COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES

GEOLOGY OF ST. PAUL AND CARBO QUADRANGLES, VIRGINIA

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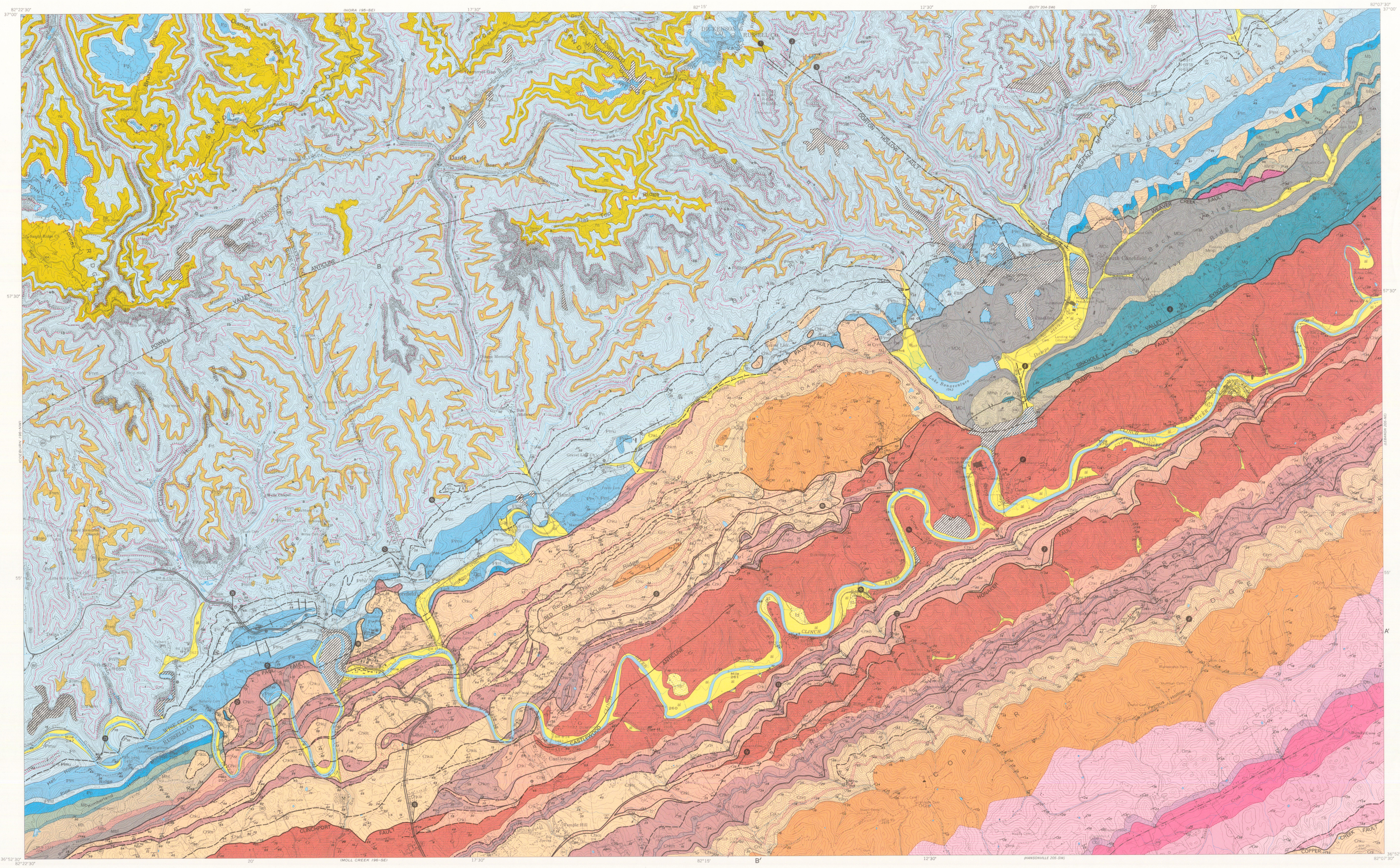
GEOLOGY OF THE ST. PAUL AND CARBO QUADRANGLES, VIRGINIA
PLATE 1



