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GEOLOGY OF THE LAKESIDE VILLAGE QUADRANGLE, VIRGINIA

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GEOLOGY OF THE LAKESIDE VILLAGE QUADRANGLE, VIRGINIA

David B. Spears

INTRODUCTION

The Lakeside Village 7.5-minute quadrangle is located in the Piedmont physiographic province, along the James River in central Virginia. It includes parts of Cumberland, Fluvanna, Buckingham, and Goochland counties. Geologically, the quadrangle lies along the southeastern margin of the Chopawamsic terrane, an Ordovician-age volcanic-plutonic arc (Pavlides, 1981; Coler and others, 2000). The southeastern part of the quadrangle includes part of the Spotsylvania high-strain zone, interpreted to be the boundary between the Chopawamsic and Goochland terranes (Spears and others, 2004). Two elongate fault-bounded blocks, the Pegmatite Belt and Elk Hill Complex, occur between the Chopawamsic and Goochland terranes (Figure 1). All of these rocks are intruded by Jurassic-age diabase dikes.

The Chopawamsic terrane, occupying the northwestern portion of the Lakeside Village quadrangle, includes the Columbia pluton and the Chopawamsic Formation. The Columbia pluton is a foliated to lineated granite-granodiorite that intrudes layered metavolcanic and metasedimentary gneisses of the Chopawamsic Formation. Both the Columbia and the Chopawamsic are late Ordovician in age (Wilson, 2001; Coler and others, 2000; Horton and others, 2010). The southeastern boundary of the Chopawamsic terrane is defined by the Lakeside Fault in the southern part of the quadrangle and the Little Fork Church Fault in the northern part of the quadrangle. The Pegmatite Belt, initially described by Taber (1913), lies between the Little Fork Church and Lakeside faults. It is composed of strongly deformed pegmatite, amphibolite, granitic gneiss, and layered mixed-composition gneiss. The Elk Hill Complex, also described by Taber (1913), consists of amphibolite, tonalite, felsic metavolcanic rocks, biotite gneiss, and weakly gneissic coarse-grained diorite. No age has been established for either the Pegmatite Belt or the Elk Hill Complex. They are lithologically and structurally distinct from both the Chopawamsic and Goochland terranes.

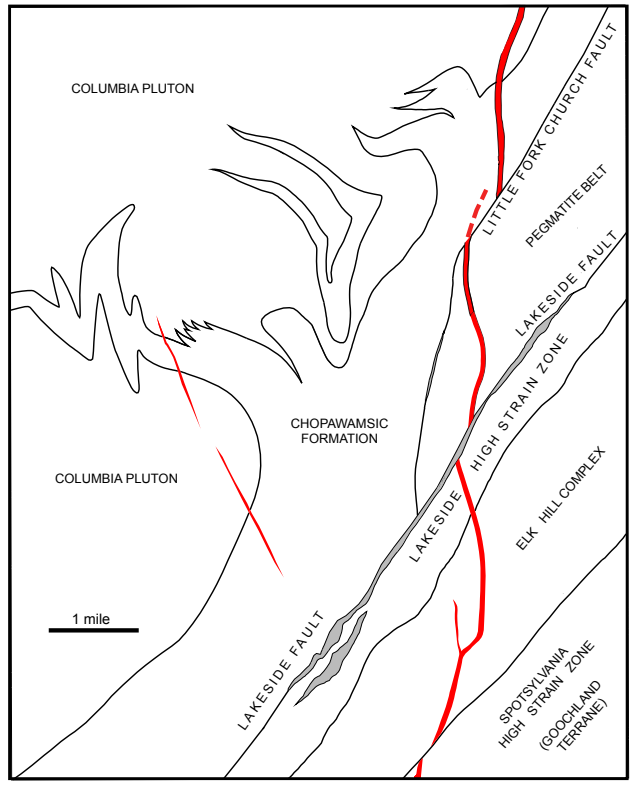

Figure 1. Generalized geologic map of the Lakeside Village quadrangle. Shaded areas represent siliceous fault breccia; large diabase dikes are shown in red.

The southeastern corner of the quadrangle is underlain by mylonitic rocks of the Spotsylvania high-strain zone, a southeast-dipping ductile fault zone that extends from North Carolina

northeastward through the Virginia Piedmont to where it disappears beneath the Coastal Plain in Spotsylvania County. In Lakeside Village quadrangle, sillimanite-bearing schist within the Spotsylvania high-strain zone is considered to be part of the middle Proterozoic to middle Paleozoic Maidens Gneiss of the Goochland terrane (Farrar, 1984; Spears and others, 2004).

Pre-Mesozoic rocks in the Chopawamsic terrane were metamorphosed at amphibolite facies conditions, apparently in a single Late Paleozoic regional metamorphic event (Burton and others, 2000). Rocks within and southeast of the Spotsylvania high-strain zone experienced a granulite-facies regional metamorphic event, originally interpreted as having occurred in the middle Proterozoic (Farrar, 1984). More recent work (Owens and Sampson, 2004) indicates that this event may have been as late as the Devonian. The Pegmatite Belt and Elk Hill Complex also display amphibolite-facies mineral assemblages, but the timing of this metamorphic event has not been established.

Rocks in the Chopawamsic terrane display a single foliation that has been folded with compositional layering into map-scale, northeast-plunging recumbent folds with axial surfaces striking generally northwest to southeast. A later generation of upright to overturned folds also plunges northeast but displays axial surfaces that strike southwest to northeast. A strongly developed northeast-plunging mineral lineation is locally present and is most evident in the Columbia pluton. In the Pegmatite Belt, Elk Hill Complex, and Spotsylvania high-strain zone, map-scale folds are not evident, but foliation and compositional layering are locally folded at the outcrop scale.

Tabular, subvertical Jurassic-age diabase dikes truncate compositional layering, regional foliation, and mylonitic fabrics. A large diabase dike is offset in a right-lateral sense by the Lakeside Fault and possibly by the Little Fork Church Fault. The fault zones are characterized by distinctive siliceous cataclasite and high-strain mylonitic gneiss. The traces of the Lakeside (Bourland, 1976) and Little Fork Church (Spears and Bailey, 2002; Spears and others, 2004) faults are marked by discontinuous siliceous cataclasite, indicating a brittle character for at least part of their history. Because the cataclasite is unfoliated and the faults appear to cut diabase dikes, brittle movement on these faults is considered to be Jurassic or later. The association of the Lakeside Fault with the western boundary of the Farmville Mesozoic basin to the southwest and the right-lateral offset of a large diabase dike suggest that the cataclasites possibly developed while the faults were undergoing normal to oblique motion during Mesozoic extension. The Lakeside Fault also has a zone of mylonite in its hanging wall; the mylonite is similar to the mylonite in the Spotsylvania high-strain zone. The mylonites are considered to have developed while the faults were undergoing ductile reverse motion during one or more Paleozoic contractional events.

The James River has incised a generally west-to-east-trending valley through this area that cuts across major structures such as folds and faults. The floor of the valley lies as much as 250 feet (75 meters) lower in elevation than the surrounding uplands. The valley of the Willis River, with 150 feet (45 meters) of topographic relief, trends in a northeasterly direction generally following the trace of the Lakeside Fault; it meets the valley of the James just east of the eastern quadrangle boundary, near Cartersville. Extensive flood plains are developed in the valleys of both rivers, and ancient river terraces occupy uplands at a variety of elevations along the valley margins. The highest elevations in the quadrangle are flat uplands capped by terrace deposits along the James River.

PREVIOUS WORK

Taber (1913) produced the first detailed description of the geology of the central Virginia Piedmont. He reported on a belt of gold-bearing rocks that crosses the James River west of Columbia, and published a generalized geologic map of the area. Taber named and described the Pegmatite Belt and Elk Hill Complex. Jonas

(1932) reported on the kyanite deposits of the Virginia piedmont, and included a more detailed geologic map of central Virginia. C.B. Brown (1937) produced a geologic map of Goochland County, which includes the northeastern extremity of the Lakeside Village quadrangle. Smith and others (1964) published a geologic map of Fluvanna County that includes the northwestern portion of this quadrangle. W.R. Brown (1969) mapped the Dillwyn 15-minute quadrangle, which adjoins the western boundary of Lakeside Village quadrangle. Bourland (1976) mapped a narrow corridor along the James River extending eastward from Columbia, in the northeastern part of this quadrangle. More recently, faculty and students of the College of William & Mary produced a geologic map of the Columbia quadrangle (Bailey and others, 2005), which adjoins the northern border of the Lakeside Village quadrangle.

