Virginia Department of Mines Minerals and Energy

DRAFT - subject to revision

Open-File Report 2019-10
Geologic Map of the Newport Quadrangle, Virginia
Virginia Division of Geology and Mineral Resources

GEOLOGIC MAP OF THE NEWPORT QUADRANGLE, VIRGINIA

Compiled by PHILIP S. PRINCE

with data from Mervin J. Bartholomew, Arthur P. Schultz, and Philip S. Prince

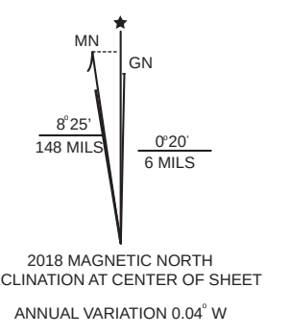
2019

Basemap, modified U.S. Geological Survey Topographic Map, Newport Quadrangle, Virginia, 2016.

Projection: UTM 17S

Digital elevation model, derived from 2007 VGIN orthophotography elevation control data

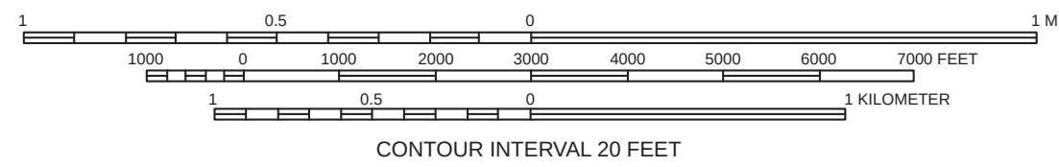
Digital Cartography by Philip S. Prince and William Swanger



2018 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

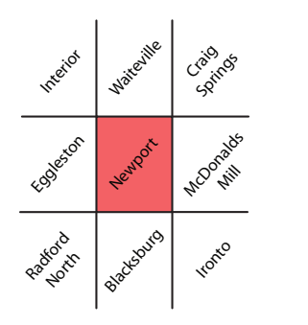
ANNUAL VARIATION 0.04° W

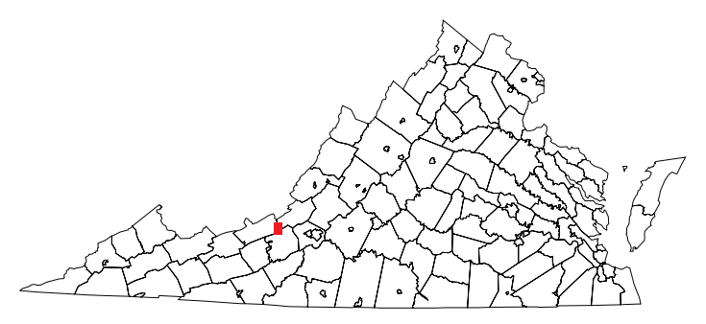
SCALE 1:24000

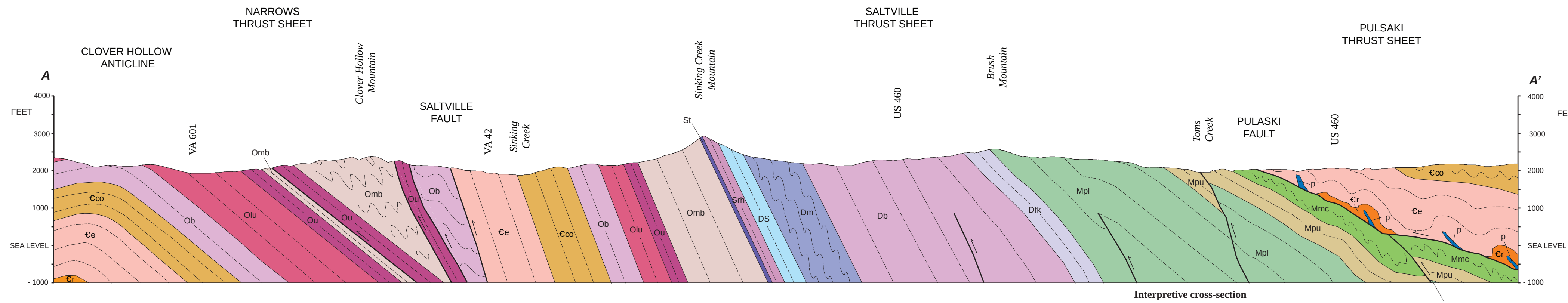


CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1988

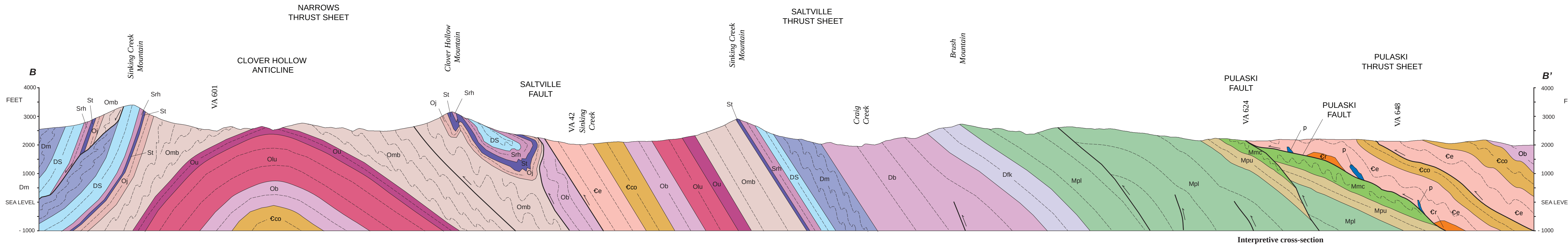
Geology mapped from September 2018 to August 2019







Interpretive cross-section
1. Surficial deposits are not shown.
2. Subsurface structures interpreted from surface measurements.
3. No vertical exaggeration.