Base map from U.S. Geological Survey, 7.5-minute series
St. Paul, 1958, PR 1969 and 1978; Carbo 1958, PR 1969 and 1978

UTM GRID AND 1978 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DASHED LINES REPRESENT HALF-INTERVAL CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Project funded by the Commonwealth of Virginia and the U.S. Department of Interior, Office of Surface Mining, under a Technical Data Management System grant

EXPLANATION

QUATERNARY

- al — Alluvium
- c — Colluvium
- td — Terrace deposits

PENNSYLVANIAN

- ℙw — Wise Formation, undivided
- ℙg — Gladeville Sandstone
- Norton Formation
  - ℙn — interbedded siltstones and sandstones
  - ns — unnamed sandstone
  - n — Norton coal bed
  - h — Hagy coal bed
  - ub — Upper Banner coal bed
  - lb — Lower Banner coal bed
  - k — Kennedy coal bed
  - ℙnm — McClure Sandstone Member
  - a — Aily coal bed
  - r — Raven coal bed
  - jb — Jawbone coal bed
  - c — coal bed of uncertain correlation
- Lee Formation
  - ℙlmu — Middlesboro Member, upper quartzarenite
  - ℙlm — Middlesboro Member, interbedded siltstone and sandstone
  - ℙlml — Middlesboro Member, lower quartzarenite
- Pocahontas Formation (ℙp)
  - bf — Burton's Ford coal bed

MISSISSIPPIAN

- Mb — Bluestone Formation
- Hinton Formation
  - Mht — Tallery Sandstone Member
  - Mh — Hinton Formation, undivided (includes middle red member)
  - Mhs — Stony Gap Sandstone Member
- Mbf — Bluefield Formation
- Mg — Greenbrier Limestone
- Mmpr — Maccrady and Price Formations, undivided

DEVONIAN

- MDc — Chattanooga Shale, undivided

SILURIAN

- Sc — Clinch Sandstone

ORDOVICIAN

- Limestone formations of Middle to Upper Ordovician age
  - rls — unit c, red limestone and calcareous mudstone
  - ls — unit b, non-cherty limestone
  - cls — unit a, chert limestone
- Obl — Blackford Formation
- Omk — Mascot and Kingsport Formations, undivided
- OꞒcc — Chepultepec and Copper Ridge Formations, undivided

CAMBRIAN

- Ꞓmn — Maynardville Limestone
- Nolichucky Formation
  - Ꞓnu — upper shale member
  - Ꞓnm — middle limestone member
  - Ꞓnl — lower shale member
- Honaker Formation
  - Ꞓhku — upper limestone member
  - Sh — shale member
  - Ꞓhkm — dolomite member
  - Ꞓhkl — lower limestone member
- Ꞓhkls — Honaker limestone member, stratigraphic position undetermined
- Ꞓr — Rome Formation
- b — Carbonate-rock breccia

KEY

CONTACTS

- Contact between rock units; dashed where inferred
- Coal bed; dashed where inferred

FAULTS

- Fault; dashed where inferred; T, upper plate; D, downthrown side; U, upthrown side; arrows indicate sense of movement

FOLDS

- Trace of anticline axis; direction of plunge
- Trace of syncline axis; direction of plunge
- Trace of overturned syncline axis; direction of plunge
- Minor anticline; direction of plunge
- Minor syncline; direction of plunge
- Strike and dip of axial plane of minor fold
- Bearing and plunge of minor fold axis

ATTITUDE OF BEDS

- Strike and dip of bed
- Strike and dip of vertical bed
- Horizontal bed
- Strike and dip of overturned bed
- Average strike of contorted beds
- Average strike and average dip of contorted beds