DESCRIPTION OF ROCK UNITS

DEPOSITS OF QUATERNARY AGE

The Lakeside Village quadrangle contains three broad categories of surficial deposits: alluvium, colluvium, and terrace deposits. Alluvium consists of unconsolidated sand and silt with minor gravel occupying the modern flood plains of rivers and creeks. It also includes rounded boulders and cobbles lying just above bedrock in the flood plain of the James River, as well as silt and sand in low terraces as much as 35 feet (11 meters) above local mean water level. Cobble and boulder compositions include vein quartz, quartzite, granite, granitic gneiss, and sandstone. Colluvium is locally developed on steep slopes near large diabase dikes. At one locality along the northwest side of the James River, one mile (1.6 kilometer) north-northeast of Stearnes in Fluvanna County, colluvium forms a fan-shaped deposit of unconsolidated granite boulders with sparse sandy matrix.

Ancient river terraces occupy low-relief upland surfaces of tens to hundreds of acres along the James and Willis rivers. The terraces are composed of unconsolidated, well rounded to subrounded cobbles and gravel in a sandy matrix (Figure 2). The highest, oldest terraces are weathered to a reddish-brown color. Clasts are dominantly white vein quartz and fine-grained, very hard white sandstone. White sandstone cobbles commonly contain *Skolithos* trace fossils. Minor clast lithologies include coarse alkali feldspar granite, fine-grained quartz-muscovite-garnet schist, and maroon sandstone. The maximum thickness of the upland terrace deposits is estimated to be 50 feet (15 meters). Although the terraces have not been dated on Lakeside Village quadrangle, Hancock and Harbor (2002) estimate that a similar terrace near Howardsville is approximately 1.1 million years old, based on analysis of cosmogenic ^{10}Be.

Figure 2. Cobbles and gravel in terrace deposit (Qt) at Stearnes, Fluvanna County. Approximate elevation 330 feet. Field notebook is 9 inches (22 centimeters) long.

ROCKS OF MESOZOIC AGE

Diabase

Diabase occurs in near-vertical dikes ranging in width from a few feet to over 200 feet (60 meters). Outcrops are sparse, but dikes can be traced by following rounded boulders with a distinctive orange-brown weathering rind. The diabase is massive, dense, very fine-grained, and dark bluish-gray or greenish-gray

on fresh surfaces. In thin section, randomly oriented strongly twinned plagioclase laths form a framework enclosing grains of clinopyroxene, orthopyroxene, serpentine, and opaque minerals. Roundish clots of serpentine, talc, and chlorite may represent former olivine grains. Most of the dikes strike north-northwest, but one very large dike strikes almost due north. One half-mile (0.8 kilometer) north of Route 602, this large dike contains xenoliths of fine-grained, light gray granitoid (Figure 3). Aeromagnetic maps indicate that this dike extends southward to the southern border of Virginia in Mecklenburg County. Elsewhere in Virginia, similar dikes have been dated at ~200 Ma (Jurassic) by Sutter (1988) and Kunk and others (1992).

Figure 3. Fine-grained granitoid xenoliths in large diabase (Jd) dike, one half-mile (0.8 kilometer) north of intersection of State Routes 602 and 605, Cumberland County. Hammer is 16 inches (40 centimeters) long.

Where diabase intrudes hornblende gneiss, biotite granodiorite, and biotite-rich mylonitic gneiss, the dikes are locally bordered by distinctive strongly magnetic gneiss. The magnetic gneiss is very hard, fine-grained, medium to light gray, and strongly foliated. In thin-section, magnetite is abundant in small subhedral porphyroblasts and dark gray aggregates of fine opaque grains, apparently partially replacing hornblende or biotite. Outcrops are sparse, but the distribution of float blocks suggests that the magnetic gneiss occurs in thin zones near the edges of diabase dikes. It is therefore interpreted to be a thermal alteration product of diabase dikes in contact with surrounding country rock.

ROCKS OF ORDOVICIAN AGE

Columbia Pluton

Watson (1907) described "gray biotite gneiss" quarried at Columbia, on the north bank of the James River, just north of the Lakeside Village quadrangle. Watson (1910) gave a more detailed description of this quarry in a survey of granite resources in the southeastern United States. Taber (1913) was the first to apply the name "Columbia granite" to the rock in these quarries. He noted that, due to the predominance of plagioclase over potassium feldspar, the rock is not a true granite, but "may more properly be called a granodiorite or quartz diorite." Subsequent workers (Smith and others, 1964; Brown, 1969; Fullagar, 1971; Bourland, 1976; Goodman and others, 2001; Bailey and others, 2005) report compositions ranging from granite to tonalite. The Columbia pluton is equivalent to the "granodiorite unit" of Smith and others (1964) and "gneissic granitic rocks" in the Hatcher Complex of Brown (1969).

Stose and Stose (1948) distinguished the Columbia granite from "the granite near Carysbrook" (about four miles [6.5 kilometers] northwest of Columbia) based on differences in composition and texture. This interpretation is reflected in the compilation of the most recent Geologic Map of Virginia (Virginia Division of Mineral Resources, 1993). Earlier workers, however, while acknowledging the difference in the appearance of the rocks at the two localities, were not convinced that two separate plutons were present. Taber (1913) noted "a gradual but very noticeable change" in composition and texture from Columbia toward the northwest, but

nothing resembling a contact between different plutons, stating, "nowhere is there any evidence of a sudden change such as would be expected if there were rocks present belonging to different periods of intrusion" (p. 63). Similarly, Smith and others (1964) noted no mappable lithologic break in an extensive area of granodiorite in eastern Fluvanna County, which includes the area northwest of the James River in Lakeside Village quadrangle. Brown (1969) correlated gneissic granitic rocks in his Hatcher Complex northeast of Dillwyn with those in the Columbia area.

Results of this study and of Goodman and others (2001) and Bailey and others (2005) support the findings of Taber (1913), Smith and others (1964), and Brown (1969). No major lithologic break divides the outcrop area of the Columbia pluton, except local infolds and inclusions of metavolcanic country rock. The granitic rocks near Carysbrook are medium- to coarse-grained, weakly to moderately foliated, plagioclase-quartz-biotite granodiorite with accesory epidote and sphene. This lithology extends southeastward into the northwestern corner of Lakeside Village quadrangle (Figure 4). These rocks grade rapidly southeastward into strongly lineated, moderately foliated, fine-grained plagioclase-quartz-biotite granodiorite gneiss with accessory hornblende, garnet, and epidote (Figure 5). This transition coincides with a regional transition from greenschist- to amphibolite-facies metamorphism recognized in the mineral assemblages of metvolcanic and metasedimentary rocks. It reflects an increase in metamorphic grade and deformation intensity toward the southeast (Goodman and others, 2001; Spears and Bailey, 2002; Bailey and others, 2005).

Figure 4. Massive to weakly foliated and weakly lineated northwestern facies of Columbia pluton (Ogc). Boulders excavated from pond site along State Route 656, one mile (1.6 kilometer) northwest of the James River, Fluvanna County. Coin is 0.9 inch (2.5 centimeters) in diameter.

Figure 5. Strongly lineated, southeastern facies of the Columbia pluton (Ogc). View is to the northwest, showing northeast-plunging (left to right) mineral lineation. Outcrop in abandoned Cowherd Quarry, State Route 6, Columbia, Fluvanna County, just north of quadrangle boundary in Columbia 7.5-minute quadrangle. Coin is 0.9 inch (2.5 centimeters) in diameter.

Reported isotopic ages for the Columbia granite vary widely (Table 1), from Late Proterozoic to Pennsylvanian, but the most recent ages (Mose and Nagel, 1982; Wilson, 2001) are late Ordovician. Comparative ages (~470 Ma for the Chopawamsic Formation and ~457 Ma for the Columbia pluton) indicate that the Columbia pluton intruded an already-existing volcanic pile.

