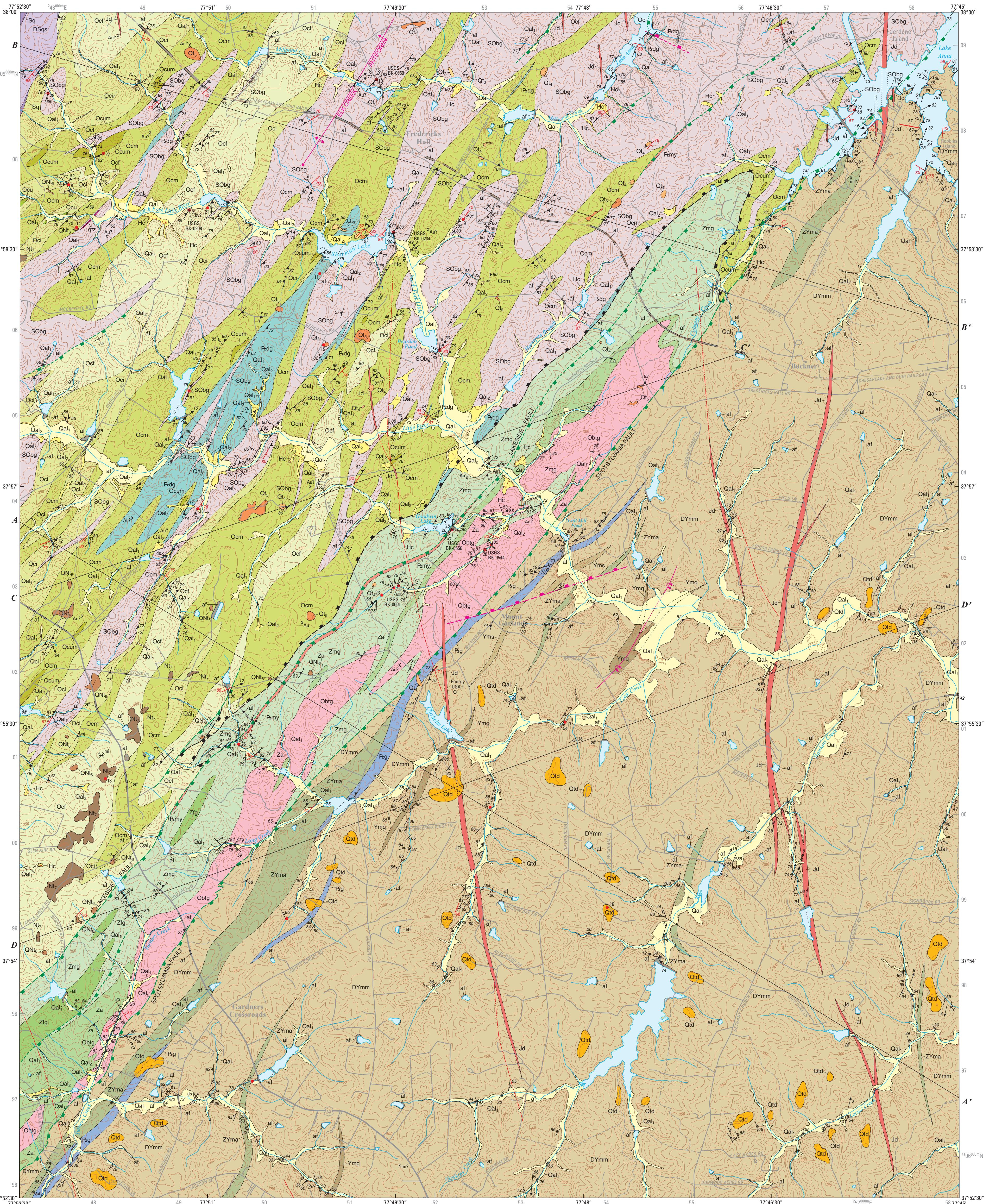
U.S. Department of the Interior
U.S. Geological Survey

Prepared in cooperation with the
Virginia Department of Energy, Geology and Mineral Resources Program

Scientific Investigations Map 3533
Pamphlet accompanies map



Base hydrology and topography from Virginia QL2 lidar project, 2016
Base modified from U.S. Geological Survey, 2019
Universal Transverse Mercator, zone 18, north
North American Datum of 1983

