- to coarse-grained feldspathic biotite-muscovite gneiss containing scattered pebbles of quartz. It closely resembles the boulder gneiss lithofacies of the Wissahickon Formation of Southwick and Fisher (1967, p. 12-13). Locally the gneiss contains pebbles, cobbles, and boulders of metagraywacke, biotite schist, laminated metasiltstone, and chlorite-actinolite schist, some of them identical with rock types found in the Chopawamsic Formation. This body of pebble gneiss has an outcrop width of at least 15,000 feet in the Quantico and Joplin 7½-minute quadrangles. It has been traced along strike from Neabsco Creek in the Occoquan 7½-minute quadrangle as far southwest as Aquia Creek in the Stafford quadrangle, a distance of about 10 miles. Northwestward it apparently grades into a fine-grained pelitic schist or phyllite facies of the Wissahickon Formation. In Quantico Creek (reference section 1) and in all sections to the southwest, the contact between the Chopawamsic Formation and the Wissahickon is apparently sharp. There is no evidence of interbedding or gradation but neither is there evidence of structural discordance.

Northeast of Quantico Creek, in the northwestern part of the Quantico and southwestern part of the Occoquan quadrangles, map patterns strongly suggest that parts of the Wissahickon Formation interfinger northeastward with and pass laterally into the basal part of the Chopawamsic Formation. Along Neabsco Creek southeast of Virginia Highway 640, pebble gneiss of the Wissahickon Formation containing numerous pebbles of fine-grained greenstone is locally interbedded with bedded mafic tuff, mafic volcanic breccia, and a medium-grained strongly foliated greenish-gray biotite gneiss containing distinctive round granules of sky-blue quartz 0.25-0.5 inch in diameter. The last-named rock was described by Lonsdale (1927, p. 68-69) as arkosic quartzite. The rock probably was derived from a volcanic sediment, but it is not clear whether the quartz granules are clastic grains, resorbed phenocrysts, or possibly amygdule fillings. It is here included in the Chopawamsic Formation.

The suggestion that parts of the Wissahickon and Chopawamsic Formations are lateral equivalents is further substantiated by the presence of pebbles similar to the volcanic rocks of the Chopawamsic Formation in

Wissahickon gneiss that is northwest of the Chopawamsic outcrop belt. This indicates that some of the pebble gneiss is younger than some of the volcanic rocks of the Chopawamsic. Excellent exposures of gneiss containing such pebbles occur along Quantico Creek just east of the footbridge south of Camp No. 1 in Prince William Forest Park (Quantico 7½-minute quadrangle).

PRIMARY FEATURES

Shearing and recrystallization have erased sedimentary and volcanic structures and textures from some parts of the Chopawamsic Formation, but in many places primary features are well preserved.

Amygdular flows of andesitic greenstone are exposed in the floor of a shallow gravel pit near the south branch of Quantico Creek just below Camp No. 3 in Prince William Forest Park (Quantico 7½-minute quadrangle), and at several localities in the gorge farther downstream (reference section 1). The amygdules are as large as 1 cm (centimeter), tectonically flattened, and filled with quartz, calcite, albite, epidote, or combinations of these minerals. Farther downstream, about 0.2 mile northwest of Interstate Highway 95, are exposures of a coarse mafic breccia consisting of ovoid clasts as long as 2 feet. The clasts are all composed of slightly amygdular greenstone and are in a fine-grained matrix of nearly identical composition. Interbedded with a breccia are units of laminated siltstone (now schistose) a few inches to a few feet thick.

Felsic rocks with relict phenocrysts of oligoclase and quartz occur in the formation east of Camp No. 4 in Prince William Forest Park (Quantico 7½-minute quadrangle). The phenocrysts generally are smaller than 1 mm (millimeter) and invariably show some evidence of granulation and recrystallization. The oligoclase phenocrysts that have withstood these effects show only faint zoning and are in general simply twinned. Groundmass textures have not survived metamorphism.

Some parts of the formation have well-preserved thin beds of intimately interlayered felsic and mafic schists. Some beds locally show internal laminations. Subangular to subrounded grains of clastic quartz are preserved in a few sandy beds, and in a few places graded beds are found. Locally some thin beds have complex internal deformation, probably due to slumping. These features are well shown in outcrops in the type section along Chopawamsic Creek about 0.15 mile below the dam.

MINERALOGY AND PETROGRAPHY

The rocks of the Chopawamsic Formation are fine-grained gray-green, gray, or white schists or granofels composed of minerals typical of the greenschist facies of metamorphism. Quartz, sodic plagioclase, epidote,

TABLE 1.—*Mineral assemblages observed in the Chopawamsic Formation*

Minerals	Assemblage														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Quartz	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Sodic plagioclase[1]	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Microline	—	—	—	—	—	—	—	—	—	—	—	—	×	×	×
Epidote	—	×	×	×	×	×	—	×	—	—	×	×	×	×	—
Chlorite	×	×	×	×	×	—	×	×	×	×	×	×	×	×	×
Biotite	—	—	×	—	×	×	×	×	×	×	×	×	×	×	×
Actinolite[2]	×	×	×	×	×	×	×	—	—	—	—	—	—	—	—
Muscovite	—	—	—	—	—	—	×	—	×	×	×	—	×	×	×
Carbonate	—	—	—	×	×	—	—	—	×	—	—	×	—	×	—

[1] The composition of the sodic plagioclase has not been determined precisely. In some rocks it is albite, but in others it contains some anorthite.