Northwest of the James River, the pluton contains tabular bodies of mafic and felsic gneiss which are concordant with the foliation and mappable over short distances. These are identical to mafic and felsic gneiss within the Chopawamsic Formation (described below) and

SOURCE	REPORTED AGE
Smith and others (1964)	301 +/- 15 Ma (K-Ar biotite)
	400 +/- 125 Ma (Rb-Sr whole-rock + K-feldspar)
	400 +/- 50 Ma (Lead-alpha, zircon)
Fullagar (1971) “tonalite”	590 +/- 80 Ma (Rb-Sr whole-rock)
	342 +/- 70 Ma (mica + feldspar + whole-rock)
Bourland (1976)	574 +/- 10 Ma (zircon)
Mose and Nagel (1982)	454 +/- 9 Ma (Rb-Sr whole-rock)
Wilson (2001)	457 +/- 7 Ma (U/Pb SIMS)

Table 1. Reported ages for the Columbia pluton.

are likely to be remnants (screens or pendants) of the volcanic rocks into which the pluton was injected.

Chopawamsic Formation

Pavlides (1980) applied the name “Chopawamsic Formation” to compositionally layered, generally felsic metavolcanic rocks in the Fredericksburg area. He later extended its usage southwestward as far as the James River, encompassing all metavolcanic and metasedimentary rocks southeast of the Columbia-Quantico syncline and west of the Spotsylvania Lineament fault zone (Pavlides, 1981). Mapping for this project demonstrates that the Chopawamsic Formation extends south of the James River. Southwestward, it is equivalent to hornblende gneiss in the Hatcher Complex of Brown (1969).

In the Lakeside Village quadrangle, the Chopawamsic Formation is heterogeneous. The most common rock type is hornblende-rich gneiss, which varies from nearly black amphibolite (Figure 6) to light gray hornblende-quartz-plagioclase-garnet gneiss. The hornblende gneiss contains very local zones of ultramafic rock (Figure 7) and hornblende gabbroid. Felsic gneiss is the next most common rock type (Figure 8), followed by strongly layered biotite gneiss (Figure 9). Magnetic siliceous ironstone occurs in a small area near the southern edge of the map.

Coler and others (2000) dated a sample of felsic gneiss from the Chopawamsic Formation in Fluvanna County, about 15 miles (22 kilometers) north-northwest of Lakeside Village. Their work yielded an age of ~470 Ma, placing the age of this

Figure 6. Hornblende-rich gneiss of the Chopawamsic Formation (Ochm) at Trenton Mills, Cumberland County. Pencil is 7 inches (18 centimeters) long.

Figure 7. Massive, coarse-grained, greenish-gray ultramafic rock (u) of the Chopawamsic Formation. Outcrop on low ridge along west side of east branch of Hooper Rock Creek, one mile south of the James River, Cumberland County. Pen is 5.5 inches (14 centimeters) long.

Figure 8. Fine-grained, leucocratic, weakly compositionally layered felsic gneiss (Ochf) in the Chopawamsic Formation. Outcrop along unnamed creek on Mount Elba farm, one half-mile (0.8 kilometer) west of Trice Lake, Cumberland County. Hammer is 13 inches (33 centimeters) long.

part of the Chopawamsic Formation in the late Middle Ordovician. Horton and others (2010) dated a sample of the Chopawamsic Formation from northern Virginia and derived a younger age of 453 +/- 4 Ma (Late Ordovician). The span of dates suggests multiple phases of volcanism (Horton and others, 2010).

Metamorphic hornblende from outcrops of the Chopawamsic Formation along the Willis River in Buckingham County, about 25 miles (40 kilometers) southwest of Lakeside Village, yielded ages of 318 to ~284 Ma (Burton and others, 2000). This is interpreted as the age of a single late Paleozoic (Pennsylvanian-Permian) regional metamorphic event related to the Alleghanian orogeny.

Figure 9. Strongly layered quartzofeldspathic biotite gneiss of the Chopawamsic Formation (Ochb). Outcrop along unnamed creek one mile (1.6 kilometer) east of Duncan's Store, Cumberland County. Body of pocket transit is 6 inches (15 centimeters) long.

ROCKS OF UNCERTAIN AGE

Elk Hill Complex

Taber (1913) applied the name "Elk Hill Complex" to a northeast-trending belt of dominantly amphibolitic rocks in Cumberland and Goochland counties. Brown (1937) continued the usage of this name in his geologic map of Goochland County. Spears and Bailey (2002) extended this usage south into the Lakeside Village area, applying it to strongly compositionally layered gneiss southeast of the Lakeside Fault and northwest of the Spotsylvania high-strain zone (Figure 10). While the hornblende-rich gneiss in this belt is similar to that in the Chopawamsic

Figure 10. Strongly compositionally layered gneiss in the Elk Hill Complex (ehu). Fine-grained light gray felsic gneiss alternates with dark gray hornblende- and biotite-rich gneiss. Outcrop in spillway of farm pond on Boston Branch one mile (1.6 kilometer) south of State Route 690, Cumberland County. Hammer is 16 inches (40 centimeters) long.

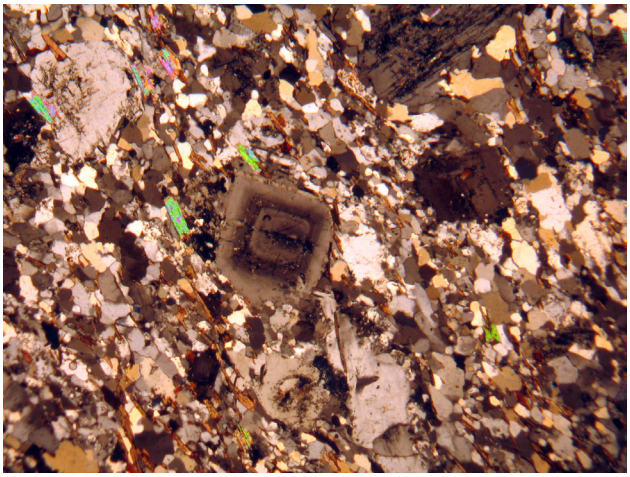

Figure 11. Photomicrograph of plagioclase feldspar phenocryst displaying concentric compositional zoning in felsic metavolcanic rock of the Elk Hill Complex (eh). Sample from headwaters of Snowquarter Creek, one mile (1.6 kilometers) west-southwest of Bush Park, Cumberland County. Crossed niccols; width of field of view approximately 3 millimeters.

Formation, the Elk Hill also contains felsic rocks that are quite different. In outcrop, these rocks are poorly foliated, extremely hard, and contain visible feldspar phenocrysts. In thin-section, they display strongly zoned, subhedral plagioclase phenocrysts, presumably of primary volcanic origin (Figure 11). The name "Elk Hill Complex" has been retained because this map unit contains distinct rocks and is separated from the Chopawamsic Formation by at least two faults, the Lakeside and Little Fork Church faults. The age of the Elk Hill Complex is unknown.

Distinctive coarse-grained hornblende diorite (Figure 12), first described by Spears and others (2004), occurs in the structurally lowest part of the Elk Hill Complex, adjacent to the Lakeside Fault, and in a small area to the east of the main body of the Elk Hill Complex. Although this diorite occurs in several blocks mapped as being separated from the Elk Hill Complex by ductile fault rocks, these rocks appear to be spatially associated with the Elk Hill Complex, and are therefore considered to be part of it.

Figure 12. Block of weakly gneissic coarse-grained hornblende diorite (dg) from an outcrop along State Route 663, one quarter-mile (0.4 kilomter) southeast of Willis River, Cumberland County. Lens cap is 1.75 inches (4.5 centimeters) in diameter.

Pegmatite Belt

The "Pegmatite Belt" was originally named by Taber (1913), who described an area of pegmatite and "much interleaved granite" in western Goochland County and northern Cumberland County. Brown (1937) also mapped a pegmatite unit in western Goochland County. Farrar (1984) interpreted the pegmatite in western Goochland County to be associated with the intrusion of the Columbia pluton. Spears and others (2004) recognized that this belt of rocks is fault-separated from the Chopawamsic terrane (including the Columbia pluton) by the Little Fork Church Fault, and from the Elk Hill Complex by the Lakeside Fault. In Lakeside Village quadrangle, the Pegmatite Belt is divided into four map units: amphibolite; pegmatite and weakly layered granitic gneiss (Figure 13); pegmatite and granitic gneiss with amphibolite boudins; and strongly layered heterogeneous gneiss containing amphibolite, biotite gneiss, leucocratic grantitic gneiss, and pegmatite. Pegmatite and amphibolite within the granitic gneiss are typically in lens-shaped masses or trains of boudins. In thin-section, the pegmatite is dominated by coarse potassium feldspar that is typically clouded with sericite. Fine fractures cut across grains of feldspar, quartz, and mica, indicating strong deformation within this belt. The age of the rocks in the Pegmatite Belt is unknown.