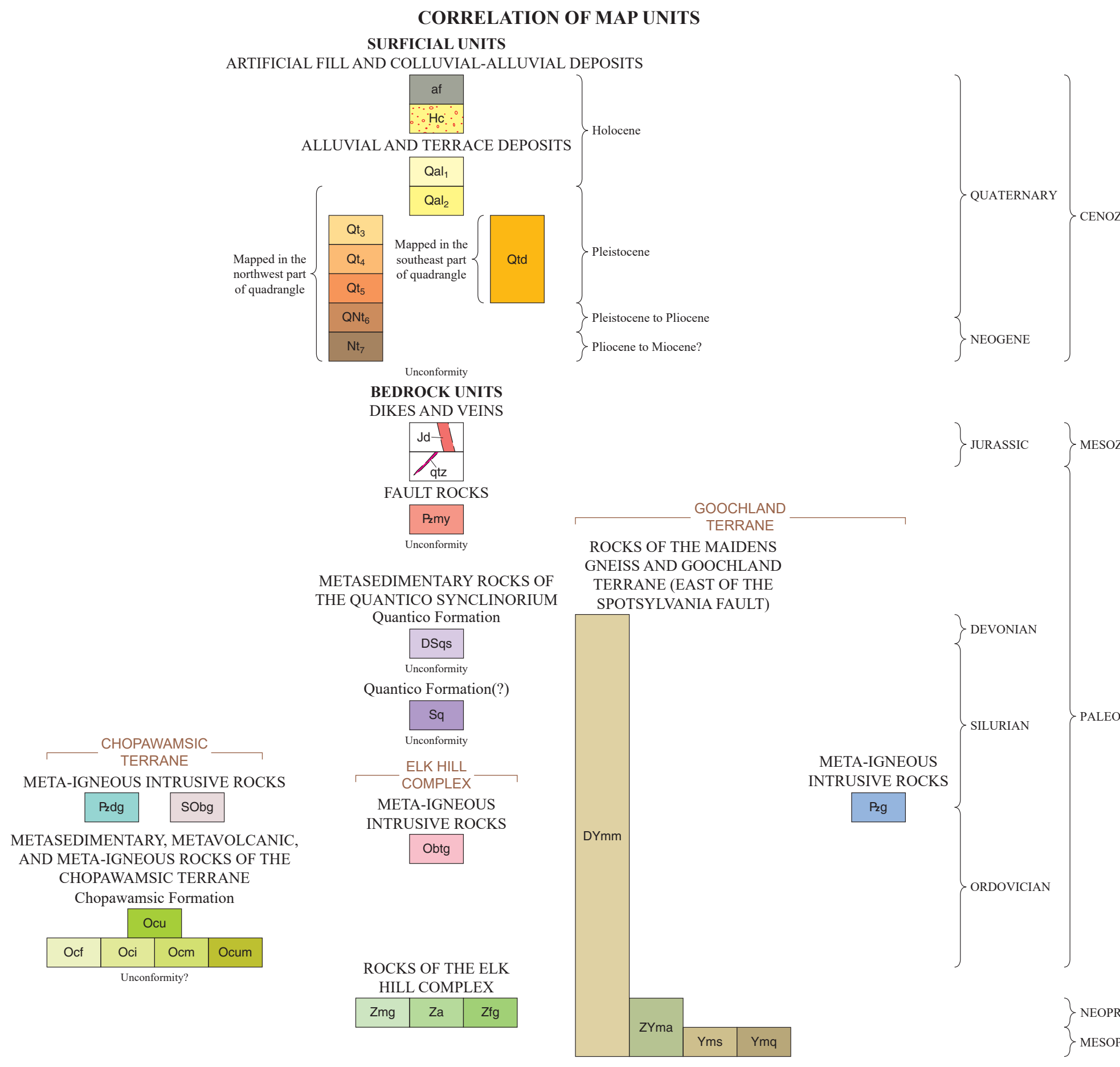
APPROXIMATE MEAN DECLINATION, 2025

SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1988

MAP LOCATION

Geology mapped by Carter, Spears, Latane, and Horton, 2016–20
Compilation and database by Weinmann, Crider, Mangum, and Carter
Edited by Zachary P. Younger
Cartography by D. Paul Mathieux

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

SURFICIAL UNITS

ARTIFICIAL FILL AND COLLUVIAL-ALLUVIAL DEPOSITS

af **Artificial fill (Holocene)**—Unconsolidated to variably consolidated rock, sand and gravel, soil, and debris of local origin and derived in part from alluvium and saprolite. Artificial fill is used for land modification and grading, including roadway creek crossings, earthen dams, and ponds. Thickness is variable, but locally up to 7.5 meters (m)

Hc **Colluvial-alluvial material (Holocene)**—Unconsolidated clay, silt, sand, and gravel are present in hillslope, toe slope, and stream channelway landslide colluvium, as well as in alluvial-colluvial fan deposits overlying floodplain alluvium at stream mouths. These deposits are interpreted to have been derived from extensive erosion of topsoil and saprolite since European settlement in the 1700s. This unit was only observed and mapped in the northwestern half of the Buckner 7.5-minute quadrangle. Thickness is variable, but likely no more than 3 m

ALLUVIAL AND TERRACE DEPOSITS

[Contacts for these deposits were constructed from both field observations (using the topographic map as a base) and shaded relief images (derived from 1-m light detection and ranging data)]

Qal$_1$ **Younger alluvium (Holocene)**—Unconsolidated clay, silt, sand, gravel, and organic material deposited in floodplains along modern stream courses. Gravel is present in active and abandoned channelways and consists of angular to subrounded pebbles, cobbles, and boulders of mostly vein quartz, with some locally sourced bedrock clasts. In active channelways, these deposits lie just above bedrock. Locally, alluvial sand and gravel is consolidated to semi-lithified by clay and iron-oxide precipitation. Thickness is variable, but likely no more than 6 m

Qal$_2$ **Older alluvium (Pleistocene)**—Unconsolidated clay, silt, sand, and gravel deposited in morphologically distinct and elevated landscape positions along the margin of modern floodplains, at the head of second- and higher-order branch streams, and in abandoned stream channels. Although the mode of deposition of these sediments was dominantly alluvial, significant colluvial transport and mixing has also occurred. Gravel in these deposits consists of subangular to subrounded pebbles, cobbles, and boulders of vein quartz, locally sourced bedrock clasts, and few well-rounded clasts remobilized from topographically higher terrace deposits. This unit was only observed and mapped in the northwestern half of the quadrangle. Thickness is variable, but likely no more than 5 m

Qt$_3$ **Lowest-level terrace deposits (Pleistocene)**—Unconsolidated light-yellowish-brown sand with mostly subrounded to well-rounded pebbles and cobbles of vein quartz and white sandstone or weathered quartzite. A few clasts are of locally sourced bedrock. In the Little River drainage basin, deposits cap hills and mantle gentle side slopes at elevations ranging from 305 to 285 feet (ft) above sea level and about 15 ft above modern drainages; in the North Anna drainage basin, deposits cap hills and mantle gentle side slopes at elevations ranging from 305 to 250 ft above sea level and about 10 ft above modern drainages. This unit was only observed and mapped in the northwestern half of the quadrangle. Thickness is variable, but likely no more than 3 m

Qt$_4$ **Low-level terrace deposits (Pleistocene)**—Unconsolidated light-yellowish-brown sand with mostly subangular to well-rounded pebbles and cobbles of vein quartz and white sandstone or weathered quartzite. A few clasts are of locally sourced bedrock. Rounded nodules (up to 1 centimeter [cm] in diameter) of iron-cemented quartz sand are locally common. In the Little River drainage basin, deposits cap hills and mantle gentle side slopes at elevations ranging from 325 to 310 ft above sea level and 20 to 50 ft above modern drainages; in the North Anna drainage basin, deposits cap hills and mantle gentle side slopes at elevations ranging from 380 to 305 ft above sea level and 30 to 40 ft above modern drainages. This unit was only observed and mapped in the northwestern half of the quadrangle. Thickness is variable, but likely no more than 3 m

Qt$_5$ **Mid-level terrace deposits (Pleistocene)**—Unconsolidated light-yellowish-brown sand; in some deposits, the sand is more clay rich and iron stained. Fluvial clasts within the sand are mostly subrounded to well-rounded pebbles and cobbles of vein quartz and white sandstone or weathered quartzite but are locally mixed with angular to subangular vein quartz clasts of likely colluvial origin. Few of the clasts are of locally sourced bedrock; clasts of *Skolithos*-bearing quartzite are very rare. Some clasts have well-developed, millimeter (mm)- to centimeter-thick weathering rinds of iron and manganese mineralization. Rounded nodules (up to 1 cm in diameter) of iron-cemented quartz sand are locally common. Deposits cap hills at an elevation of about 365 ft above sea level in the North Anna drainage basin, at elevations ranging from 350 to 330 ft above sea level in the Little River drainage basin, and at elevations about 345 ft above sea level on the drainage divide between the river systems. All deposits are 50 to 70 ft above modern drainages. This unit was only observed and mapped in the northwestern half of the quadrangle. Thickness is variable, but likely no more than 3 m

Qtd **Terrace deposits, undivided (Pleistocene)**—Unconsolidated brown silty sand with subangular to rounded gravel and cobbles of moderately iron-stained vein quartz and sparse rounded cobbles of white sandstone. Deposits cap hilltops at elevations ranging from 50 to 80 ft above modern streams. These deposits were only observed and mapped in the southeastern half of the quadrangle and are probably more extensive than those observed in the field and shown on the map. Thickness is variable, but estimated to be less than 10 m