Interpretive cross-section
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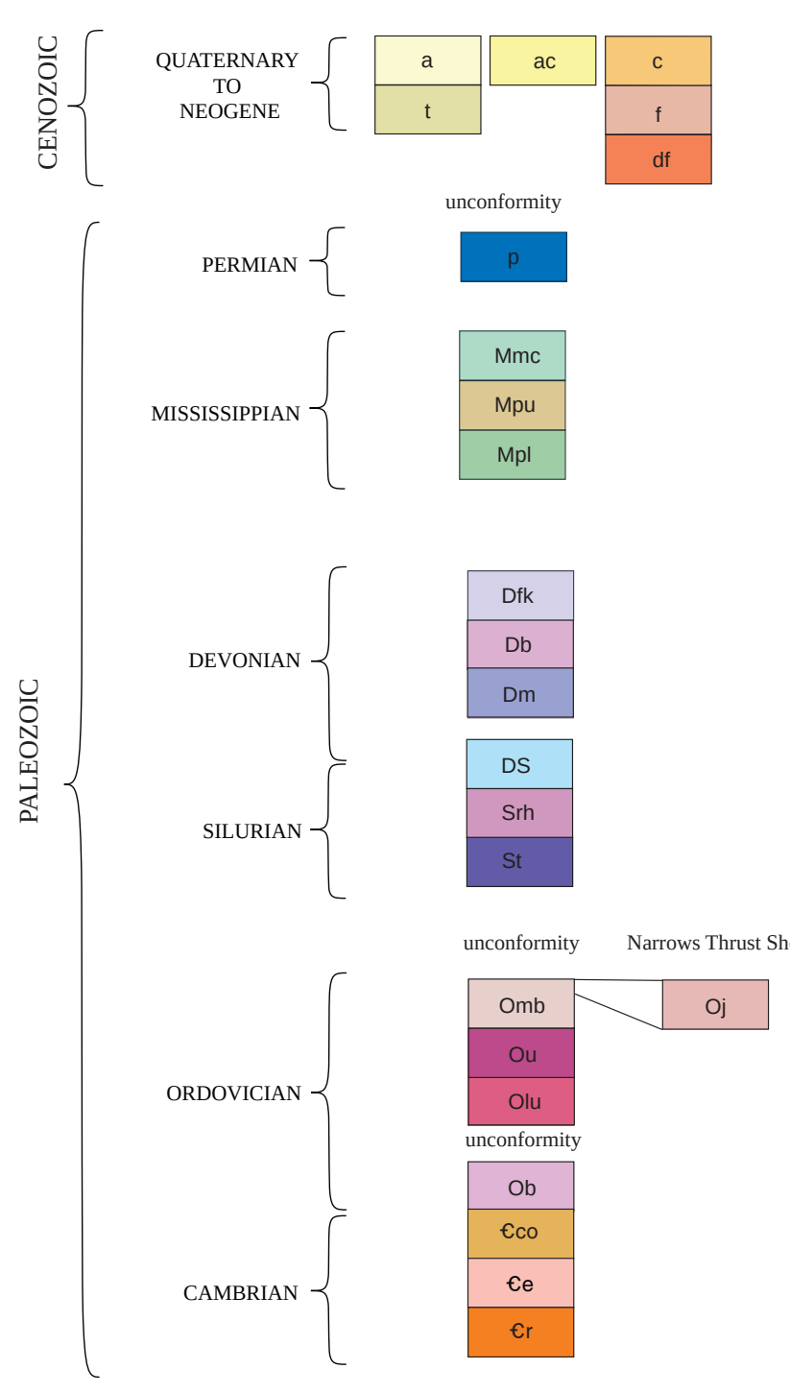
CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

a — **Alluvial deposits** – Channel deposits consist of unconsolidated clay, silt, sand, granules, pebbles, cobbles, and boulders. The composition, color, grain size, rounding, and sorting of these deposits are variable. Streams that drain terrace and fan deposits contain material that is reworked from older deposits. Flood-plain deposits consist of overbank deposits of clay, silt, sand, and minor cobbles within active flood plains. Areas underlain by these deposits are subject to flooding. Thickness less than ~20 feet (6 m).

ac — **Alluvial and colluvial deposits** – Channel and ravine-fill deposits of unconsolidated quartz sandstone/quartzite, lithic sandstone, and pebble conglomerate cobbles and boulders in a variable matrix. Deposits reflect channel transport of coarse debris derived from steep slopes and in some cases may include debris flow materials. Clast weathering is variable. These deposits are distinguished from alluvial deposits by their association with elevated, low-order headwater streams and the more significant gravitational component of their development and transport. The unit often transitions into alluvial deposits in valley floor topography along higher order stream courses. Thickness is undetermined but probably does not exceed ~20 feet (6m).

t — **Terrace deposits** – Older alluvial deposits preserved on stream-carved flats and benches above active surface streams and floodplain. These unconsolidated deposits consist of small boulders, cobbles, and gravel, predominately sandstone, in a variable matrix. Field evidence suggests all terraces in the map area are strath terraces cut into bedrock and do not represent alluival cut-and-fill. These terraces are often heavily altered by action of the modern channel network, but may show intact treads and risers. Clasts may be highly weathered, and the clay-rich matrix is typically red. Thickness less than 20 feet (6 m).

c — **Colluvium** – Boulder fields, boulder streams, and talus deposits containing predominantly sandstone boulders with minor siltstone and shale. Debris is angular and reflects minimal transport from source areas. Unit grades from upslope talus aprons into concentrated, debris-flow like fill in ravines and topographic lows. Deposits reflect progressive accumulation of material. Small and widespread colluvial deposits are not shown. Thickness is undetermined.

f — **Fan deposits** – Overlapping alluvial fan-type deposits associated with channels draining high topography. Deposits often coalesce into a continous "apron" of debris conntaining numerous quartz sandstone clasts in a variable matrix. This unit is distinguished from non-fluvial colluvium (c) and debris flow (df) deposits due to its association with channel transport leading to distribution over broad valley floor areas. Fan deposits are fed by channels that often contain the **ac** unit. Contacts between **ac** and **f** are marked where the deposits begin to spread onto valley floors. Thickness is likely up to several meters in some locations.

df — **Debris-flow deposits** – Unconsolidated deposits of landslide-derived debris associated with steep, caprock-supported hillslopes and ancient giant landslides of Gap and Sinking Creek Mountains. Sandstone clasts and boulders predominate. Debris-flow deposits are mapped using LiDAR hillshade imagery and are very difficult to distinguish from progressively emplaced colluvium in the field. Matrix is often brown to tan and contains less clay than terrace deposits. Thickness is undetermined.

MAP SYMBOLS

For all contact, fault, and fold symbols: lines are long-dashed where the location is known or approximate and very short-dashed where the location is concealed. Alternating long dashes and dots indicate intraformational contacts between fans. Queries (?) added where existence is uncertain.