COAL MINES

- Mine adit
- Adit of abandoned mine
- Coal outcrop or prospect
- Surface mine, hachures toward highwall

TEST WELLS FOR OIL AND GAS

- Gas well
- Gas well, shut in
- Dry hole

REPOSITORY NUMBERS

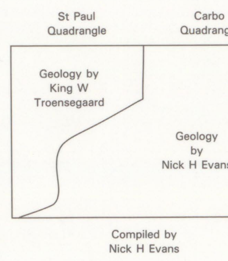
- R; Repository number of surface coal sample and analysis on file at the Virginia Division of Mineral Resources
- R; Repository number of underground coal sample and analysis on file at the Virginia Division of Mineral Resources

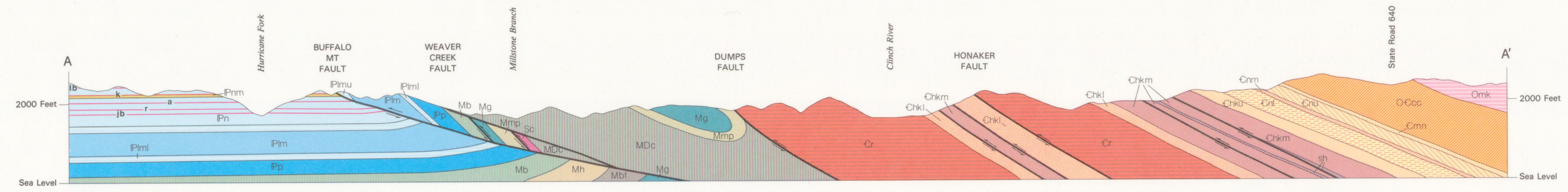
QUARRIES

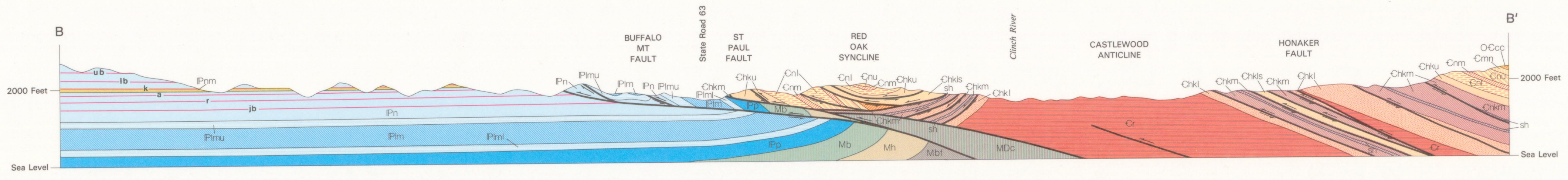
- Active limestone quarry
- Abandoned sandstone quarry
- Abandoned limestone quarry
- Borrow pit, carbonate rock breccia

MODIFIED LAND

- Mine dump, valley fill, or area of extensive reclamation
- Landfill, active
- Landfill, inactive