Maidens Gneiss

Rocks in the southeastern corner of the Lakeside Village quadrangle include mylonitic, porphyroclastic gneiss and sillimanite-bearing schist. These strongly deformed rocks fall within the Spotsylvania high-strain zone (Bailey and others, 2004). The protolith is considered to be part of the Maidens Gneiss of Farrar (1984). On the most recent Geologic Map of Virginia (Virginia Division of Mineral Resources, 1993), these rocks were included in a separate "Central Piedmont" terrane, but clear lithologic and mineralogic similarities to the Maidens Gneiss described by Farrar (1984), and the absence of an observed structural discontinuity to the southeast, suggest that the rocks are part of the Maidens. The more biotite-rich porphyroclastic gneiss, because of its universally mylonitic nature, is

Figure 13. Medium-grained, light grayish-pink, feldspar-rich granitic gneiss (pgg) with discontinuous zones of very coarse grained pink microcline feldspar, a lithology typical of the Pegmatite Belt. Block from outcrop on unnamed creek one half-mile (0.8 kilometer) north of intersection of State Routes 602 and 603. Pocket transit is 2.75 inches (7 centimeters) across.

Figure 14. Saprolite of biotite-rich mylonitic gneiss in the Lakeside high-strain zone. View is to the northeast; foliation dips southeast. Outcrop in unnamed creek running parallel to State Route 690, one half mile (0.8 kilometer) west of intersection with State Route 611, Cumberland County. Hammer is 13 inches (33 centimeters) long.

mapped as a unit (my) with similar tectonites developed along the Lakeside Fault.

The Maidens Gneiss was at one time interpreted as Middle Proterozoic in age (e.g., Farrar, 1984; Aleinikoff and others, 1996). More recent work, however, indicates that parts of the western portion of the Maidens may be as young as middle Paleozoic (Owens and Sampson, 2004; Shirvell and others, 2004).

Tectonites

Rocks in this quadrangle have experienced both ductile and brittle deformation. Ductile fault zones are characterized by mylonitic gneiss with abundant plagioclase porphyroclasts and discontinuous zones of coarse, white, strongly deformed quartz-feldspar-muscovite pegmatite. In thin-section, recrystallized quartz ribbons and strongly-strained plagioclase porphyroclasts are common. This rock type occurs in narrow belts southeast of the Lakeside Fault (Figure 14), and in the Spotsylvania high-strain zone. Locally, tectonically-displaced blocks of more competent country rock such as amphibolite are incorporated into the mylonitic gneiss (Figure 15).

Brittle fault zones are characterized by distinctive siliceous breccia, a generally massive, cryptocrystalline quartz rock with multiple generations of quartz-filled fractures (Figure 16). Fractures are commonly incompletely filled and lined with terminated quartz crystals. Taber (1913) reported the presence of small amounts of sulfide minerals including sphalerite, pyrite, chalcopyrite, and galena in these rocks. This unit occurs discontinuously along the trace of the Lakeside Fault and sparsely along the Little Fork Church Fault. The breccia is resistant to weathering, typically forming low ridges. These rocks are interpreted to have formed during Mesozoic faulting.

Figure 15. Tectonically displaced blocks of amphibolite in mylonitic gneiss of the Lakeside high-strain zone. Outcrop on Boston Branch, 1800 feet (600 meters) north of Rt. 690, Cumberland County. Hammer is 16 inches (40 centimeters) long.

Figure 16. Massive siliceous breccia (b) containing multiple generations of quartz-filled fractures. Outcrop along trace of Lakeside Fault, State Route 605, one half-mile (0.8 kilometer) northwest of the Willis River, Cumberland County. Coin is 0.9 inch (2.5 centimeters) in diameter.

STRUCTURAL GEOLOGY

Lakeside Village quadrangle is located along the southeastern edge of the Chopawamsic

terrane, a southwest-to-northeast trending belt of metavolcanic, metaplutonic, and metasedimentary rocks of late Ordovician age (Coler and others, 2000). The eastern boundary of this belt has been defined as the Spotsylvania high-strain zone, a major structural boundary separating rocks of the Chopawamsic terrane on the west from rocks of the Goochland terrane on the east (Pratt and others, 1988; Spears and others, 2004). Rocks within the Spotsylvania high strain zone in the extreme southeastern portion of the quadrangle are here interpreted to be part of the Goochland terrane. Work by Bailey and others (2004) indicates that the Spotsylvania high strain zone records dextral transpression, which resulted in southwestward transport of the Goochland terrane with respect to the Chopawamsic terrane.

FAULTS

The fault bounding the western edge of the Farmville Mesozoic basin was mapped as extending into northern Cumberland County as early as 1928 (Virginia Geological Survey, 1928). Bourland (1976) applied the name "Lakeside Fault" to this structure and extended it across the James River into Goochland County. The fault trace is characterized by discontinuous, map-scale zones of siliceous breccia with multiple generations of partly to completely quartz-filled fractures. The Lakeside Fault is interpreted to be a down-to-the-southeast brittle normal fault. Bourland (1976) and Bourland and others (1979) also identified ductile fabrics in a narrow belt of rocks parallel to and immediately southeast of the brittle zone. Brown (1986) used the term "Lakeside mylonite" for this zone of ductile fault rocks. Rocks in the zone are herein mapped as mylonitic gneiss. They contain a single foliation that dips gently to the southeast.

The name "Little Fork Church Fault" was applied by Spears and Bailey (2002) to a fault mapped as branching northward from the Lakeside Fault about one-half mile (800 meters) east of Trice Lake. This fault separates the well-layered, generally fine-grained schists and gneisses of the Chopawamsic Formation to the west from the generally coarser-grained pegmatitic gneisses of the Pegmatite Belt to the east. The fault is marked by a sharp boundary between these two groups of rocks, and by locally-developed siliceous breccia similar to that occurring along the Lakeside Fault. North of the James River, the fault is marked locally by limonitic breccia and zones of fractures with slickensides (Spears and Bailey, 2002).

The Spotsylvania high-strain zone is a belt of generally mylonitic rocks that forms the boundary between the Chopawamsic and Goochland terranes (Spears and others, 2004; Bailey and others, 2004). It was originally recognized by Neuschel (1970) as a linear, northeast-trending aeromagnetic and aeroradiometric anomaly, which became known informally as the "Spotsylvania Lineament." Later workers (Farrar, 1984; Pratt and others, 1988; and Glover and others, 1989) interpreted it as a major fault along which the Goochland terrane was thrust northwestward. Marr (1991) described rocks 15 miles (25 kilometers) to the southwest along strike as melange, and interpreted the zone to be a major tectonic suture. Bailey and others (2004), citing evidence that included strike-parallel dextral asymmetry in porphyroclast tails and boudins, interpret the Spotsylvania to be a zone of dextral transpression that records significant southwestward translation of the Goochland terrane relative to terranes to the northwest.

FOLDS, FOLIATION, AND LINEATION

The Spotsylvania high-strain zone and the Lakeside and Little Fork Church faults divide the quadrangle into structurally distinct blocks with distinct structural styles. The Chopawamsic terrane occupies the area northwest of the Lakeside and Little Fork Church faults. A single well-developed foliation occurs parallel to compositional layering in the mafic gneiss, felsic gneiss, and biotite gneiss units. The foliation

is present, but less strongly developed, in the Columbia pluton. The foliation is folded with compositional layering into map-scale, northeast-plunging recumbent folds with axial surfaces trending generally southeast to northwest. A later generation of upright to overturned folds also plunges northeast but displays axial surfaces that trend southwest to northeast. Poles to foliation are scattered along a well-defined great circle with an axis plunging 30° N55E, indicating folding around a northeast-plunging axis (Figure 17). Average strike of the foliation and compositional layering is N63E with an average dip of 15° SE. A moderately to strongly developed mineral lineation is observable in most outcrops, but is especially well-expressed in the southeastern portion of Columbia pluton. Locally, the lineation is more pronounced than the foliation, especially in a northeast-trending belt for about a mile (1.6 kilometers) on either side of the James River southwest of Columbia. The orientation of the lineation is fairly uniform, with an average plunge of 29° N50E (Figure 18).