Stratigraphic Contacts

Fault Contacts

Thrust (teeth on upthrown block)

Landslide boundaries

Landslide toe thrust - teeth on mobile mass

Upslope boundary of landslide mass

Lateral margin of landslide mass; arrow on slide body

Folds

Anticline

Overturned syncline

8 Trend and plunge of inclined hinge, minor antiform

Geologic Observations

35 Strike and dip of inclined beds

80 Strike and dip of overturned beds

Strike of vertical beds

⊕ Horizontal beds

⊙ Sinkhole - area of subsidence

Karst area - larger area of subsidence or area with multiple sinkholes

⚒ Abandoned mine or quarry (c-coal)

ALLEGHANIAN FAULT-RELATED ROCKS

p — **Pulaski Fault tectonic breccia** – Light green to grayish green chlorite phyllite breccia occurring in dikes or pipes sourced from the Pulaski Fault. Outcrops occur as isolated pods near the surface trace of the fault. Breccia contains fragments of phyllite, dolomitic argillite, and dolomite. Crush breccias dominated by limestone and dolomite fragments with less gray-green phyllite also occur. Breccia is quite distinct from host bedrock due to crushing and the presence of tectonic clasts. All breccias are mechancuially weak, particularly when weathered, and may pose engineering challenges.

SEDIMENTARY ROCKS OF THE VALLEY AND RIDGE PROVINCE

Mmc — **Macrady Formation** – Grayish-red and grayish-green mudstone with minor sandstone and limestone or dolomite interbeds. Sandstone is gray to dusky red, medium to coarse grained, and lithic. The lowest bed of dusky red sandstone is used as the base of the formation on the neighboring Blacksburg quadrangle (Henika, 2012). The unit produces a distinictive thin maroon soil. It is distinguishable from underlying units by the predominance of mudstone/shale, which results in minimal topographic expression. Thickness is approximately 600 feet (185 meters), but the unit is deformed due to its position in the immediate Pulaski Fault footwall.

Mpu — **Upper Price Formation** – Medium-grained, thick-bedded quartzose sandstone, dusky-red to green mudstone, dark gray laminated siltstone and black carbonaceous argillite and sub-anthracite coal (Lewis and Hower, 1990; Bartholomew and Brown, 1992). Sub-anthracite coal measures were mined along the southeastern slopes of Brush Mountain into the early 20th century. Coal beds are often highly deformed and duplexed due to their position in the immediate footwall of the Pulaski Fault, range in thickness from 1.5-20 feet (0.5-6 meters), and are interlayered with dark gray to black, laminated, and occasionally root-traced argilliate and slate (Brown, 1983). At the map scale, the coal beds occur near the base of the Upper Price Formation, very close to its contact with the underlying marine Lower Price Formation (see Figure 1). Estimated thickness is 600 feet (183 meters), but may reflect structural thickening.

Mpr — **Lower Price Formation** – Basal coarse-grained, gray to white quartz sandstone and pebble conglomerate, fining upward into laminated to cross-bedded sandstone, gray siltstone, and gray-green argillaceous shale. Basal horizons are notable for blue quartz grains (sand and pebble) and extreme hardness. Some conglomerate outcrops contain extremely coarse clasts with long axes approaching 4 inches (10 centimeters). Pebble conglomerate outcrops appear to be separate, lenticular zones, preventing delineation of a distinct "Cloyd Conglomerate" horizon as in adjacent areas (Bartholomew and Brown, 1992). Bed thickness is highly variable, ranging from a few feet (~1 meter) to up to 45 feet (13 meters). Cross bedding is common in thicker beds. Parallel alignment of mica flakes produces a strong lamination in many sandstone and siltstone beds. Coarse sandstones and conglomerates at the base of the formation were quarried for millstones in the 19th and early 20th centuries. Structural thickening prevents a thickness estimate.

Dfk — **Foreknobs Formation** – Gray-brown to maroon, medium- to coarse-grained sandstone with minor siltstone, reddish shale, and "fossil hash" beds. Sandstone beds are massive and up to 6.6 feet (2 meters) thick near the base, with hummocky cross-bedding commonnear near the top of the unit. Slightly calcareous fossil hash layers are characteristic of the unit. The base of the unit is defined by the oxidized character of sandstone relative to the underlying gray, unoxidized Brallier beds. Fossil hash is brachiopod- and crinoid-rich, and may exhibit vuggy weathering due to minor calcite cement. A white quartz sandstone to pebble conglomerate may be observed in the middle of the unit in some locations, but most of the Foreknobs is consistent in its oxidized appearance. The uppermost beds are hematite-cemented pebble conglomerate (~0.4 inch/1 cm clasts) that resemble the Hampshire Formation of Dennison (1970). The unit is a ridge-former despite some degree of calcareous cement and lithic content, including feldspathic material. Estimated thickness is 750-1,000 feet (230-305 meters) in the mapped area, thickening to the northeast.

Db — **Brallier Formation** – Interbedded sequence of gray to olive shale and dark gray to light gray, fine- to medium-grained sandstone, generally coarsening upward. Some lithic content is present in the sandstone beds, and mica is often visible on bedding plane surfaces. Sandstone bed thickness increases towards the top of the unit where single horizons may exceed 3.3 feet (1 meter) in thickness. The Brallier is typically organized into interbed packages more than 33 feet (10 meters) thick, including Bouma-type sequences. Interbeds reflect submarine slope depositional conditions and are distinct from the isolated and non-sequential sandstone beds of the Millboro. The base of the unit is in gradational contact with the black, fissile, white-weathering Millboro. This contact is often topographically distinct, but may be difficult to accurately locate due to intense deformation of the lower Brallier and underlying upper Millboro Formation (Dm). Mapping suggests a thickness of over 3,500 feet (1,066 meters); given the change in dip across the unit, this thickness likely represents structural thickening.

Dm — **Millboro Formation** – Dark gray to black, fissile to sub-fissile shale and mudstone with very minor interbedded dark gray, medium-grained sandstone and minor limestone. Sandstone beds are thin (4-8 inches; 10-20 centimeters) near the base of the unit, and may be entirely absent over large areas. Concretions (carbonate or iron oxide) are abundant. Sandstone and limestone beds are randomly interspersed and distinct from meter-scale interbed packages seen in the Brallier Formation. Shale fissility increases towards the base of the unit, but fissile domains are present throughout. The contact of the top of the unit with the Brallier Formation (Db) can be discerned by a set of small knobs visible in digital topography; the beds producing these knobs are not obviously distinct from underlying beds with the exception of their tendency to weather to pink. Penetrative folding and faulting prevent a thickness estimate. The Needmore Formation was not observed at the base of the formation in the mapped area. Thickness is not estimated due to deformation.