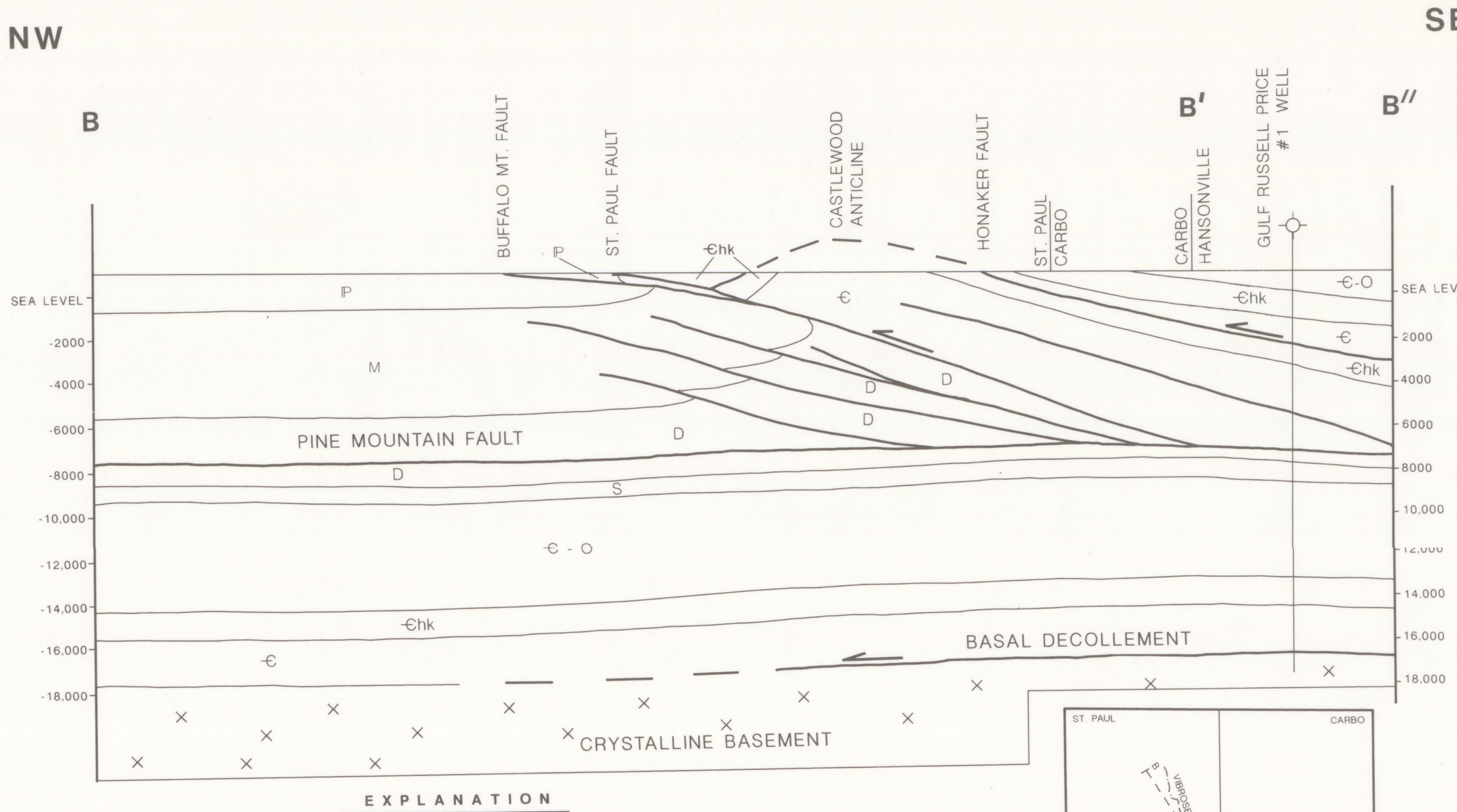






Cross Section Design

1. No vertical exaggeration.
2. Subsurface units interpreted from surface and drill-hole data.
3. Coal bed thickness is diagrammatic.



EXPLANATION

- D — DEVONIAN - AGE ROCKS
- S — SILURIAN - AGE ROCKS
- M — MISSISSIPPIAN - AGE ROCKS
- ℙ — PENNSYLVANIAN - AGE ROCKS
- Ꞓhk — HONAKER FORMATION
- Ꞓ — LOWER AND MIDDLE CAMBRIAN - AGE ROCK
- ꞒO — UPPER CAMBRIAN - THROUGH ORDOVICIAN - AGE ROCKS