[2] All pale-bluish-green amphiboles are lumped under the term actinolite, even though some are probably aluminous and may properly be called hornblendes.

chlorite, biotite, actinolite, and muscovite are the principal minerals (table 1). The felsic rocks differ mineralogically from the mafic ones chiefly in having more plagioclase and quartz. Chlorite, biotite, and actinolite all occur in the felsic rocks, but are less abundant there than in the mafic rocks. The commonest mineral assemblages in mafic to intermediate rocks are Nos. 2 and 3 of table 1, whereas the most common assemblage in felsic rocks is No. 8. Sphene, apatite, iron-titanium oxides, pyrite, and zircon are the chief accessory minerals.

Granoblastic textures are typical of all rocks of the formation. Rocks rich in quartz and feldspar commonly are granular and very fine grained, except for scattered remnants of phenocrysts. The mafic rocks tend to be somewhat more coarsely recrystallized and more strongly foliated. Porphyroblastic textures are limited to some of the well-layered actinolite-bearing schists, in which sieved needlelike porphyroblasts of actinolite as long as 1 cm are randomly oriented on the foliation surfaces.

CHEMICAL COMPOSITION

The volcanic parentage of the many rocks in the Chopawamsic Formation, amply demonstrated by relict structures and textures, is further substantiated by two chemical analyses (table 2). Both analyzed samples are chemically similar to albitized and zeolitized flows and tuffs of comparable SiO_2 content from several younger volcanic-tectonic belts (for example, Oregon: Dickinson, 1962; Japan: R. S. Fiske, oral commun., 1966; the Aleutians: Hamilton, 1963, p. 71; Puerto Rico: Glover, 1970) but are chemically rather unlike typical nonvolcanic shales and graywackes (Pettijohn, 1957).

TABLE 2.—*Chemical analyses of rocks from the Chopawamsic Formation, Quantico 7½-minute quadrangle, Virginia*

[Analyses by S. D. Botts, G. W. Chloe, James Kelsey, Lowell Artis, Hezekiah Smith, and J. L. Glenn, U.S. Geol. Survey, using methods described by Shapiro and Brannock (1962), supplemented by atomic absorption]

	1	2
SiO_2	74.4	56.3
Al_2O_3	11.5	13.0
Fe_2O_3	----	2.5
FeO	2.9	4.9
MgO	.69	6.2
CaO	2.4	8.3
Na_2O	3.0	1.9
K_2O	1.1	.35
H_2O+	1.1	2.5
H_2O-	.11	.17
TiO_2	.35	.67
P_2O_5	.11	.14
MnO	.09	.17
CO_2	1.0	2.3
S as SO_3	$<.01$	$<.01$
Volatiles other than CO_2 and H_2O	1.0	.00
Total	100.1	99.9

1. Schistose felsite composed of quartz, albite, biotite, chlorite, and muscovite with traces of carbonate. Located on Powells Creek 1.5 miles N. 70° W. from Interstate 95 bridge (Q–30–85).
2. Well-foliated greenstone composed of quartz, sodic plagioclase, biotite, chlorite, and epidote. Located on Powells Creek 1.6 miles N. 70° W. from Interstate 95 bridge (Q–31–87).

AGE AND CORRELATION

The stratigraphic position of the Chopawamsic Formation conformably beneath the Quantico Slate of Late Ordovician age (Watson and Powell, 1911) and conformably above the Wissahickon Formation of late Precambrian(?) age (Southwick and Fisher, 1967) suggests that the Chopawamsic includes rocks of early Paleozoic and possibly latest Precambrian age. Metavolcanic rocks of the same general age and character occur in the Evington Group beneath the Arvonia Slate of Ordovician age in central Virginia (Smith and others, 1964; Brown, 1969), but there they are apparently separated from the overlying slate by an unconformity (Brown, 1970; Brown and Griswold, 1970). Metamorphosed volcanic rocks are associated with the Wissahickon Formation in the northeastern part of the Piedmont in Maryland—the James Run Gneiss in Baltimore and Harford Counties and the "Cecil County volcanic complex" in Cecil County (Marshall, 1937; Southwick, 1966, 1969; Southwick and Fisher, 1967). Zircons from the James Run Gneiss have yielded discordant ages that would be consistent with an original age of about 550 million years (Tilton and others, 1970). All these volcanic units may be at least in part correlative with the Chopawamsic Formation. The Chopawamsic Formation and other volcanic units in the northern Piedmont may be a northern extension of the Carolina slate belt where volcanic and sedimentary rocks of Ordovician and Cambrian age have been recognized (White and others, 1963; St. Jean, 1965; Stromquist and Sundelius, 1969; Sundelius, 1970).

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