DS — **Lower Devonian rocks, undivided** – Grouped unit consisting of rocks between the overlying Millboro formation and the underlying Rose Hill Formation. Huntersville chert: Very light gray to dark gray, highly fractured chert which weathers to a chalky white, often observed as float. The chert horizon is discontinuous, and this member may be entirely absent from large tracts of the section. Greenish glauconitic sandstone interbeds are reported in adjacent areas, but were not observed in the mapped area. This portion of the unit is typically poorly exposed if Huntersville chert is absent. Rocky Gap Sandstone: Burnt orange or brown, black-stained ferruginous and manganiferous medium-grained sandstone, ranging from limonite-stained to hematite-cemented, immediately below the Huntersville. The sandstone is typically thinly cross-bedded (~0.4 inch (1 centimeter) beds), and develops a distinct vuggy, stained weathered appearance. Keefer-Eagle Rock Sandstone: White to gray, massive to cross-bedded, medium-grained sandstone beneath the ferruginous Rocky Gap beds. This unit comprises the majority of the DS unit and is homogeneous within the mapped area. Estimated thickness is approximately 500 feet (152 meters) on the Saltville Thrust Sheet and 600 feet (182 meters) on the Narrows Thrust Sheet.

Srh — **Rose Hill Formation** – Reddish-brown to maroon to purple, fine-grained sandstone and shale with gray-green shale interbeds. Bed thickness is variable, and interbedding is random. Cross-bedding is apparent within sandstone horizons. Lenses or thin beds of hematitic quartz pebble conglomerate (clasts <0.4 inch/1 centimeter) may be present. The unit is poorly exposed outside of fresh roadcuts or stream gorges. Estimated thickness is ~300 feet (60 meters), with potential for local structural thickening or thinning.

St — **Tuscarora Formation** – Light gray to brilliant white, medium- to coarse-grained orthoquartzite with occasional quartz pebble conglomerate lenses (clasts <0.4 inch/1 centimeter). Minor thin bedded sandstone and greenish shale horizons occur at the base of the unit. The Tuscarora is a strong ledge-former due to its extremely high quartz content and extensive recrystallization. The unit can be distinguished from the lower Devonian sandstones (DS) higher in the section by its hardness and resistance to chemical weathering, preventing the development of the granular, friable character seen in outcrops of DS sandstone. Estimated thickness is approximately 100 feet (30 meters). Fresh outcrop is found at or near ridge crests, but upper and lower contacts are often obscured by soil or colluvium.

Oj — **Juniata Formation (Narrows Thrust Sheet)** – Dusky red to maroon to grayish-brown sandstones and interbedded siltstone with minor shale. Yellow-weathering sandstone near the top of the unit is occasionally seen as float along ridge crests. The unit is rarely exposed in natural outcrop, but can be mapped accurately on the Narrows Thrust Sheet using LiDAR-derived hillshade imagery. The unit is not mappable on the Saltville Thrust Sheet, and is grouped into the Martinsburg Formation. Estimated thickness is 150-200 feet (45-60 meters).

Omb — **Martinsburg Formation** – Gray shale, often calcareous, and limestone, siltstone, lithic wacke, and sandstone, coarsening upwards. Exposure of the unit is almost non-existent in the map area and is delineated by the base of the overlying Tuscarora Formation (St) and the top of the topographically distinct Bays, Mocassin, and Eggleston Formation (Ou) below. The Martinsburg is prone to significant structural alteration of thickness. Shale horizons produce tan soil chips and a rich-soil forest assemblage; coarser clastic beds may develop a sandier, more gravelly soil. Fresh exposures of shale and coarse beds are typically gray (marine) in surrounding areas, but do not occur in the map area. Estimated thickness is ~ 1,900 feet (580 m) on the Saltville Thrust Sheet, where the Juniata Formation is included. Deformation prevents a thickness estimate on the Narrows Thrust Sheet.

Ou — **Bays, Moccasin, and Eggleston Formations (undivided)** – Due to extremely limited outcrop, these units are grouped into a topographically-distinct interval that is readily delineated by digital topography. Bays Formation: Olive to brown, fine- to medium-grained quartz sandstone beds 3-5 feet (1-1.5 meter) thick with some lithic content, interbedded with olive and maroon siltstone and shale. Bays sandstone beds contribute to a distinct "knob" topography. Moccasin Formation: Pink to brownish-red thin-bedded limestone, mudrock, and shale. Color and pressure solution cleavage are diagnostic of this unit. Eggleston Formation: Thin-bedded gray limestone and calcareous mudstone. Bedding surfaces are irregular, wavy and undulose at the centimeter scale. The unit is prone to karst development and forms a distinct topographic low immediately upsection of the Middle Ordovician Limestones. Poor outcrop and possible structural thickening/thinning in the mapped area preclude an accurate undeformed thickness estimate for the grouped unit.

Olu — **Middle Ordovician Limestones, undivided** – Grouped limestone unit consisting of four sub-units. Effna-Murat: Light gray, medium- to coarse-grained, bioclastic grainstone. Lincolnshire: Dark gray, medium- to coarse-grained, cobbly weathering wackestone with silty laminae and black chert stringers. New Market: Compact, medium gray micrite with calcite rhombs. Blackford: Dark gray magnesian limestone with dolomite beds and intercalated silts near lower contact with Beekmantown Formation. Exposure is very limited in the study area. Cooper (1944) estimated a combined unit thickness at 295-360 feet (95-110 meters); mapping in this study suggests a thickness of ~600 feet (182 meters) on the Saltville Thrust sheet and up to 1,600 feet (488 meters) on the Narrows Thrust Sheet. The unit is highly prone to karst development.

Ob — **Beekmantown Formation** – Light gray, tan-weathering finely crystalline laminated dolomite containing abundant white, gnarled chert that dominates soil as float clasts and blocks up to 4 feet (1.2 meters) across. Gray micrite and angular dolomite breccia beds occur near the top of the unit, which is in uncomformable contact with the overlying Middle Ordovician limestones. Thin limestone beds occur near the base of the unit. Broughton (1971) estimated thickness at 985 feet (~300 meters) northeast of the study area; estimated thickness in this map area is approximately 800 feet (243 meters). Thickness estimate is based on Saltville Thrust Sheet outcrop; the upper and lower contacts of the unit are not exposed on the Narrows Thrust Sheet, where thickness may differ (see above).