QNt$_6$ **Upper-level terrace deposits (Pleistocene to Pliocene)**—Unconsolidated to semi-lithified light- to moderate-brown clay-rich sand consisting of iron-stained grains of angular to well-rounded quartz. Fluvial clasts within the sand are subrounded to well-rounded pebbles and cobbles of vein quartz and yellowish sandstone or weathered quartzite and are mixed with abundant angular to subangular vein quartz clasts of likely colluvial origin. Rounded nodules (up to 1 cm in diameter) of iron-cemented quartz sand are common. Cobbles and boulders of iron- and manganese-cemented sand and angular quartz fragments are locally present in some terrace deposits. Few of the clasts are of locally sourced bedrock; clasts of *Skolithos*-bearing quartzite are very rare. Deposits cap hills at elevations ranging from 390 to 355 ft above sea level in the Little River drainage basin, at elevations ranging from 370 to 355 ft above sea level in the South Anna drainage basin, and at an elevation of about 380 ft above sea level on the drainage divide between the river systems. All deposits are 50 to 70 ft above modern drainages, and about 30 ft or more above headwater streams. Deposits in the South Anna drainage basin are equivalent to Qt$_2$ terraces mapped by Spears and others (2013) on the west-adjacent Pendleton 7.5-minute quadrangle. If these deposits are younger than Neogene, they may be correlative to Qt$_3$ deposits of Malenda (2015), who reported a post infrared-infrared stimulated luminescence at 225 degrees Celsius age of about 392 thousand years ago. This unit was only observed and mapped in the northwestern half of the Buckner quadrangle. Thickness is variable, but likely no more than 3 m

Nt$_7$ **Highest-level terrace deposits (Pliocene to Miocene?)**—Deposits are characterized by an accumulation of pebbles, cobbles, and boulders consisting of iron- and manganese-cemented sand, angular quartz fragments, and fluvially rounded clasts of similar lithology. Some boulders preserve crude bedding. The deposits also consist of abundant angular to subangular vein quartz clasts of likely colluvial origin. Ironstone, ferricrete, and vein quartz clasts exist as pebbles, cobbles, and boulders in a matrix of iron-stained quartz sand. Deposits cap hills at elevations ranging from 415 to 395 ft above sea level in the Little River drainage basin, at elevations ranging from 405 to 380 ft above sea level in the South Anna drainage basin, and at elevations ranging from 415 to 405 ft above sea level on the drainage divide between the river systems. All deposits are 30 to 40 ft above headwater streams. The composition (which is like some deposits preserved in the Coastal Plain Province of Virginia 50 kilometers to the east) and position (high on the landscape and well above modern stream courses) of these deposits indicate that they may be as old as Miocene. Carter and others (2019) suggested they are the remnants of Neogene laterites. This unit was only observed and mapped in the northwestern half of the quadrangle. Thickness is variable but likely no more than 3 m

BEDROCK UNITS

DIKES AND VEINS

Jd **Diabase (Jurassic)**—Dark-green-gray to black diabase, weathering to a dark reddish brown. Diabase is aphanitic to very finely crystalline to medium crystalline locally. Diabase is ophitic, sub-ophitic, sub-idiomorphic to porphyritic, and non-foliated. Mineralogy consists of randomly oriented plagioclase laths that form a framework that encloses grains of clinopyroxene, serpentine minerals, strongly fractured and altered olivine, opaque minerals, and very minor quartz. Olivine is partly altered to serpentine, biotite, talc, chlorite, and iddingsite. Diabase typically contains abundant magnetite and the rock is strongly magnetic. Rocks of this unit are north-northwest- to north-northeast-striking dikes that locally intrude older units throughout the map area. Diabase commonly weathers to smooth, dense, spheroidally rounded boulders with a distinctive soft, orange-brown rind, which can be easily traced along strike when outcrops are absent. Diabase dikes are of early Jurassic age (Kunk and others, 1992; Jourdan and others, 2009) and were emplaced throughout the Piedmont Physiographic Province during continental extension and the opening of the Atlantic Ocean in the Mesozoic (Manspeizer and others, 1989)

qtz **Vein quartz (Mesozoic? to Paleozoic)**—White to bluish-white vein quartz, weathering to very pale orange. Vein quartz is fine to very coarsely crystalline and sub-idiomorphic to sugary textured. Mineralogy consists of quartz with minor amounts of muscovite, ilmenite, and magnetite locally. Vein quartz exists as dikes and sills that locally intrude older units throughout the map area, but most are too small to accurately map at 1:24,000 scale. The one map-scale outcrop is in the northwest corner of the quadrangle. Vein quartz commonly weathers to pebbles, cobbles, and boulders of angular to subrounded fragments and white to very pale orange sand, which mantles the surface above quartz veins. Quartz veins likely crystallized from regional metamorphic fluids during late Paleozoic metamorphism or Mesozoic continental rifting

FAULT ROCKS

Pzmy **Biotite-muscovite phyllonite (late Paleozoic)**—Brownish-gray phyllonite, weathering to brownish red. Phyllonite is medium crystalline, lepidoblastic, mylonitic, strongly foliated, lineated, and crenulated. Mineralogy consists mostly of muscovite and biotite, with minor quartz and feldspar. Phyllonite is associated with compositionally well-layered mica gneiss (with layers up to about 1 cm thick) consisting of alternating quartzofeldspathic- and mica-rich layers. Phyllonite consistently exhibits mylonitic shear banding, with dextral kinematic indicators. Phyllonite is intruded by pegmatite dikes up to 0.1 m wide; an ^{40}Ar/^{39}Ar plateau age of about 295 Ma (mega-annum) from muscovite from a discordant pegmatite provides a minimum age of deformation

METASEDIMENTARY ROCKS OF THE QUANTICO SYNCLINORIUM

Quantico Formation

DSqs **Garnet-mica schist (Devonian to Silurian) (age revision in Carter and others [2020])**—Dusky-blue-green schist, weathering to grayish red. Schist is fine to medium crystalline, lepidoblastic, protomylonitic, strongly foliated, lineated, and crenulated. Mineralogy consists mostly of muscovite and chlorite, with garnet porphyroblasts (up to several millimeters in diameter). Chloritoid ± staurolite porphyroblasts (randomly oriented on foliation surfaces) and graphite are present locally. Quartz forms thin (less than or equal to several millimeters thick) compositional selvages and layers in some outcrops. Schist weathers to a reddish-brown soil with abundant flakes of mica and garnet, which are stained to completely replaced by iron oxide

Quantico Formation(?)