In the Pegmatite Belt, which lies between the Little Fork Church and Lakeside faults, the rocks are strongly foliated and mineral lineations are generally weak. Poles to foliation form a diffuse cluster spread weakly along a great circle (Figure 19), indicating slight folding about an axis plunging 10° N45E. Average strike of foliation is N57E with an average dip of 49° SE. Mineral lineations form a weak cluster with average plunge of 23° N63E (Figure 20). Map-scale folds are not apparent, and outcrop-scale folds are sparse with the notable exception of the extreme eastern part of the belt, where the strongly layered heterogeneous unit is typically folded and faulted at the outcrop scale. Examples of these structures occur in a saprolite bank at the "Bodatious" race track (Figure 21). The presence of these structures along the eastern edge of the Pegmatite belt is possibly due to the proximity of the Lakeside Fault.

Southeast of the Lakeside Fault, in the area that includes the Elk Hill Complex and the

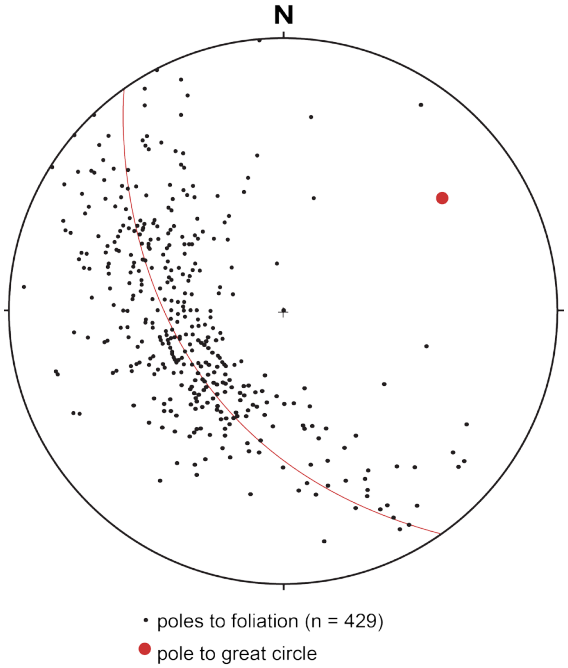

Figure 17. Equal-area stereonet plot of poles to foliation in the Chopawamsic terrane in Lakeside Village quadrangle.

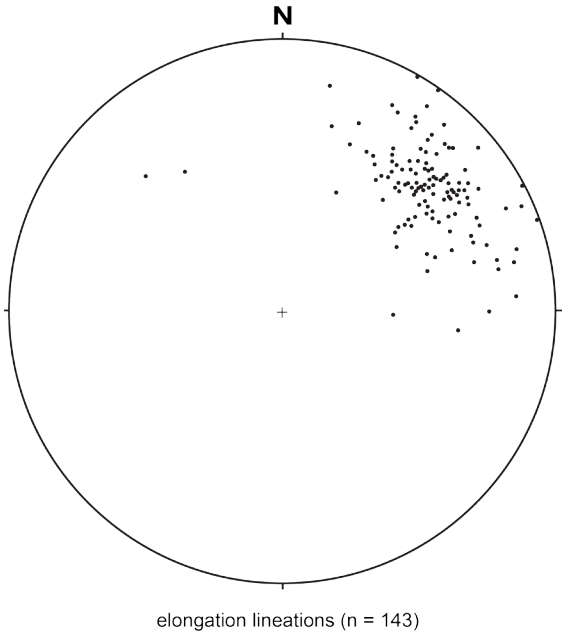

Figure 18. Equal-area stereonet plot of lineations in the Chopawamsic terrane in Lakeside Village quadrangle.

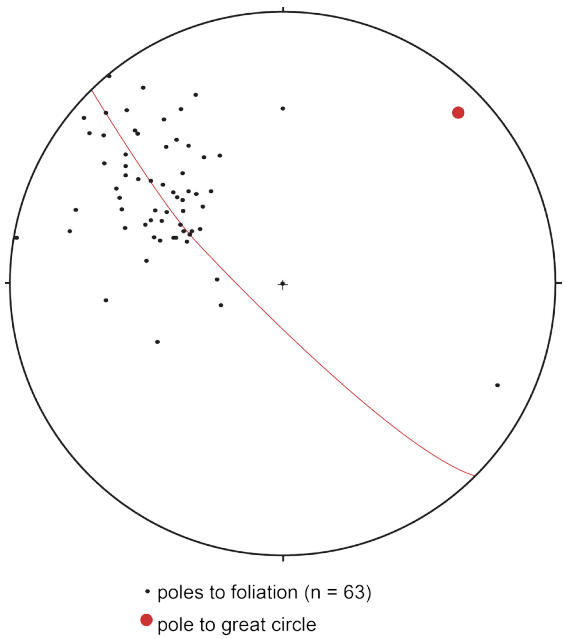

Figure 19. Equal-area stereonet plot of poles to foliation in the Pegmatite Belt in Lakeside Village quadrangle.

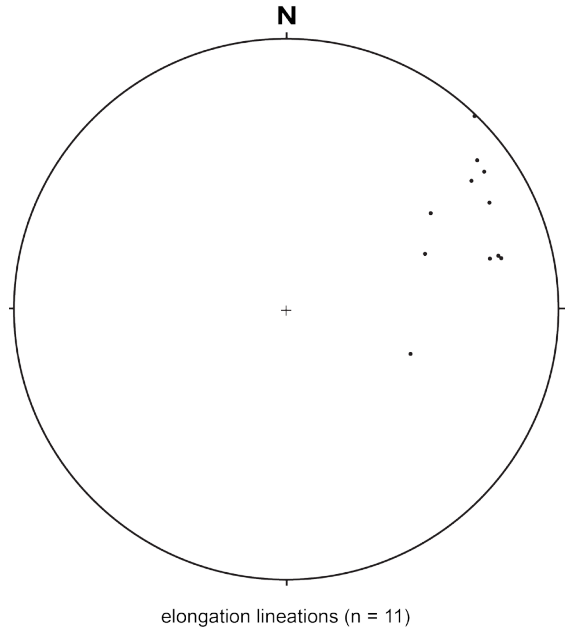

Figure 20. Equal-area stereonet plot of lineations in the Pegmatite Belt in Lakeside Village quadrangle.

Figure 21. Saprolite of complex structure in strongly layered mixed-composition gneiss (pgl), structurally highest part of the Pegmatite Belt in the footwall of the Lakeside Fault. Bodatious dirt track, State Route 605, 0.6 mile (0.9 kilometer) northwest of Willis River, Cumberland County. View is to northeast. Hammer is 16 inches (40 centimeters) long.

Spotsylvania high-strain zone, most of the rocks are strongly foliated and exhibit a moderate to strong mineral lineation. Poles to foliation form a moderate cluster weakly distributed along a great circle; average strike is N58E with an average dip of 32° SE. The axis of the great circle (fold axis) plunges 8° N53E (Figure 22). Mineral lineations plunge shallowly, with an average plunge of 12° N56E (Figure 23).

JOINTS

All bedrock units are cut by one or more sets of planar, subvertical joints. A rose diagram of joint orientations (Figure 24) indicates two dominant joint sets and several lesser sets. The strongest set strikes approximately N70W; the second most dominant set averages N30W. Other joints range from northwesterly to northeasterly orientations, but do not form a strong cluster.