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GEOLOGY OF ST. PAUL AND CARBO QUADRANGLES, VIRGINIA

Nick H. Evans

INTRODUCTION

St. Paul and Carbo 7.5-minute quadrangles are located in southern Dickenson, eastern Wise, and northwestern Russell Counties, Virginia, and have a combined area of about 120 square miles (Plate 1). The northern portion of these quadrangles contains almost horizontal, coal-bearing, Pennsylvanian-age strata of the Appalachian Plateaus physiographic province. The Alleghenian structural front, northwest limit of the Valley and Ridge physiographic province, trends diagonally from southwest to northeast through the center of the area. Along the front, imbricated Cambrian- and Ordovician-age rocks have been thrust-faulted on top of overturned and imbricated Silurian-, Devonian-, Mississippian-, and Pennsylvanian-age rocks. Structural complexity decreases southeastward from the structural front; in southeastern Carbo quadrangle, Cambrian- to Upper Ordovician-age rocks form a gently southeast-dipping sequence that is overridden by the Copper Creek thrust sheet.

Field work for this study was conducted from 1986 to 1988. Geology was mapped at a scale of 1:24,000, providing much greater detail than earlier maps published at smaller scales (Campbell, 1899; Giles, 1921; Eby, 1923; Butts, 1933). This project has provided considerable insight regarding stratigraphic relations and geologic structure in this part of southwest Virginia.

STRATIGRAPHY

A detailed description for each map unit is given in the columnar section. Additional points related to stratigraphy are discussed below.

Complex faulting and folding in the Rome Formation (Figure 1) within the study area rendered accurate measurement of stratigraphic sections in this unit impractical. Carbonate rocks within the Rome were not mapped separately because of poor exposure and the apparent lenticular nature of those units. As a result, the map pattern of the Rome Formation rocks is not very informative with respect to geologic structures within the unit.

Figure 1. Anticline outlined by carbonate beds within the Rome Formation (Reference Locality 6).

Campbell (1899) recognized that the area between Castlewood and Cleveland contains a facies transition zone for rocks stratigraphically above the Rome Formation and below the Nolichucky shales. Southwest of Castlewood, this interval has a lower limestone unit (Rutledge), a shale unit (Rogersville), and an upper limestone unit (Maryville); these units were mapped northeastward along strike from type localities in the Appalachian Valley of eastern Tennessee by earlier workers (Campbell, 1894; Brent, 1963). Northeast of Cleveland, this stratigraphic interval is mapped as Honaker Formation, and is predominantly dolomite, with subordinate limestone at the top and bottom (Figure 2). The type locality of the Honaker Formation is at Honaker, about ten miles northeast of Carbo quadrangle (Campbell, 1897). Farther northeast along strike, in Giles County, Virginia, the Honaker consists almost entirely of dolomite (Figure 3; Shultz and others, 1986).

Figure 2. Argillaceous, ribbon-banded limestone typical of the lower part of the Honaker Formation.

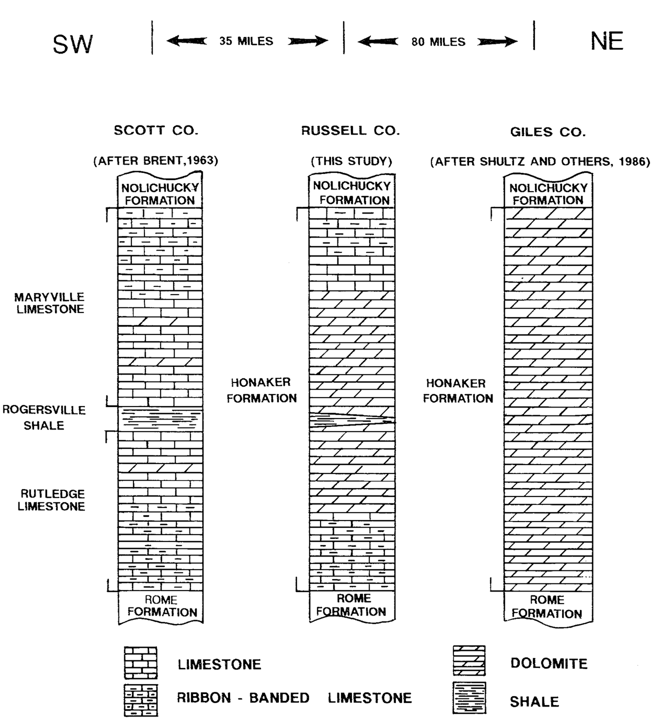


Figure 3. Stratigraphic columns representing the Honaker Formation (this study), and equivalent units along strike to the southwest and northeast of the study area.