Sq **Quartzite (Silurian)**—Light-gray quartzite, weathering to yellowish gray to dark reddish gray. Quartzite is fine to medium crystalline, granoblastic, and non-foliated to foliated. Mineralogy consists mostly of quartz and white mica (sericite and muscovite). Quartzite is commonly ferruginous, contains magnetite locally, and is typically cemented with hematite. Quartzite is discontinuously present beneath garnet-mica schist (map unit DSqs). U-Pb geochronology of detrital zircons grains from an exposure of equivalent quartzite on the west-adjacent Pendleton 7.5-minute quadrangle yielded a maximum depositional age of about 427 Ma (Carter and others, 2020). On the northwest- and north-adjacent Mineral and Lake Anna 7.5-minute quadrangles, respectively, Carter and others (2019) assigned a more diverse assemblage (including quartzite with graphitic schist, felsic schist, greenstone, and amphibolite) to an Ordovician to Silurian unit of interlayered metasedimentary and metavolcanic rocks; this unit is bounded by unconformities from garnet-mica schist of the Quantico Formation above and rocks of the Chopawamsic Formation below. Only quartzite from that assemblage was identified at the base of the Quantico Formation on the Buckner 7.5-minute quadrangle

META-IGNEOUS INTRUSIVE ROCKS

Pzdg **Amphibolitic metadiorite and metagabbro (Paleozoic)**—Dark-grayish-green amphibolite, weathering to yellowish red. Amphibolite is medium to coarsely crystalline, granoblastic to nematoblastic, non-foliated to foliated, and locally strongly lineated, with one penetrative foliation preserved locally. Major mineral constituents are hornblende, plagioclase, garnet, and some quartz. Coarsely crystalline laths of amphibole (up to 1 cm in length and randomly oriented on weak foliation surfaces) are common in many outcrops, and quartz-feldspar leucosomes (up to several centimeters thick) are common in some outcrops. Rocks of this unit weather to reddish-yellow punky-weathered float in a brownish-red clay-rich soil. Rocks of this unit are present in the Chopawamsic Formation of the Chopawamsic terrane, west of the Lakeside fault and the Elk Hill Complex. Texture, mineralogy, and map relations indicate that this unit is meta-igneous. The unit may be equivalent to metapyroxenite described by Brown (1937) and Spears and others (2004) to the southwest near Hadensville, Virginia, but more highly metamorphosed and altered

Pzg **Metagranitoid (Paleozoic)**—Light-gray metagranitoid that is finely crystalline, non-foliated to weakly foliated, and weakly compositionally layered. Mineralogy consists of quartz-microcline-plagioclase with minor finely crystalline biotite and very sparse muscovite and apatite. Rocks of this unit are present in the Maidens Gneiss of the Goochland terrane east of the Spotsylvania fault and are likely highly strained Paleozoic meta-igneous intrusions within the Spotsylvania high-strain zone. Metagranitoid is likely correlative with the informal granite of Little Lickinghole Creek of Spears and Evans (2020)

SObg **Granodiorite of Elk Creek (Silurian to Ordovician)**—Informal unit consisting of light-bluish-gray metamorphosed granodiorite, weathering to light yellowish gray. Metamorphosed granodiorite is fine to medium crystalline, porphyritic, porphyroclastic, granoblastic, and locally protomylonitic. Mineralogy consists of quartz, plagioclase, alkali-feldspar, biotite, pargasitic hornblende, riebeckite, and magmatic epidote. Muscovite, myrmekite, calcite, garnet, and magnetite-ilmenite are accessory minerals. Metamorphosed granodiorite is well foliated, with one penetrative foliation preserved. Metamorphosed granodiorite is locally intruded by meter-scale dikes of foliated to non-foliated pegmatite (coarsely to very coarsely crystalline quartz, feldspar, and muscovite) and well-foliated granodioritic rocks containing significant biotite and hornblende in addition to quartz and feldspar. Outcrop- and map-scale xenoliths of layered amphibolite (map unit Ocm) were locally observed within metamorphosed granodiorite. Metamorphosed granodiorite weathers to a light-brown loamy soil with scattered flakes of mica. Rocks of this unit were observed as sheet-like mappable bodies as well as a few dikes (most too small to accurately separate and map at 1:24,000 scale) in the Chopawamsic Formation of the Chopawamsic terrane west of the Lakeside fault and the Elk Hill Complex. Mixon and others (2000) assigned conterminous rocks on the north-adjacent Lake Anna West 7.5-minute quadrangle to the Carboniferous Falmouth Intrusive Suite of Pavlides (1980) and Pavlides and others (1982); however, Carter and others (2020) reported Sensitive High-Resolution Ion Microprobe with Reverse Geometry (SHRIMP-RG) U-Pb zircon crystallization ages from two samples from the Buckner quadrangle that range from about 442 to 456 Ma, ages that show that these rocks are not part of the Carboniferous Falmouth Intrusive Suite

Obtg **Hornblende-biotite tonalitic gneiss (Ordovician)**—Light-bluish-gray tonalitic gneiss, weathering to light yellowish gray. Tonalitic gneiss is fine to medium crystalline, porphyroclastic, granoblastic, and protomylonitic. Rocks of this unit consist of quartz, plagioclase, alkali feldspar, muscovite, biotite, and hornblende. As a result of high strain, tonalitic gneiss is strongly foliated and well layered. Layering consists of quartz and feldspar layers (several millimeters thick) alternating with hornblende + biotite + muscovite dominated zones (several millimeters thick). Diagnostic of this unit are decimeter- to meter-scale blocks of layered amphibolite (from map unit Za) within tonalitic gneiss. Layering in these amphibolite blocks is discordant and randomly oriented to high-strain layering in tonalitic gneiss. Outcrop-scale field relations indicate that these angular blocks are original xenoliths within tonalitic gneiss rather than dismembered and boudinaged mafic dikes and sills. Rocks of this unit are present between the Lakeside and Spotsylvania faults in the Elk Hill Complex. Carter and others (2020) reported a SHRIMP-RG U-Pb zircon crystallization age of 452±6 Ma from one sample near Goodwin Lake

METASEDIMENTARY, METAVOLCANIC, AND META-IGNEOUS ROCKS OF THE CHOPAWAMSIC TERRANE

Chopawamsic Formation

Ocu **Rocks of the uppermost part of the Chopawamsic Formation (Ordovician)**—Rocks of the uppermost part of the Chopawamsic Formation consist of chlorite-garnet calc-silicate granofels interlayered with biotite gneiss and amphibolite. These rocks may be equivalent to those mapped at the top of the Chopawamsic Formation on the west-adjacent Pendleton 7.5-minute quadrangle (Spears and others, 2013; Burton and others, 2014, 2015a). Chlorite-garnet calc-silicate granofels is light greenish gray, weathering to yellowish gray. Granofels is finely to very coarsely crystalline, generally granoblastic, but locally nematoblastic to lepidoblastic (depending on chlorite and amphibole content), and non-foliated to well foliated. Mineralogy consists of quartz and feldspar, variable amounts of amphibole and chlorite, and large (up to 3 cm in diameter) garnet porphyroblasts. Many garnet porphyroblasts are flattened and deformed by high strain, with significant retrogression to chlorite. Interlayered biotite gneiss is medium dark gray, weathering to dark yellowish brown. Biotite gneiss is fine to medium crystalline, granoblastic to lepidoblastic (depending on mica content), well foliated, and locally lineated. Mineralogy consists of quartz, feldspar, biotite, muscovite, minor hornblende, and garnet locally. Biotite gneiss is locally compositionally layered, with layering ranging from several millimeters to about 1 cm thick and consisting of alternating quartzofeldspathic and mica-rich layers. Rare lithic fragments indicate a volcaniclastic origin. Amphibolite is dusky yellowish green, weathering to moderate brown. Amphibolite is fine to medium crystalline, granoblastic to nematoblastic (depending on amphibole content), non-foliated to well foliated, and locally lineated. Mineralogy consists of hornblende, biotite, chlorite, plagioclase, and quartz. Rocks of unit Ocu were observed as two map-scale bodies in the northwestern part of the Buckner quadrangle, along a third-order tributary of the North Fork of the Little River