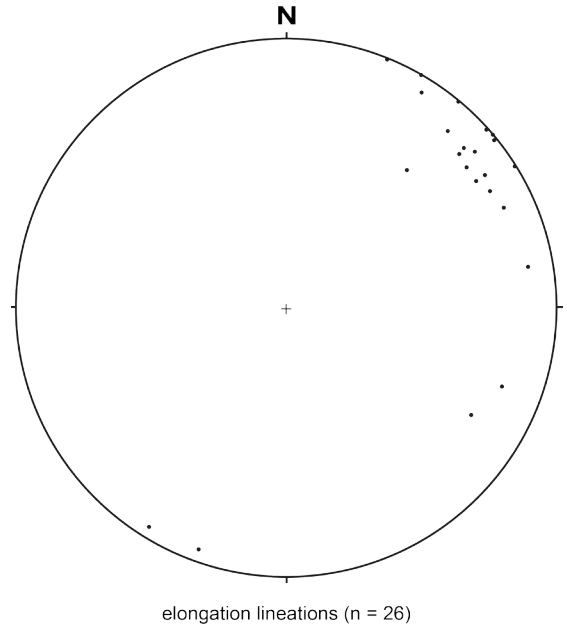

Figure 23. Equal-area stereonet plot of lineations in the Elk Hill Complex and Spotsylvania high-strain zone in Lakeside Village quadrangle.

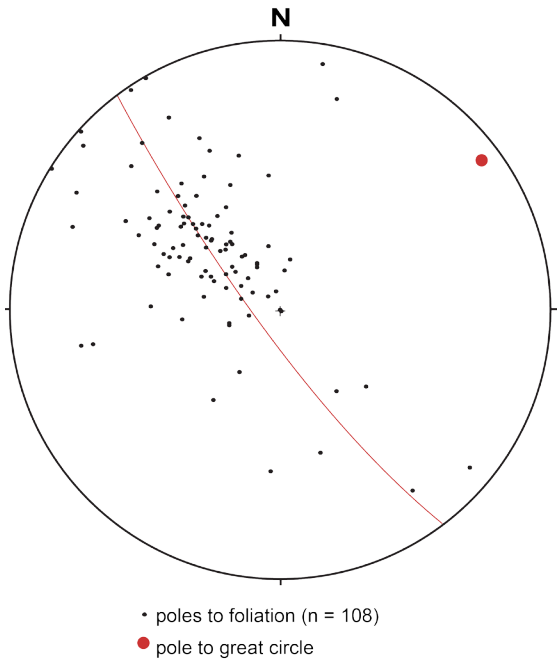

Figure 22. Equal-area stereonet plot of poles to foliation in the Elk Hill Complex and Spotsylvania high-strain zone in Lakeside Village quadrangle.

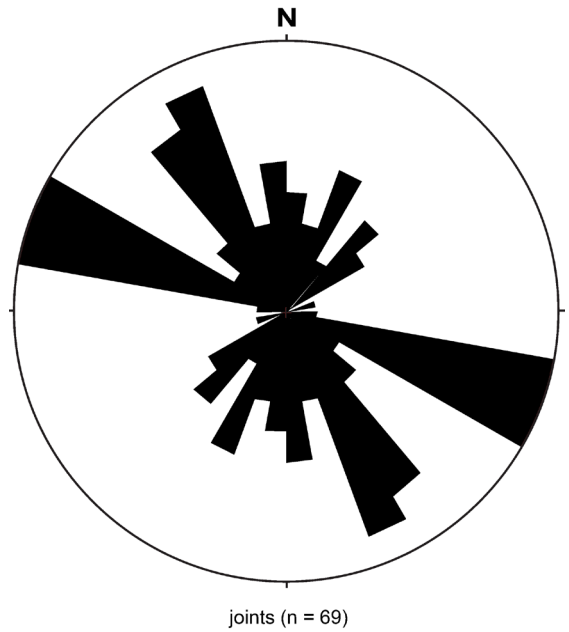

Figure 24. Rose diagram of joint orientations in Lakeside Village quadrangle.

ECONOMIC GEOLOGY

Dimension stone, gravel, and road fill have been produced in this quadrangle. Gold was prospected unsuccessfully at one site. Potential exists for future production of crushed stone, dimension stone, sand and gravel, and possibly sulfide minerals. No commercial mineral producers are currently active in the area.

DIMENSION STONE

Several rock types were quarried locally in the past for building foundations, chimneys, and canal aqueducts. The largest abandoned quarry in this quadrangle is in the bluff south of the James River, about 1500 feet (450 meters) west-southwest of the Route 690 bridge. Here, blocks of lineated gneissic granite were broken from the rock face using drills and wedges. Blocks showing drill marks litter the site; similar blocks have been used in the foundations of old homes in the area. Two small dimension-stone quarries are present in granite along the railroad north of the James River (Figure 25). Nearby, the railroad crosses South Creek on a bridge made of granite blocks (Figure 26). This structure was probably originally built as an aqueduct for the James River and Kanawha Canal (Dunaway, 1922).

A stone-and-concrete low-water bridge on an abandoned state road crosses an unnamed creek 1.6 miles (2.6 kilometers) east-northeast of Duncan's Store. A small pit in biotite gneiss along the north bank of the creek provided the stone for this structure. Local residents report that the Civilian Conservation Corps carried out this work in the 1930s.

An abandoned early 19th century mill along Route 613 at Sports Lake (Figure 27) was built from hornblende gneiss blocks quarried from two nearby pits. The mill was roofed with slate from the Arvonia district in Buckingham County. Stone ruins at several other mill sites were observed in the course of mapping; rocks of the Columbia pluton and diabase dikes were employed in their construction.

Figure 25. Small, abandoned dimension-stone quarry in granite of the Columbia pluton (Ogc) along west side of CSX Railroad, 1.5 miles (2.4 kilometers) north-northeast of Stearnes, Fluvanna County. View is to the west; note northeast-plunging (left to right) mineral lineation. Head of hammer is 7 inches (17.5 centimeters).

AGGREGATE AND FILL

A pit was opened in granite saprolite along Virginia Highway 6 one mile (1.6 kilometers) east of Columbia, apparently to provide fill for the construction of the highway. Gravel from a small pit on an unnamed island in the James River

Figure 26. Arched canal aqueduct, now used as a railroad bridge, made of quarried blocks of Columbia granite. CSX railroad crossing over South Creek, Fluvanna County.

Figure 27. Abandoned early 19th century mill constructed of local blocks of hornblende gneiss and formerly roofed with Arvonia slate. Roof is now collapsed. State Route 613 at Sports Lake, Cumberland County.

two miles (3 kilometers) northeast of Stearnes was used locally for driveways. Residents report that this gravel was deposited on the island by floods accompanying Hurricane Agnes in June of 1972.

Upland terrace deposits in the vicinity of the James and Willis rivers may contain economic quantities of sand and gravel resources. Although these deposits have not been commercially exploited in the past, their thickness and extent suggest a considerable volume of available material. A single small terrace along the James River in northern Buckingham County, about 25 miles (40 kilometers) west of Lakeside Village quadrangle, was studied by the Virginia Division of Mineral Resources and found to contain uneconomic quantities of titanium, sand, clay, and gravel resources (Giannini, 1984).

The Columbia pluton may hold potential for development of crushed stone resources. It is similar in composition and texture to the Ellisville pluton in Louisa County, which was extensively developed for crushed stone by the Luck Stone Corporation.

PRECIOUS METALS

Gold was prospected in siliceous breccia along the Lakeside fault about 1500 feet (500 meters) northeast of Route 605, half a mile (0.8 kilometer) west of the Willis River. Known as the "G. S. Dickey Prospect," a small shaft and several pits were dug (Sweet and Trimble, 1983), but no commercial production was established. Taber (1913) reported the presence of small amounts of sphalerite, pyrite, chalcopyrite, and galena at this site; assays reportedly showed traces of gold and silver.

In this study, samples of chlorite-quartz-garnet schist containing visible pyrite were collected from a small weathered exposure in the Chopawamsic Formation near the James River. Fire assay of the samples indicated < 0.002 ounces per ton of gold and < 0.05 ounces per ton of silver. Although these results are not encouraging, similar rocks produced substantial quantities of gold to the north in Goochland and Fluvanna counties in the 19th and early 20th centuries (Sweet and Trimble, 1983).