In this study, the rocks in the stratigraphic interval between the Rome and the Nolichucky Formations are assigned to four units in the Honaker Formation: lower limestone, middle dolomite, shale, and upper limestone. This assemblage of rock types is similar to the package at the type locality at Honaker. The overall thickness of the Honaker section is about 1100 to 1200 feet throughout the mapped area, but from northwest to southeast among different thrust sheets, and northeast along strike within a given thrust sheet, the proportion of dolomite in the section increases and the thickness of the shale interval decreases. These trends are consistent with the map pattern portrayed on Big A Mountain quadrangle (Miller and Meissner, 1977) and Honaker quadrangle (Meissner and Miller, 1981); both quadrangles are northeast of Carbo quadrangle.

Limestone stratigraphically above the Blackford Formation in southeastern Carbo quadrangle was assigned to three unnamed map units on the basis of lithologic characteristics that could be recognized in the field. Units defined by Cooper (1945) for Middle Ordovician limestone in this strike-belt could not be mapped at 1:24,000 scale.

Mississippian-age rocks throughout the mapped area are for the most part overturned and poorly exposed. Rigorous stratigraphic treatment of these rocks on the basis of outcrops in this area was not practical; thickness estimates take into account information from drill logs of wells northwest of the Allegheny structural front. The drill logs are on file at the Virginia Division of Mineral Resources.

The Lee Formation in Carbo and St. Paul quadrangles contains two persistent ridge-forming quartzarenite units separated by about 600 feet of shale, siltstone, and coal (Figure 4). In keeping with the original lithostratigraphic definition of the Lee (Campbell, 1894), the top of the Lee Formation was mapped as the top of the uppermost quartzarenite. The Bee Rock Sandstone and Hensley Members of the Lee were not mapped in this area. Gathright (1964) and Whitlock and others (1988) have shown that the Bee Rock grades by facies transition from a quartzose sandstone into the feldspathic McClure Sandstone Member of the Norton Formation west of the area of this study. Siltstone and coal below the McClure and above the uppermost quartzarenite of the Middlesboro Member of the Lee were mapped as lower Norton Formation. These rocks are equivalent to the Hensley Member of the Lee, mapped by others southwest of this study area.

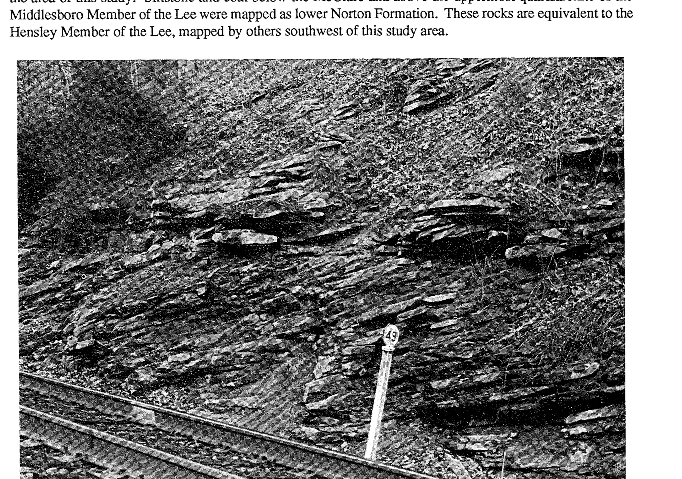


Figure 4. Cross-bedded quartzarenite in the Lee Formation: at this locality in southwest St. Paul quadrangle, the beds are right-side up and nearly horizontal.