Ocf **Felsic metasedimentary and metavolcanic rocks (Ordovician)**—Kyanite-muscovite-quartz schist, quartzite, and felsic gneiss. Kyanite-muscovite-quartz schist is yellowish gray, weathering to moderate yellow. Schist is medium to coarsely crystalline, lepidoblastic and granoblastic, strongly foliated, lineated, and crenulated. Mineralogy consists mostly of muscovite and quartz, with porphyroblasts of coarsely crystalline bladed kyanite locally. Schist is locally compositionally layered, with layering up to about 1 cm thick and consisting of alternating quartz-dominated and mica-rich layers. Many outcrops exhibit multiple foliations and polydeformed folds. Schist weathers to a reddish yellow-brown clayey soil with abundant flakes of mica. Quartzite is very pale orange, weathering to pale yellowish orange. Quartzite is medium to coarsely crystalline, granoblastic, and non-foliated to strongly foliated. Mineralogy consists mostly of quartz with porphyroblasts of fine to medium crystalline muscovite along foliation surfaces. Quartzite is locally compositionally layered, with layering up to about 1 cm thick and consisting of alternating quartz-dominated and mica-rich layers. Felsic gneiss is pale greenish yellow, weathering to grayish yellow. Non-foliated to foliated, aphanitic to finely crystalline, granoblastic felsic gneiss is most common. Locally, gneiss is compositionally layered, with layering up to several centimeters thick and consisting of alternating quartzofeldspathic and mica ± amphibole-bearing layers. Rarely, felsic gneiss preserves subhedral to euhedral quartz phenocrysts up to 2 mm in diameter. Felsic gneiss weathers to a very pale orange clayey kaolinitic soil. All felsic rock types are locally interlayered with amphibolite, from several centimeters up to about 1 m thick. Rocks of unit Ocf are similar to, but of higher metamorphic grade than, the Chopawamsic Formation rocks mapped in the Mineral volcanogenic massive sulfide district, which is approximately 10 kilometers to the north and northwest on the adjoining Mineral and Lake Anna West 7.5-minute quadrangles (Carter and others, 2019) and is described by Duke (1983) and Sauer (1984). A sample of felsic schist from these adjoining quadrangles yielded a SHRIMP-RG U-Pb crystallization age of 471±4 Ma (Carter and others, 2020). This unit is also likely equivalent to metavolcanic rocks of felsic composition of the Chopawamsic Formation mapped on the west-adjacent Pendleton 7.5-minute quadrangle (Spears and others, 2013)

Oci **Biotite gneiss (Ordovician)**—Mostly biotite gneiss, interlayered locally in outcrop and at map scale with biotite schist and amphibolite. Biotite gneiss is medium dark gray, weathering to dark yellowish brown. Biotite gneiss is fine to medium crystalline, granoblastic to lepidoblastic (depending on mica content), non-foliated to well foliated, and locally lineated. Mineralogy consists of quartz, feldspar, biotite, muscovite, and sparse hornblende and garnet. Biotite gneiss is compositionally layered, with layering ranging from several millimeters to several centimeters thick and consisting of alternating quartzofeldspathic and mica-rich layers. Massive biotite gneiss, in layers up to several meters thick, consists mostly of quartz, plagioclase, and biotite, lacks significant muscovite, and may be intrusive granitoid. Biotite gneiss weathers to a light-brown loamy soil with abundant flakes of mica. This unit is likely equivalent to metavolcanic rocks of intermediate composition of the Chopawamsic Formation mapped on the west-adjacent Pendleton 7.5-minute quadrangle (Spears and others, 2013) and on the northwest- and north-adjacent Mineral and Lake Anna West 7.5-minute quadrangles (Carter and others, 2019)

Ocm **Layered amphibolite (Ordovician)**—Grayish-olive amphibolite, weathering to light olive brown to dusky yellow. Amphibolite is fine to medium crystalline, nematoblastic to lepidoblastic (depending on mica content), and well foliated. Mineralogy consists of hornblende and other amphibole minerals, biotite, plagioclase, quartz, and garnet locally. Amphibolite is compositionally layered, with layering ranging from several millimeters to about 1 cm thick and consisting of amphibole ± plagioclase and quartz layers alternating with mica-rich layers. In outcrop, amphibolite is locally interlayered at centimeter to decimeter scale with leucocratic rocks of felsic composition. Quartz-feldspar felsic gneiss is pale greenish yellow, weathering to grayish yellow. Felsic gneiss is typically finely crystalline to aphanitic, granoblastic, and non-foliated to foliated. Felsic gneiss is also locally compositionally layered, with layering ranging from several millimeters to about 1 cm thick and consisting of quartz and feldspar layers alternating with amphibole ± mica-rich layers. Garbenschiefer, or "turkey-track" texture, is locally common on foliation and compositional-layer surfaces in felsic gneiss and consists of radiating bundles of randomly oriented amphibole needles. Layered amphibolite weathers to reddish-yellow punky-weathered cuboid chips in a reddish-brown clay-rich soil, with variable mica content. Coler and others (2000) reported a thermal ionization mass spectrometry (TIMS) U-Pb zircon crystallization age of about 470 Ma for mafic rocks of the Chopawamsic Formation. Layered amphibolite is likely equivalent to metavolcanic rocks of mafic composition mapped on the west-adjacent Pendleton 7.5-minute quadrangle (Spears and others, 2013) and on the northwest- and north-adjacent Mineral and Lake Anna West 7.5-minute quadrangles (Carter and others, 2019)

Ocum **Altered ultramafic rocks (Ordovician)**—Altered ultramafic rocks mostly consisting of dusky-blue-green amphibole-mica schist, which weathers dark greenish gray. These rocks are fine to medium crystalline, granoblastic to nematoblatic, non-foliated to well foliated, and locally lineated. Mineralogy consists of acicular needles of amphibole, chlorite, biotite, some talc, minor quartz and feldspar, and garnet locally. Multiple foliations and associated intersection lineations were observed in few outcrops. Coarse compositional layering, defined by variable amphibole content in alternating centimeter-thick zones, was also observed in few outcrops. Garbenschiefer, or "turkey-track" texture, is locally common on foliation and compositional-layer surfaces. Cross-biotite texture, defined by coarsely crystalline biotite porphyroblasts crosscutting foliation, has also been observed in few outcrops and in float. Rocks of this unit weather either to a thin, olive-green clay-rich loamy soil or thick, reddish-brown clayey soil. Rocks of this unit exist as mappable pods and lenses within layered amphibolite (map unit Ocm), but layers of altered ultramafic rocks have not been observed within layered amphibolite at outcrop scale. These rocks are either igneous intrusive plugs, stocks, and dismembered dikes and sills, or were tectonically emplaced within layered amphibolite. Equivalent altered ultramafic rocks exist on the northwest- and north-adjacent Mineral and Lake Anna West 7.5-minute quadrangles (Carter and others, 2019)