Єco — **Conococheague Formation** – Blue-gray, fine-grained algal limestone alternating with gray to pink-tan, laminated silty dolomite. Facies are organized into 10-16 foot (3-5 meter) cycles grading upward from limestone conglomerate through thin-bedded limestone into massive gray dolomite. Limestone beds can be a major karst-forming horizons. Sandy horizons within the unit form small but notable ridges. These sandy domains, which are composed of siliceous oolite and quartzose sandstone, are resistant to erosion and control location of the Eastern Continental Divide on the Pulaski Thrust Sheet. Estimated thickness in surounding areas is ~300-360 feet (91-110 meters) (Broughton, 1971; Henika, 1997; Koerschner, 1983; Reinhardt and Hardy, 1976). This mapping suggests a thickness of 1,400 feet (427 meters) on the Saltville Sheet.

Єe — **Elbrook Formation** – Upper member: Medium to light gray limestone and cherty dolomite in wavy, "ribbon" laminated interbed cycles; cycles are ~16 feet (5 meters) thick. Lower member: Light olive and pale pink slaty dolomite and argillite with pods of heavily fractured and veined tectonic breccia in the vicinity of the Pulaski thrust. Estimated thickness in the map area is ~1,400 feet (427meters). On the Saltville Thrust Sheet, the unit is only exposed in the immediate hanging wall of the Saltville Fault, where its thickness changes, presumably due to a shifting glide plane. The unit is intensely penetratively deformed on the Pulaski Thrust sheet, preventing a reasonable thickness estimate.

Єr — **Rome Formation** – Brownish-red, green, and yellow phyllite, laminated argillite, minor sandstone, and crystalline gray dolomite, all intensely deformed and damaged due to proximity to the Pulaski Fault. Henika (2012) reported slaty cleavage and proto-foliation due to orientation of micaceous grains in phyllites. The unit is only exposed in a small area along the southern edge of the map. Deformation and limited outcrop preclude a thickness estimate; map patterns suggest the Pulaski Fault glide plane transitions between the Elbrook Formation and Rome Formation, making the Rome intermittently present on the Pulaski Thrust Sheet and in outcrop (see cross section). Haynes (1991) measured the equivalent Waynesboro Formation to be 1137-1170 feet (~350 meters) thick north of Roanoke; only a partial thickness that is further reduced by mylonitization is interpreted to be present here.

SUMMARY OF STRUCTURAL AND SURFICIAL GEOLOGY

OVERVIEW

The Newport quadrangle is structurally complex, containing portions of the Pulaski, Saltville, and Narrows thrust sheets and exposing the Pulaski and Saltville faults along with numerous smaller splay faults. These thrust sheets show decreasing maximum burial, respectively, with parts of the Pulaski Thrust Sheet likely having experienced protometamorphic conditions (Lewis and Hower, 1990). The southeastern corner of the quadrangle is underlain by the Pulaski Thrust Sheet, which exposes highly deformed Cambrian carbonate units, Rome Shale, and isolated outcrops of chloritized breccia from within the fault zone itself. Mesoscopic folding is ubiquitous within this part of the Pulaski Thrust Sheet. Northwest of the Pulaski Fault, rocks of the Saltville Thrust Sheet show less deformation, although mesocopic folding and intraformational faulting are present in shale and interbed units of Mississippian and Devonian age due to the weakness of these lithologies (Figure 1). The upper part of the Narrows Thrust Sheet in the immediate Saltville Fault footwall is cut by several small fault splays, and shaley or interbedded units in the vicinity of the faults may be intensely folded. The northern edge of the map area shows less mesoscopic folding, but faulting and repetition of Silurian sandstone units above the Martinsburg Formation are easily seen in the map pattern.

The quadrangle is located on the eastern end of the Bane Dome, a large structural high apparently produced by duplexing of Cambrian and Ordovician units beneath the Narrows Thrust Sheet (Woodward and Gray, 1985; Kulander and Dean, 1986). As a result of the duplexing, which is centered southwest of the map area, the Clover Hollow Anticline of the Narrows Thrust Sheet plunges to the northeast, and Cambrian through Lower Devonian units of the Saltville Thrust Sheet have been back-rotated to steep dips (~60 degrees). Dips along Sinking Creek Mountain become more moderate (~35 degrees) towards the eastern boundary of the map area, away from the dome. The Narrows Thrust Sheet is likely underlain by a complete section of Silurian through Cambrian strata within the map area, but no drilling has confirmed this interpretation.

Sinking Creek (New River basin) and Craig Creek (James River basin) are the largest water features in the map area. These streams are separated by Sinking Creek Mountain and the Eastern Continental Divide. Both streams show limited terrace (t) development. Despite limited evidence of incision and topographic rejuvenation by these streams and their tributaries, numerous hillslope-related surficial deposits are mapped along the flanks of Silurian sandstone-capped ridges. Comparatively few deposits are present along Brush Mountain, which is underlain by Mississippian sandstones of the Saltville Thrust Sheet. Large, intact bedrock landslides identified by Schultz (1993) are present on the southeast slope of Sinking Creek Mountain and Gap Mountains. The slides mobilized the Silurian Rose Hill Formation (Srh) and Siluro-Devonian sandstone unit (DS), translating them downhill onto the Devonian Millboro Formation (Dm). Age and trigger mechanism of the slides is unknown. Structural data collected on the slides shows folding at the slide toes, creating northwest dips that are unusual on the otherwise intact southeast dip slope of Sinking Creek Mountain.

Immediately west of the intact landslides at the eastern edge of the map area, a large colluvium (c) deposit containing several intact blocks of Rose Hill Formation (Srh) was cut by Mountain Valley Pipeline excavations. Exposures revealed numerous back-rotated (i.e., northwest-dipping) blocks gliding in a gray-green shale horizon within the Rose Hill Formation (Srh). The gray-green shale appears to occur near the base of the unit but not at its basal contact with the underlying Tuscarora Formation (St). Several toe thrusts accommodate movement of the discrete blocks, suggesting an overall complex movement style for the deposit. Whether emplacement of the blocks was progressive and gradual or the result of a single event cannot be determined; as a result, the deposit is mapped as colluvium (c). Additional large slope failures appear to have occurred to the southwest in the same bedrock units. They can be identified by northwest-dipping sandstone exposures related to toe thrusting. These are also somewhat distinct in morphology from the large intact bedrock slides identified by Schultz (1993).