The Norton Formation contains at least five prominent feldspathic sandstone units in addition to the McClure. The Gladeville Sandstone is a quartzose unit that occurs stratigraphically above the Norton Formation and below the Wise Formation in northwestern St. Paul quadrangle. On the topographically high points in the north-central part of the mapped area, the Gladeville either is not present, or has undergone a facies transition into a more feldspathic sandstone. The boundary between the Norton and Wise Formations elsewhere is placed at the base of the Dorchester coal; this coal is not present within the mapped area.

The most useful stratigraphic marker in the Pennsylvanian-age section of this area is a 1-inch-thick gritty parting in the Upper Banner coal, thought to be volcanogenic. In thin section, the material is predominantly kaolinite, but also contains needles of zircon, plagioclase feldspar, and quartz. The kaolinite could be a product of chemical alteration of biotite. This marker has been recognized in the Upper Banner coal throughout the southwest Virginia coalfields, and probably is present elsewhere beyond the limits of the Upper Banner, at the same stratigraphic level in the Norton Formation.

STRUCTURE

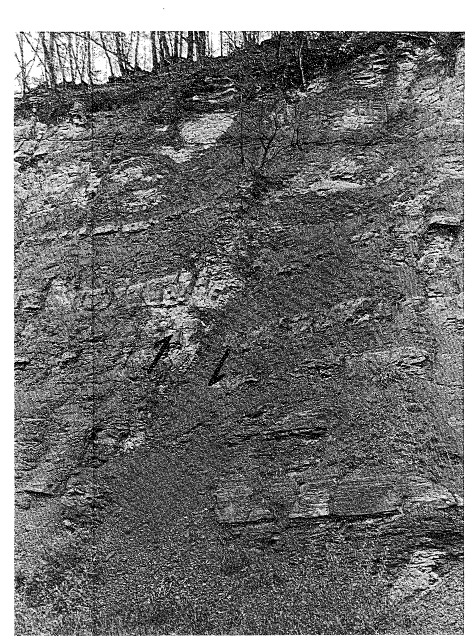
Four major structural blocks or thrust sheets are present in the mapped area: the Pine Mountain, St. Paul, Weaver Creek, and Honaker. Each carries a distinct structural style.

In the northwest portion of the mapped area, the Pine Mountain sheet contains flat-lying or gently-dipping Pennsylvanian-age sandstone, shale, and coal of the Appalachian Plateaus. At the structural front, Mississippian- and Pennsylvanian-age rocks of the Pine Mountain sheet have been folded into the asymmetric Stone Mountain syncline along the footwall of the St. Paul fault. Southwest of the mapped area, the Stone Mountain syncline was mapped as an intact structure on the southeast flank of the Powell Valley anticline from Big Stone Gap quadrangle northeastward through East Stone Gap, Fort Blackmore, and much of Dungannon quadrangles by Miller (1965), Henika (1988), Whitlock and others (1988), and Nolde and Diffenbach (1988). Throughout the area of this report, the overturned southeast limb of the Stone Mountain syncline has been detached and thrust northwestward along the Buffalo Mountain fault (Plate 1; Figure 5). Displacement on the Buffalo Mountain fault increases along strike from southwest to northeast across the mapped area. Across much of St. Paul quadrangle the detached overturned limb of the syncline has itself been imbricated along a subsidiary thrust, and folded into an open synform. Northwest of this "horse block" of overturned Lee Formation rocks, upright rocks of the Norton Formation have been thrust over flat-lying Norton rocks along another unnamed fault that, locally, imbricates the Jawbone coal (Figure 6). This has resulted in structural thickening of that seam southeast of Virginia City, in Robinette and Honey Branch Hollows, and probably elsewhere along strike. In northeastern Carbo quadrangle, the detached overturned limb of the Stone Mountain syncline has been thrust northwestward over flat-lying Norton Formation rocks; the limb is imbricated, and has been overridden by the Weaver Creek thrust sheet.