ROCKS OF THE ELK HILL COMPLEX

Zmg **Mica gneiss (Neoproterozoic)**—Medium-dark-gray mica gneiss, weathering to light brownish gray. Mica gneiss is medium to coarsely crystalline, lepidoblastic and granoblastic, strongly foliated, lineated, and crenulated. Mineralogy consists mostly of biotite, muscovite, feldspar, and quartz, with porphyroblasts of garnet, amphibole, staurolite, and kyanite locally. Well-defined compositional layering (with layers up to about 2 cm thick) is common and consists of alternating quartzofeldspathic and mica-rich layers; this layering is interpreted to be migmatitic and a product of amphibolite-facies regional metamorphism. All outcrops exhibit multiple foliations, polydeformed folds, and boudinaged quartz-feldspar layers with dextral sense-of-shear kinematic indicators. Mica gneiss weathers to a reddish-yellow-brown clay loam soil with abundant flakes of mica. West of biotite-muscovite phyllonite (map unit Pzmy) exposures near the Lakeside fault, meter-scale blocks of very coarsely crystalline, massive pegmatite (consisting of alkali-feldspar crystals several decimeters in length and books of muscovite up to about a decimeter in length) are locally scattered within the mica gneiss outcrop belt, but none have been found in place. Carter and others (2020) interpret mica gneiss to have a sedimentary protolith due to its high muscovite content, the presence of rounded cores observed in cathodoluminescence imaging of zircon grains, as well as the presence of multimodal age populations; Carter and others (2020) reported a maximum depositional age for this unit of about 926 Ma from detrital zircon analysis using the SHRIMP-RG technique. Field and map relations in the northwestern part of the Buckner 7.5-minute quadrangle indicate that mica gneiss stratigraphically or structurally underlies rocks of the Chopawamsic Formation along an overturned pre-metamorphic fault or unconformity. Mica gneiss closely resembles strongly compositionally layered gneisses southeast of the Lakeside fault and northwest of the Spotsylvania high-strain zone that were assigned to the Elk Hill Complex by Spears and Bailey (2002)

Za **Amphibolite (Neoproterozoic?)**—Dark-gray to dark-grayish-green to greenish-black amphibolite, weathering to yellowish red. Amphibolite is fine to medium crystalline, granoblastic to nematoblastic, non-foliated to foliated, and locally lineated. Major mineral constituents are hornblende, clinopyroxene, plagioclase, some quartz, and minor garnet, biotite epidote, and opaque minerals. Magnetite is rare, and these rocks are generally non-magnetic. Amphibolite is locally compositionally layered; layers are up to about 1 cm thick and consist of coarsely crystalline amphibole with plagioclase and quartz layers alternating with finer-crystalline amphibole-dominated layers. A few bodies are interlayered at map scale with mica gneiss (map unit Zmg) along concordant contacts. Rocks of the unit may be mafic volcanic rocks of equivalent age as mica gneiss, or the rocks could be younger mafic igneous intrusive rocks. The presence of xenoliths of layered amphibolite within hornblende-biotite tonalitic gneiss (map unit Obtg; dated at about 452±6 Ma) indicate that these xenoliths are older than Late Ordovician

Zfg **Felsic gneiss (Neoproterozoic?)**—Light gray felsic gneiss that is finely crystalline, non-foliated to weakly foliated, and weakly compositionally layered. Mineralogy consists of quartz, microcline, plagioclase, minor finely crystalline biotite, very sparse muscovite, and rare apatite. Bodies are interlayered at map scale with mica gneiss along concordant contacts and, based on correlation with lower metamorphic-grade rocks in similar structural position along strike to the southwest (Spears, 2011), the felsic gneiss may have originated as felsic volcanic rocks of equivalent age to mica gneiss (map unit Zmg)

ROCKS OF THE MAIDENS GNEISS AND GOOCHLAND TERRANE (EAST OF THE SPOTSYLVANIA FAULT)

DYmm **Biotite gneiss (Devonian to Mesoproterozoic)**—Mostly biotite gneiss that is locally interlayered in outcrop with pegmatite, schist, and granitoid. Biotite gneiss is medium gray, light gray to medium dark gray, weathering to brown to light brownish gray. Biotite gneiss is finely to coarsely crystalline, is porphyroclastic to porphyroblastic, and has predominantly feldspar porphyroclasts up to about 2 cm in width. Biotite gneiss consists mostly of quartz, microcline, plagioclase, biotite, and muscovite, with minor garnet, hornblende, titanite, apatite, monazite, opaque minerals, and very finely crystalline zircon. Porphyroblasts of garnet and amphibole are locally abundant. Rocks of this unit are non-magnetic. Biotite gneiss is strongly foliated, compositionally layered, locally lineated, and mylonitic. Mylonitic zones contain quartz ribbons and abundant porphyroclasts of both plagioclase and potassium feldspar. In thin section, quartz displays undulose extinction and twin lamellae in plagioclase are commonly deformed. All outcrops of biotite gneiss exhibit multiple foliations, polydeformed folds, and boudinaged quartz-feldspar layers with dextral sense-of-shear kinematic indicators. Pegmatite is composed of coarsely crystalline quartz, microcline, plagioclase, muscovite, and biotite locally. Thin zones of quartz-muscovite-biotite schist also exist locally. Small granitoid bodies also exist locally, but most are too small to map separately at 1:24,000 scale. Biotite gneiss weathers to a reddish-yellow-brown clay loam soil with abundant flakes of mica. Farrar (1984) interpreted a rock type equivalent to map unit DYmm to be Mesoproterozoic, but some meta-igneous rocks in the unit may be as young as Devonian (Owens and others, 2004, 2010; Shirvell and others, 2004)

ZYma **Amphibolite (Neoproterozoic to Mesoproterozoic)**—Mostly amphibolite that is locally interlayered in outcrop with ultramafic rocks and pegmatite. Amphibolite is dark gray, dark grayish green to black, weathering to yellowish red. Amphibolite is fine to medium crystalline, granoblastic to nematoblastic, non-foliated to foliated, and locally lineated. Major mineral constituents are hornblende and plagioclase, with some quartz, microcline, biotite, clinozoisite, and sparse opaque minerals, garnet, and very finely crystalline zircon. Amphibolite is locally strongly compositionally layered (with layering up to about 1 cm thick) and consists of coarsely crystalline amphibole ± plagioclase and quartz layers alternating with finer-crystalline amphibole-dominated layers. Amphibolite is locally associated with small lenses and layers of ultramafic rock, typically less than 1 m thick. The ultramafic rock is dark grayish green to dark greenish gray, finely crystalline, and penetratively foliated. Ultramafic rock consists of chlorite, talc, serpentine, grunerite, clinopyroxene, acicular amphibole (actinolite or tremolite), and up to 10 percent opaque minerals. The rock is soft due to its talc and serpentine content. Pegmatite is also locally present in amphibolite as thin layers and boudins in most outcrops. This rock is white to light gray, very coarsely crystalline, and consists of quartz, microcline, plagioclase, and muscovite. Coarsely crystalline black gabbro was also observed within amphibolite at one location. Rocks of unit ZYma are non-magnetic. Rocks of this unit exist as map-scale bodies within mylonitic biotite gneiss. Martin and others (2019) interpreted similar amphibolite assigned to the Sabot Amphibolite of the Goochland terrane to be Neoproterozoic in age (about 552 Ma); amphibolite within biotite gneiss may be older