PULASKI THRUST SHEET

The Pulaski Thrust Sheet is interpreted as a far-travelled thrust sheet that represents a transitional feature between the metamorphic Blue Ridge Thrust Sheet and external sedimentary thrust sheets of the Valley and Ridge. The Pulaski Thrsust Sheet is distinct from thrust sheets to the northwest in its penetrative deformation and considerable (many tens of kilometers) transport from its ramp (Woodward and Gray, 1985; Bartholomew, 1987; Schultz, 1988). The position of the ramp is unknown but is presumably beneath the Blue Ridge Thrust Sheet. In the map area, the Pulaski Thrust Sheet is gliding in Mississippian shales of the Macrady (Mmc) and Upper Price (Mpu) Formations. The sole of the thrust sheet itself is Elbrook Formation (Єe) and locally Rome Formation (Єr), which is exposed at the surface in a small area near the southern boundary of the map. Pipes or dikes of fault breccia (p) sourced from the glide plane can be observed in the hanging wall rocks near the trace of the fault. These breccias are extremely weak and prone to weathering and erosion, presenting a challenge to engineering and construction. The majority of rock exposed on the Pulaski Thrust Sheet in the map area is Elbrook Formation (Єe) dolomite. Some Coppper Ridge Formation (Єco) dolomites are also exposed, including sandy beds which support modest topography. Karst development is extensive on the Pulaski Thrust Sheet in the Roanoke River headwaters along the southeastern edge of the map area (Figure 2).

SALTVILLE THRUST SHEET

The Saltville thrust sheet exposes Mississippian- through Cambrian-aged rocks and lacks the penetrative folding of the Pulaski Thrust Sheet. Coal measures (sub-anthracite) are present near the base of the Upper Price Formation (Mpu) (Figure 1), and were heavily mined into the early 20th century. The Saltville Thrust Sheet is continuous over hundreds of kilometers in the Valley and Ridge Province of Tennessee and Virginia, but exposures of the nearly complete Cambrian through Mississippian section are limited to southwest Virginia, generally to the portion of the thrust sheet drained by the New River. In the map area, the Saltville Thrust Sheet is most conspicuous in the steep dip of its Siluro-Devonian through Cambrian strata (see cross sections). Steep dip of the bedding limits the elevation of Gap and Sinking Creek Moutnains, whose Silurian sandstone caprock typically supports higher elevations. The glide plane of the Saltville Fault appears to step deeper into the Elbrook Formation (Єe) in the central part of the map area. Subsurface relationships between the Saltville Fault and the numerous splay faults at the top of the Narrows Thrust Sheet are unknown. The Saltville Thrust Sheet flattens at depth beneath the Pulaski Thrust Sheet in the southern portion of the map and continues to the southeast in the subsurface (Woodward and Gray, 1985; Kulander and Dean, 1986); it is locally exposed in the Price Mountain Window in the neighboring Blacksburg 7.5-minute quadrangle. Depth to the top of the Pulaski sheet as portrayed in the cross sections is based on surface data and nearby boreholes described in Stanley and Schultz (1983).

NARROWS THRUST SHEET

The Narrows Thrust Sheet underlies the northwestern third of the map area. Also lacking the penetrative deformation of the Pulaski Thrust Sheet, this portion of the map area is dominated by the Clover Hollow Anticline, which involves Ordovician Beekmantown Formation dolomites through Devonian Millboro Shale at the surface. A detachment fault in the Martinsburg Formation (Omb) is folded by the anticline (Schultz, 1986c). The detachment fault ramps into Silurian strata on the northwest limb of the anticline; the doubled Silurian section was tilted northwest after faulting. Much of the southeast limb of the anticline is a tight, very highly deformed, northwest-overturned syncline in the footwall of the Saltville Fault (Figure 3). Clover Hollow Mountain is the topographic expression of this syncline. Movement on the detachment fault and folding of the underlying beds has resulted in signfiicant thickening of the Martinsburg Formation (Omb) in the core of the anticline. Northeast plunge of the anticline causes it to "disappear" beneath Cambro-Ordovician strata in a footwall horse of the Saltville Fault near the northern edge of the map. Exposures of Middle Ordovician limestone (Olu) near the core of the Clover Hollow Anticline produce excellent farmland and modest topography. Kelly Knob, an iconic Appalachian Trail landmark, is developed on Tuscarora Formation (St) outcrops in the northeast nose of the Clover Hollow Anticline (Figure 4).