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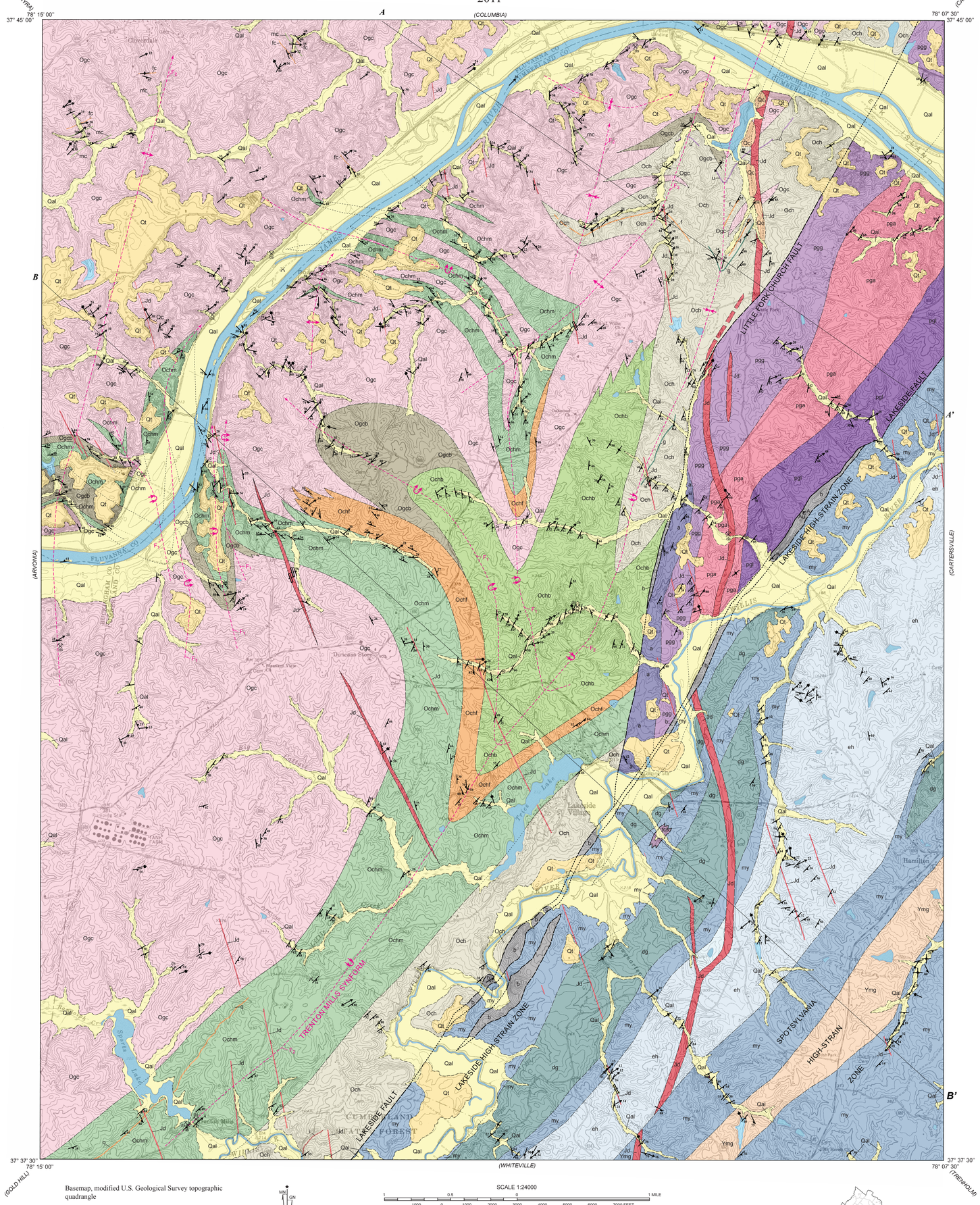
GEOLOGIC MAP OF THE LAKESIDE VILLAGE QUADRANGLE, VIRGINIA

DAVID B. SPEARS

2011



Basemap, modified U.S. Geological Survey topographic quadrangle

1969, Lakeside Village Quadrangle, Virginia

Polyconic projection
NAD 1927 Datum

Digital Cartography by Aaron Cross and Amy K. Gilmer

MN GN
9° 58' 177 MILS
1°43' 31 MILS
2010 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
ANNUAL VARIATION 0° 1'

SCALE 1:24000

1 0.5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
0.5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology mapped from April 1998 to March 2001

DESCRIPTION OF MAP UNITS

QUATERNARY

Qal — **Alluvium** – Unconsolidated sand and silt with minor gravel occupying the modern flood plains of rivers and creeks. Includes rounded boulders and cobbles lying just above bedrock in the flood plain of the James River, as well as silt and sand in low terraces as much as 35 feet (10 meters) above local mean water level. Cobbles and boulders include vein quartz, quartzite, granite, granitic gneiss, and sandstone.

Qc — **Colluvium** – Unconsolidated fan deposits composed of boulders of bedrock, locally developed on steep slopes.

Qt — **Terrace deposits** – Unconsolidated, well rounded to subrounded cobbles and gravel in a matrix of sand and silt. Matrix commonly forms deep red-orange sandy soils. Clast lithologies are dominantly white vein quartz and fine-grained quartzite. Quartzite cobbles commonly contain *Skolithos* trace fossils. Minor lithologies include coarse alkali feldspar granite, fine-grained quartz-muscovite-garnet schist, and maroon sandstone. Maximum thickness is estimated to be 50 feet.

MESOZOIC DIKES

Jd — **Diabase** – Massive, dense, very fine grained; dark bluish-gray or greenish-gray on fresh surfaces. Weathers into smooth, rounded boulders with a distinctive orange-brown weathering rind. In thin section, randomly oriented, strongly twinned plagioclase laths form a framework enclosing grains of pyroxene, serpentine minerals, and opaques. Both orthopyroxene and clinopyroxene are present. Clots of serpentine, talc, chlorite, and iddingsite may represent former olivine grains.

COLUMBIA PLUTON

Ogc (mc, fc) — **Columbia pluton** – Fine- to medium-grained, light gray, moderately foliated to strongly lineated biotite granite and granodiorite; coarser-grained and moderately foliated in the northwestern portion of the quadrangle. Mineralogy is plagioclase-orthoclase-quartz-biotite, with minor microcline, muscovite, hornblende, epidote, titanite, garnet, and opaque minerals; contains sparse xenoliths of medium gray-brown, fine-grained biotite gneiss. Northwest of the James River, the pluton contains tabular bodies of mafic (mc) and felsic (fc) gneiss which are concordant with the foliation and mappable over short distances. These are identical to mafic and felsic gneiss within the Chopawamsic Formation, described below.

Ogcb — **Columbia pluton border facies** – Gneissic biotite granodiorite interlayered at the outcrop scale with lithologies of the Chopawamsic Formation, including hornblende gneiss, biotite schist, and felsic gneiss.

CHOPAWAMSIC FORMATION

Och (i, u, f, g) — **Chopawamsic Formation, undivided** – Interlayered hornblende-rich mafic gneiss, felsic gneiss, and biotite gneiss; also includes layers of siliceous ironstone, ultramafic rock, felsic schist, and hornblende gabbroid.

Contains thin, limited-extent layers of:

Siliceous ironstone (i) – medium-gray, fine-grained, massive to weakly layered, strongly magnetic, quartz-magnetite-limonite rock. Brown limonite, presumably after magnetite, occurs in irregular blobs up to 1.5 in. (4 cm) in diameter that align to form crude layering.

Ultramafic rock (u) – massive, medium- to coarse-grained, medium greenish gray layers forming resistant, concordant ledges. Mineralogy is tremolite + chlorite + opaque minerals.

Felsic schist (f) – fine-grained, white to very light gray, strongly foliated quartz-plagioclase-muscovite schist with minor microcline, biotite, and garnet.

Hornblende gabbroid (g) – massive, greenish-black, medium-grained rock composed of hornblende, epidote, plagioclase, and opaques.

Ochm (q) — **Mafic gneiss** – Heterogeneous unit dominated by mafic lithologies, including hornblende gneiss, mesocratic gneiss, biotite-hornblende schist, gabbroid, and sparse quartzite. Dominant lithology is fine-grained, medium-gray to black, strongly foliated, strongly compositionally layered hornblende gneiss. Mineralogy is hornblende, plagioclase, and opaque minerals, plus or minus quartz, epidote, biotite, and garnet. Includes sparse zones of very fine-grained, sucrosic, gray-green quartz-epidote rock in thin, discontinuous layers up to 5 inches (12 cm) thick. Locally contains concordant layers of lighter-gray fine-grained plagioclase + quartz + hornblende gneiss with minor fine biotite and garnet and fine-grained, medium- to light-gray, massive to weakly foliated moderately magnetic quartzite (q).