Yms **Quartz-mica schist (Mesoproterozoic?)**—Light-gray to white schist that is fine to medium crystalline, strongly foliated, and compositionally layered. Mineralogy consists mostly of quartz, muscovite, and garnet. Quartz was primarily observed in ribbons separated by muscovite folia. Garnets up to 1 cm in diameter exist in irregular, lens-shaped masses of granular quartz. The unit is non-magnetic. Schist was observed as map-scale bodies within mylonitic biotite gneiss (near Mount Garland) and may be the same age as the gneiss

Ymq **Granofels (Mesoproterozoic?)**—Black granofels that is finely crystalline, equigranular, non-foliated to weakly foliated. It consists of quartz, feldspar, orthoamphibole, clinoamphibole, titanite, and opaque minerals. Granofels is compositionally layered and consists of alternating layers of granofels and biotite gneiss, each less than 10 cm thick. In hand specimen, the rock has the appearance of black quartzite. The unit is non-magnetic. Rocks of this unit exist in map-scale lenses that crop out in thin, resistant ledges within mylonitic biotite gneiss (map unit DYmm) and may be the same age as the gneiss

EXPLANATION OF MAP SYMBOLS

[Not all structural measurements (planar features, foliations, and linear features) are displayed on the map due to space constraints; for the complete dataset, see the data release associated with this publication (Weinmann and others, 2025)]

Contact—Long-dashed where approximately located to within 50 meters (m); dotted where concealed by water or surficial materials

Dike—Jurassic diabase dike located using aeromagnetic survey data; not exposed at the surface; may be up to several hundred meters below the surface

FAULTS

[Long-dashed where location is approximately located to within 50 meters (m); short-dashed where location is inferred to within 100 m; dotted where concealed by water or surficial materials. Rectangles on upthrown block]

Pre-metamorphic reverse fault

High-strain reverse fault—Delineated by phyllonite and other highly strained rocks on either side of contact

High-angle brittle reverse fault

FOLDS

[Symbols show trace of axial surface and direction of dip of limbs; location is known]

Overturned syncline

Antiform

PLANAR FEATURES

[Observation sites are centered on the strike bar or at the intersection point of multiple symbols. Some symbols have been moved for cartographic clarity]

87 **Strike and dip of outcrop-scale fault**

83 **Strike and dip of outcrop-scale inclined dike or vein**

88 **Strike and dip of inclined joint**

66 **Strike and dip of radiating inclined joint**

FOLIATION

[Observation sites are centered on the strike bar or at the intersection point of multiple symbols. Some symbols have been moved for cartographic clarity]

54 **Strike and dip of generic foliation**

82 **Strike and dip of mylonitic foliation**

70 **Strike and dip of phyllosilicate foliation**

85 **Strike and dip of compositional layering**

LINEAR FEATURES

[Observation sites are centered on the strike bar or at the intersection point of multiple symbols. Some symbols have been moved for cartographic clarity]

→ 21 **Bearing and plunge of mineral lineation**

8 **Bearing and plunge of lineation at intersection of surfaces**

49 **Bearing and plunge of outcrop-scale fold axis**

OTHER FEATURES

Mineral resources—Terms: Au, gold; cs, crushed stone; ds, dimension stone; fill, saprolitic fill material; ky, kyanite; mi, mica; ?, indicates uncertainty for which commodity was prospected or mined

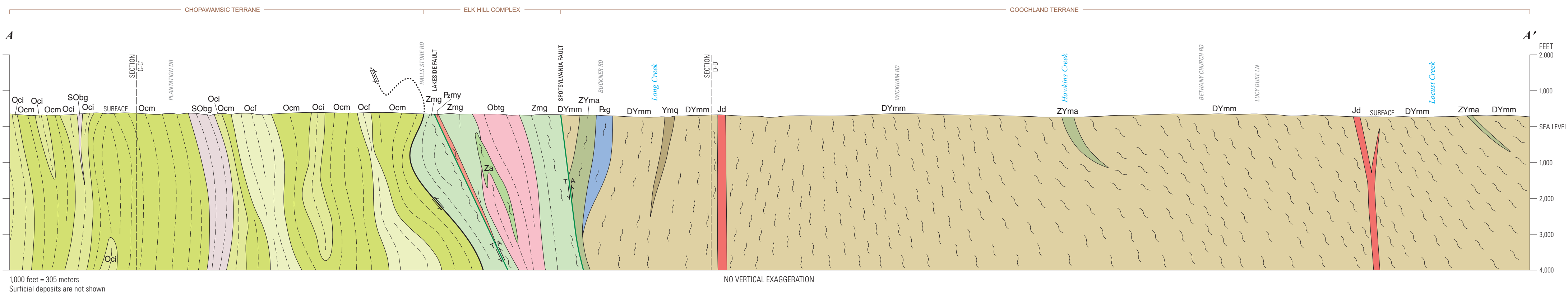
x Au? Prospect

⚒ ds Abandoned mine or quarry

○ **Abandoned oil well**—Name of well shown next to symbol

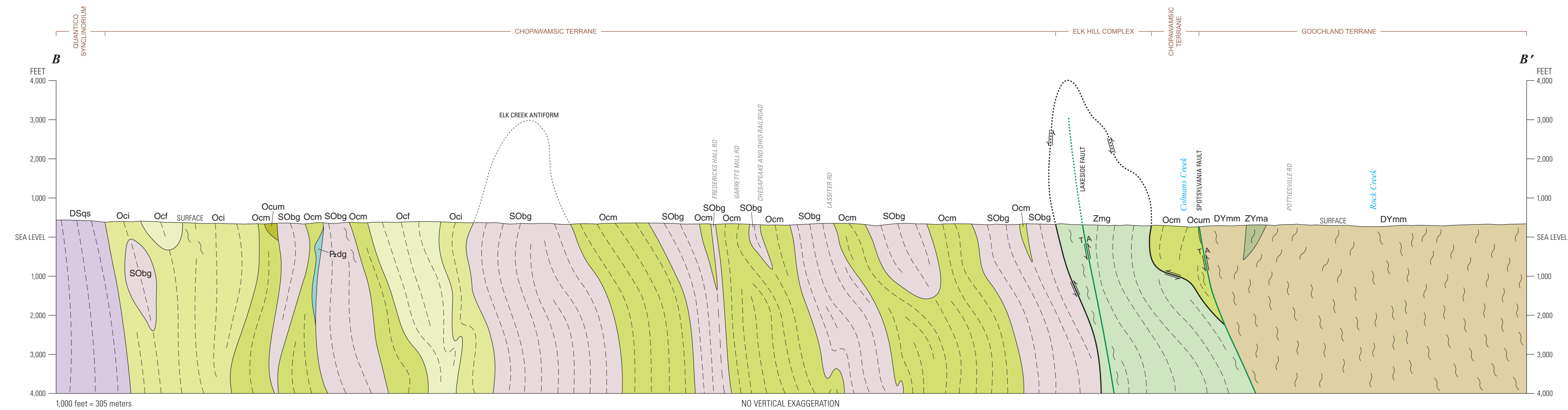
● 26 **Photograph locality**—Number corresponds to photograph locality number for some figures in accompanying pamphlet as well as the "label" field in associated data release (Weinmann and others, 2025)