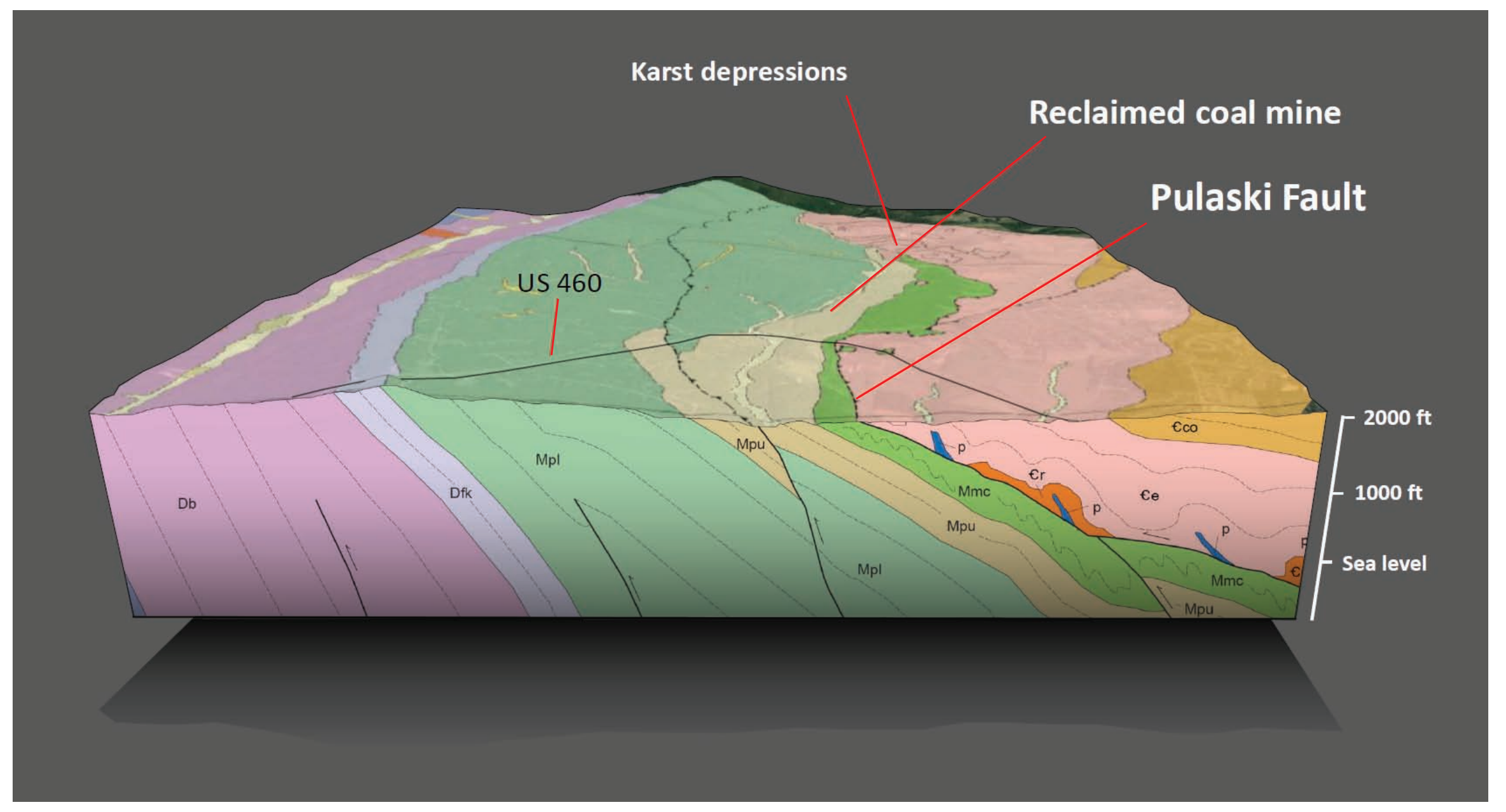


Figure 1: Block diagram (view to the northeast) combining surface and cross sectional geology along the A-A' section near the southern border of the map. Topographic and lithologic contrasts between the Cambrian carbonates and shales of the Pulaski Thrust Sheet (Єr-Єco; p) and Mississippian sandstones and shales of the Saltville Thrust Sheet (Mmc-Mpl) define this portion of the map. The gentle to moderate dip of the Pulaski Fault puts Mississippian shales (Mmc) in reach of water wells drilled begun in Pulaski Thrust Sheet carbonates just east of the surface trace of the fault. Coal measures occur near this section section line in the Upper Price Formation (Mpu) just above its contact with the Lower Price Formation (Mpl). Local presence of Rome Formation (Єr) and context of Pulaski Fault breccia (p) are illustrated conceptually; both units are seen in outcrop immediately southwest of the line of section. In the early 1980's, drilling through the Pulaski Thrust Sheet into the coal measures of the Upper Price Formation (Mpu) to assess coal bed methane potential was undertaken immediately southwest of the map area (see Stanley and Schultz, 1983). Topography source: **Google Earth**, accessed July 16 2019.

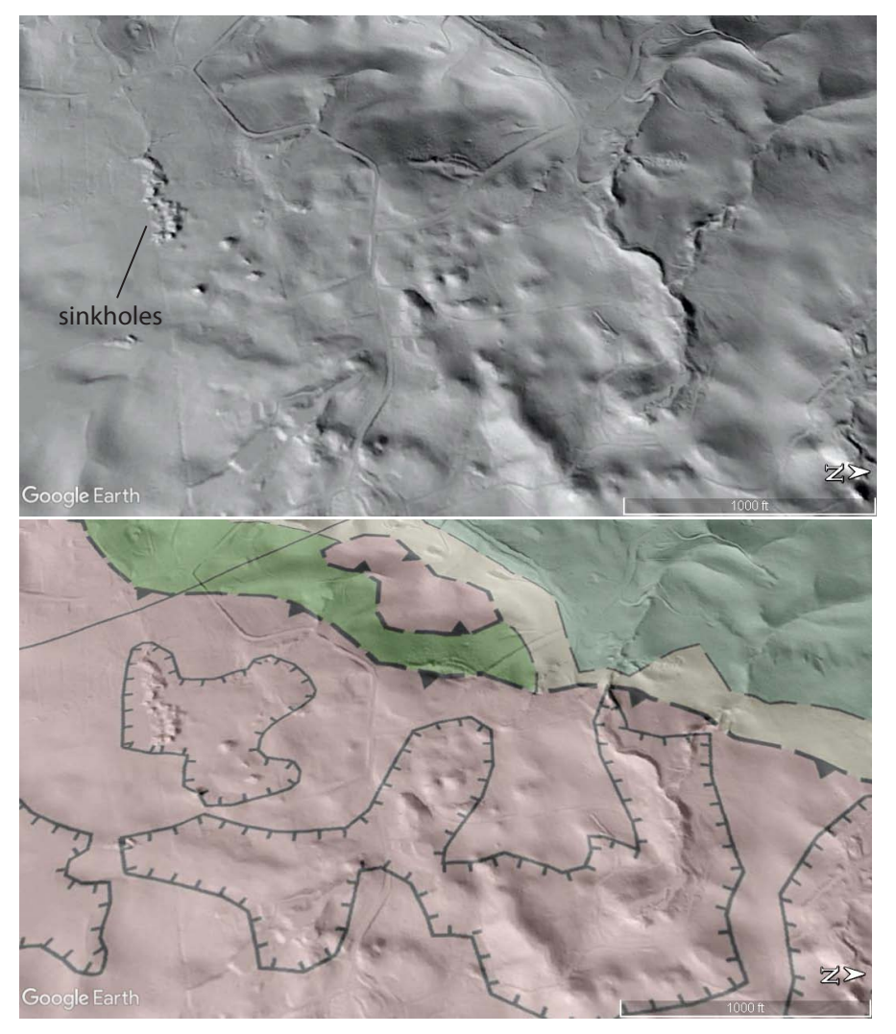


Figure 2: While all carbonate units in the map area show some karst development, it is particularly intense in the deformed Pulaski Thrust Sheet carbonate units, particularly the Elbrook Formation (Єe) along the southeastern edge of the map area. Sinkholes have coalesced into elongated, closed karst depressions into which surface streams drain. These depressions are enclosed by the hachured line seen in the bottom image. Karst development is presumably intense in this area because it is located on the Atlantic side of the Eastern Continental Divide and is underlain by highly deformed and damaged rocks neaer the Pulaski Fault. The same lithology does not show comparable karst development on the landward side of the Eastern Continental Divide nearby. Topography source: **Google Earth**, accessed July 16 2019.