Ochf — **Felsic gneiss and schist** – Fine- to very fine-grained, very light gray to nearly white, micaceous, moderately to strongly foliated gneiss and schist. Mineralogy is quartz, plagioclase, potassium feldspar, and muscovite, +/- minor biotite and garnet. Texture ranges from moderately foliated to strongly schistose.

Ochb — **Quartzofeldspathic biotite gneiss** – Strongly compositionally layered gneiss, with three distinct interlayered lithologies: very light gray, fine-grained, weakly foliated quartzofeldspathic gneiss (quartz, plagioclase, and potassium feldspar with minor biotite); fine-grained, dark gray, "salt-and-pepper" textured biotite gneiss (quartz, plagioclase, and potassium feldspar with up to 5% biotite and muscovite); and coarse-grained, irregular but generally concordant lenses of white quartz, plagioclase, microcline, and minor muscovite.

ELK HILL COMPLEX

eh — **Elk Hill complex, undivided** – Black amphibolite gneiss interlayered with medium gray, fine-grained, biotite-bearing granitic gneiss and resistant, very fine grained, light-gray felsic gneiss. Amphibolite is composed of hornblende, plagioclase, and quartz, with minor biotite, epidote, and opaques. The granitic gneiss contains quartz and plagioclase with minor biotite, muscovite, potassium feldspar, and hornblende. The fine-grained felsic gneiss is dominated by quartz and plagioclase with minor potassium feldspar, biotite, muscovite, and epidote. Strongly zoned plagioclase phenocrysts are present in some samples. Commonly contains thin, concordant, discontinuous, weakly foliated pegmatitic layers and lenses composed of coarse-grained quartz, potassium feldspar, and muscovite.

dg — **Gneissic diorite** – Medium- to coarse-grained, massive to weakly foliated, black-and-white speckled diorite. Mineralogy is hornblende-plagioclase-clinopyroxene with minor epidote, quartz, and opaque minerals.

tcs — **Talc-chlorite schist** – Greenish gray, soft, massive to weakly schistose rock composed of talc, chlorite, and opaque minerals.

PEGMATITE BELT

pgl — **Strongly layered pegmatitic gneiss** – Thinly interlayered amphibolite, biotite gneiss, leucocratic granitic gneiss, and thin, concordant discontinuous quartz-feldspar-muscovite pegmatite.

pga — **Pegmatite and granitic gneiss with amphibolite boudins** – Quartz-feldspar gneiss and pegmatite, as below, with lens-shaped inclusions of very dark greenish-gray to black hornblende amphibolite, which occurs as isolated lenses or as trains of boudins within granitic gneiss and pegmatite.

pgg — **Pegmatite and granitic gneiss** – Very light pinkish-gray to white, moderately to strongly foliated, fine-grained granitic gneiss with coarse-grained, pinkish white to light gray, quartz-microcline-muscovite pegmatite in discontinuous zones oriented parallel to foliation. Mineralogy is dominantly potassium feldspar, often partly sericitized. Also contains quartz and plagioclase, with minor biotite, muscovite, epidote, titanite, and opaques. Fine, brittle fractures are common in thin section.

a — **Amphibolite** – Fine- to medium-grained, poorly layered, nearly black, weakly foliated hornblende-plagioclase-epidote amphibolite.

MAIDENS GNEISS

Ymg — Fine-grained, medium gray, strongly foliated, moderately lineated, strongly micaceous mylonitic schist and gneiss with abundant porphyroclasts of plagioclase and potassium feldspar. Very similar to porphyroclastic biotite gneiss (below) but contains zones of silver muscovite-sillimanite-quartz schist; contains abundant pegmatite veins, often deformed into boudins parallel to foliation; and thin zones of biotite schist.

TECTONITES

b — **Siliceous breccia** – Light gray or tan to white, massive, cryptocrystalline quartz rock with multiple generations of quartz-filled fractures. Fractures are commonly vuggy and lined with terminated quartz crystals.

my — **Mylonitic gneiss** – Dark brownish-gray, fine-grained mylonitic gneiss with abundant light gray to white plagioclase porphyroclasts and discontinuous zones of coarse, white, strongly deformed quartz-feldspar-muscovite pegmatite. Recrystallized quartz ribbons and strongly-strained plagioclase porphyroclasts are common.

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SUGGESTED REFERENCE

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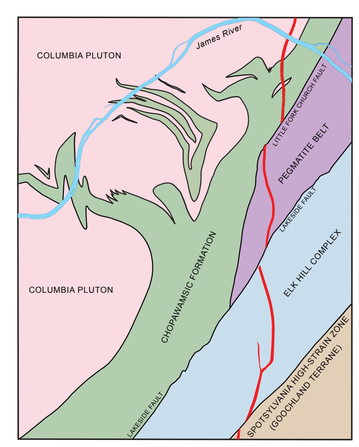


Simplified map showing major geologic units

MAP SYMBOLS

For all contact and fold symbols: lines are solid where the location is exact, long-dashed where the location is approximate, dotted where the location is concealed. Queries added where identity or existence may be questionable. For geologic observation symbols, observation sites are centered on the strike bar or at the intersection point of multiple symbols.

Contacts

Faults

Reverse - sawteeth on upthrown block

Normal - U = upthrown block, D = downthrown block

Folds - showing direction of plunge where appropriate

Anticline

Syncline

Anticline (overturned)

Syncline (overturned)

Direction and angle of plunge of minor syncline

Direction and angle of plunge of minor anticline

Abandoned sand and gravel pit

Abandoned mine or quarry (ds = dimension stone)

Abandoned shaft (Au = gold)

Geologic Observations

Inclined foliation showing strike and dip

Vertical foliation parallel to bedding

Horizontal foliation

Inclined foliation (strike approximate)

Inclined foliation with plunging lineation

Inclined foliation with horizontal lineation

Vertical dike

Inclined joint showing strike and dip

Vertical joint

Compositional layering

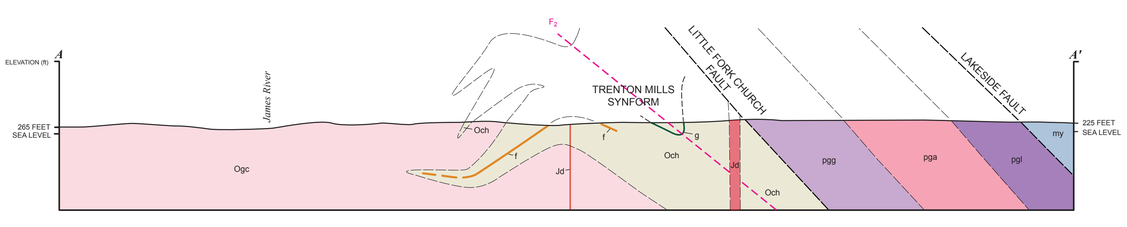
Inclined lineation, showing plunge

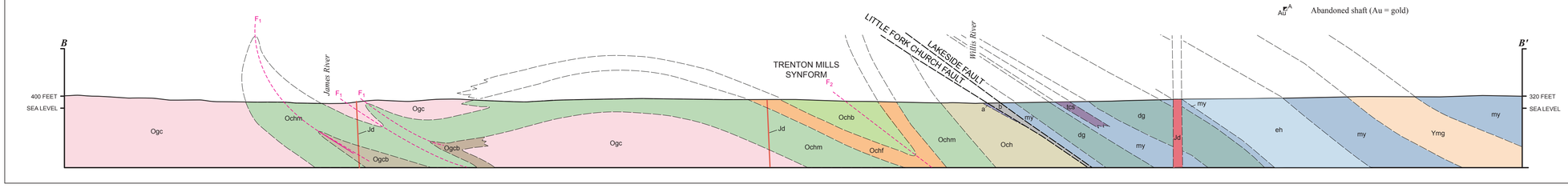
Horizontal lineation

Vertical quartz vein

Vertical foliation with planar lineation

Vertical foliation with horizontal lineation



Interpretive cross-sections:

1. No vertical exaggeration
2. Subsurface structures interpreted from surface measurements
3. Quaternary-age units omitted.