USGS BK-0208 △ **Geochronology sample location**—^{40}Ar/^{39}Ar geochronology and (or) SHRIMP-RG U-Pb zircon geochronology sample site; number corresponds to field station and sample number in associated data release (Powell and others, 2024)



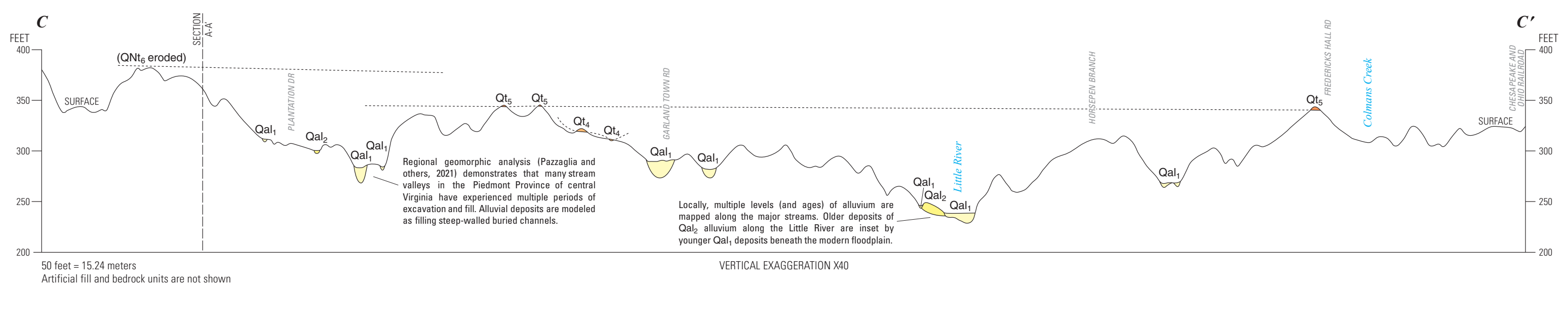
1,000 feet = 305 meters
Surficial deposits are not shown

NO VERTICAL EXAGGERATION



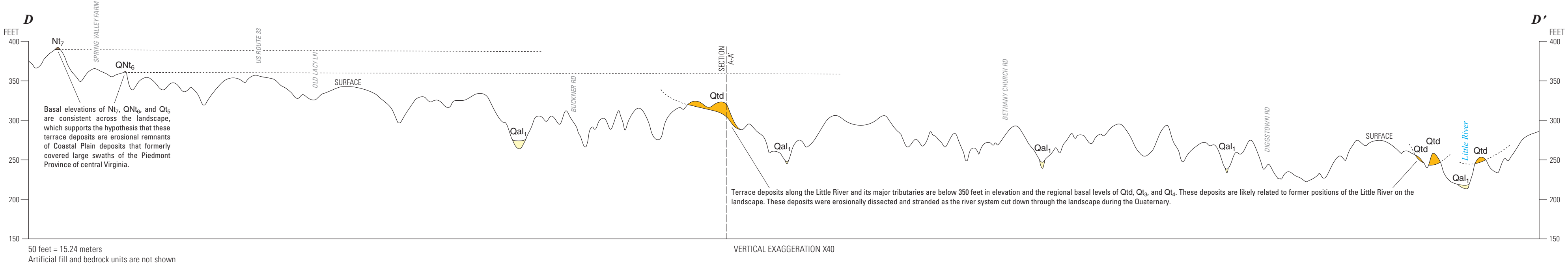
1,000 feet = 305 meters
Surficial deposits are not shown

NO VERTICAL EXAGGERATION



50 feet = 15.24 meters
Artificial fill and bedrock units are not shown

VERTICAL EXAGGERATION X40



Terrace deposits along the Little River and its major tributaries are below 350 feet in elevation and the regional basal levels of Qtd, Qt$_3$, and Qt$_4$. These deposits are likely related to former positions of the Little River on the landscape. These deposits were erosionally dissected and stranded as the river system cut down through the landscape during the Quaternary.

50 feet = 15.24 meters
Artificial fill and bedrock units are not shown

VERTICAL EXAGGERATION X40

EXPLANATION OF CROSS SECTION SYMBOLS

Stratigraphic or igneous contact—Eroded contacts are dotted where projected above the ground surface

Ductile fault (late Paleozoic)—Delineated by highly strained rocks within or on either side of contact; arrows indicate relative motion; T, toward observer; A, away from observer

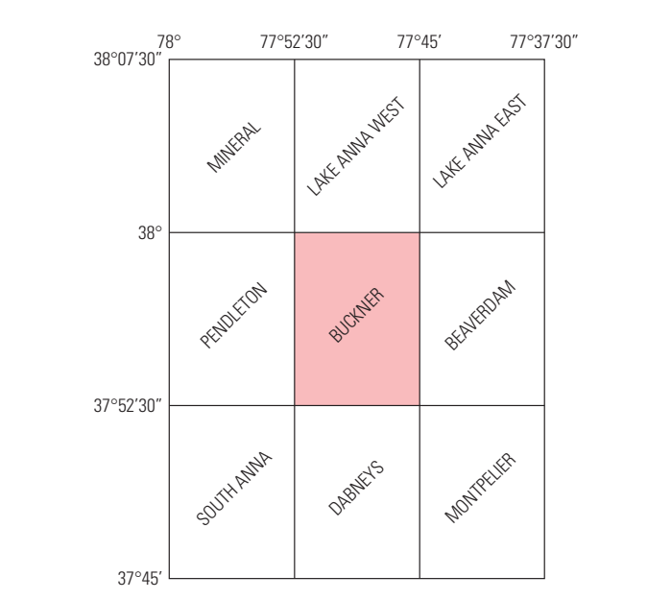
Eroded ductile fault (late Paleozoic)—Projected above the ground surface. Arrows indicate relative motion

Ductile fault (pre-metamorphic)—Arrows indicate relative motion

Eroded ductile fault (pre-metamorphic)—Projected above the ground surface. Arrows indicate relative motion

Interpretive form lines of penetrative foliation—Constructed from surface structural data and projected at depth

Interpretive form lines of shear foliation—Constructed from surface structural data and projected at depth



INDEX TO 7.5′ QUADRANGLES
[Study area shown in red]

Geologic Map of the Buckner 7.5-Minute Quadrangle, Louisa County, Virginia

By

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Weinmann, B.R., Mangum, H., Crider, E.A., Carter, M.W., Spears, D.B., and Latane, V.M., 2025, Geodatabase for the geologic map of the Buckner 7.5-minute quadrangle, Louisa County, Virginia: U.S. Geological Survey data release, https://doi.org/10.5066/P9OE8CKX.