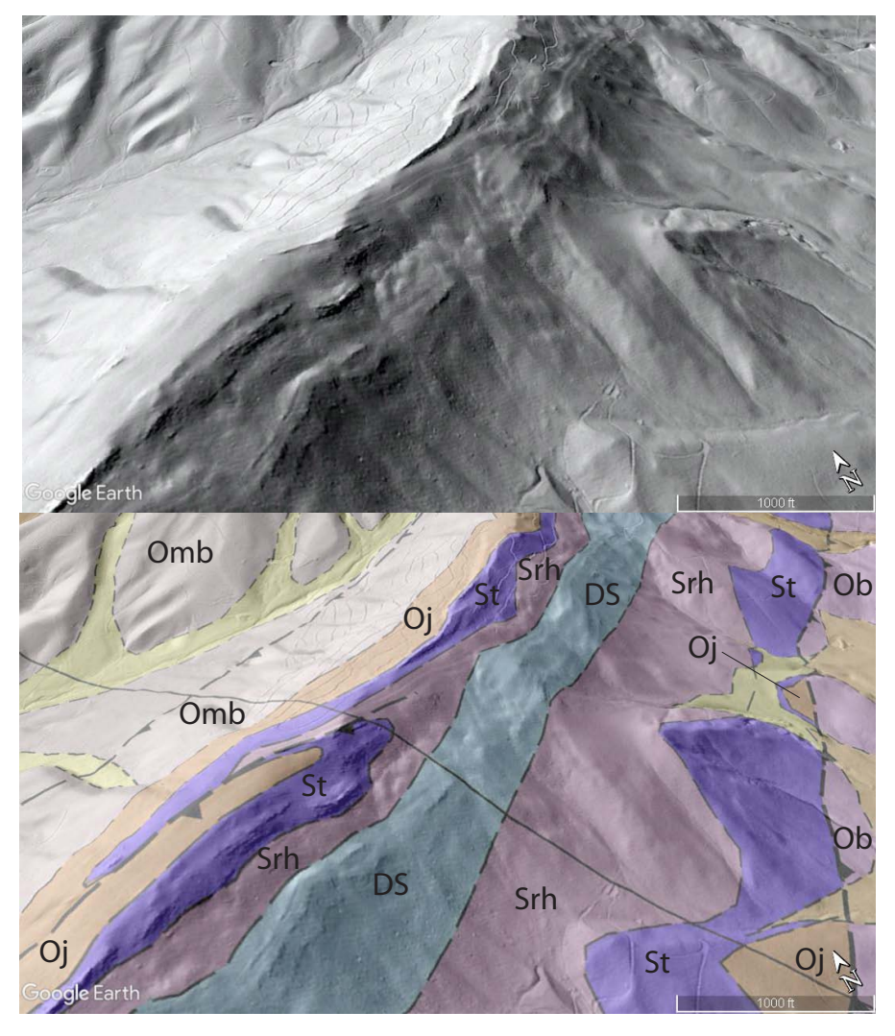


Figure 3: LiDAR imagery contributed strongly to the preparation of this map. The images shown here compare LiDAR hillshade imagery (top) with bedrock geology (bottom). The high resolution of the 1-meter LiDAR data set from which the hillshade was generated permitted individual contact beds to be followed for great distances in areas where field work was rendered less effective by vegetation cover. The complicated syncline shown here is the southeast limb of the Clover Hollow Anticline. Topography source: **Google Earth**, accessed July 16 2019.

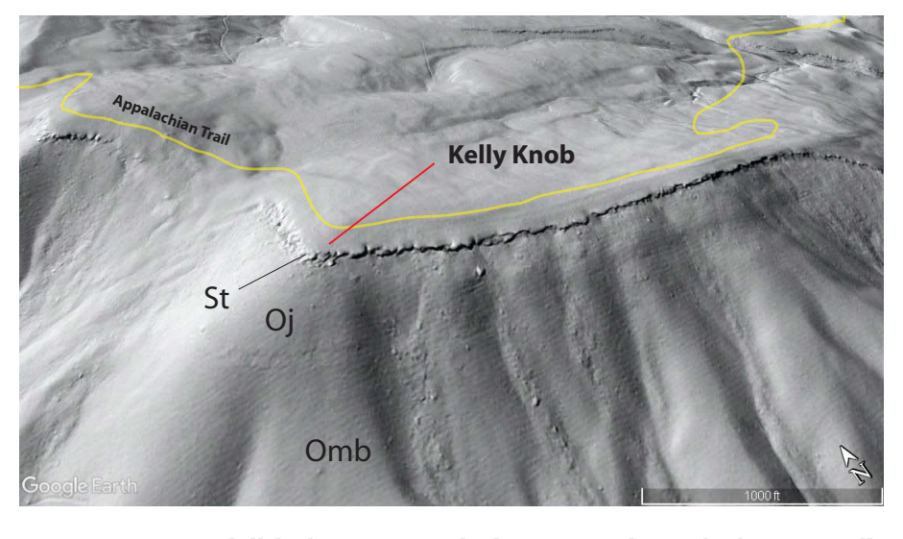


Figure 4: LiDAR hillshade image overlaid onto Google Earth showing Kelly Knob, a prominent topographic high bounded by a Tuscarora Formation (St) cliff line. Prominence of Kelly Knob results from great erosional resistance of the Tuscarora Formation (St) compared to underlying shale and carbonate bedrock units, which are physically softer and also more prone to chemical weathering. Topography source: **Google Earth**, accessed July 16 2019.

ACKNOWLEDGEMENTS

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program under STATEMAP award number G18AC00294, 2019. William Swanger provided critical assistance and support to all aspects of digital cartography.

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