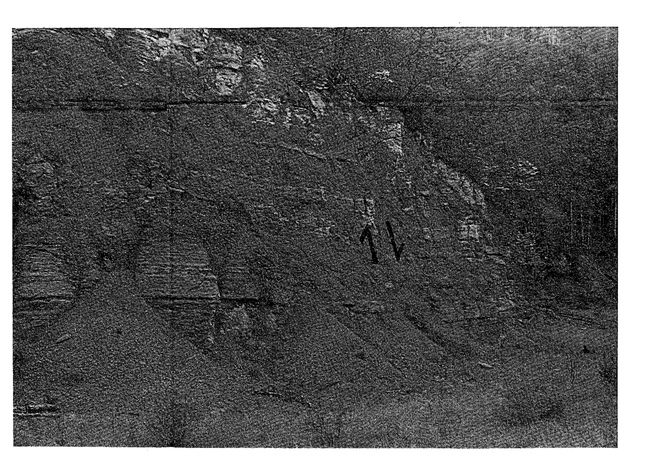
Figure 5. Outcrop photograph showing deformed Norton Formation shale beneath an overthrust block of overturned Lee Formation quartzarenite (Reference Locality 23).

Figure 6. Outcrop photograph showing a thrust fault within the Norton Formation (Reference Locality 20).

The Weaver Creek thrust sheet comprises an asymmetric syncline of Devonian- and Mississippian-age rocks. This structure plunges beneath a northwest-trending, gently southeast-dipping segment of the St. Paul fault. Rocks of the Pine Mountain and Weaver Creek sheets are cut by a series of northwest-trending high-angle faults that are not present southeast of the St. Paul fault. These faults have vertical displacements on the order of a few tens of feet and can be located with certainty only where the rock units on either side of the fault have sufficient dip to show offset of formational contacts in map view. Although the map indicates most of these faults are confined to the overturned rocks adjacent to the structural front, it is likely the faults extend northwestward into relatively flat-lying rocks to a greater extent than shown. The Dorton Hollow fault is a zone of high-angle faults that has been mapped across much of northwestern Carbo quadrangle on the basis of exposures in Lower Banner high-walls (Figure 7) and information from mine maps.



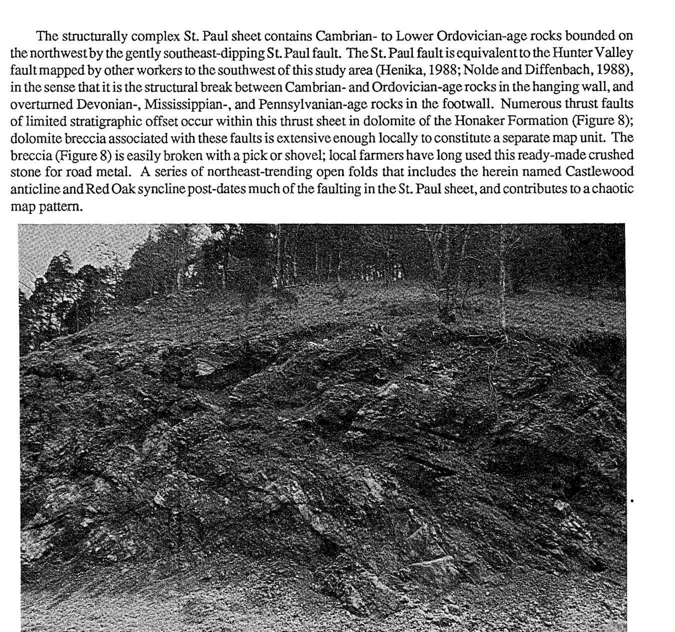
a



b

Figures 7a and 7b. Outcrop photographs showing high-angle faults in Lower Banner surface-mine highwalls (Reference Locality 2).

The structurally complex St. Paul sheet contains Cambrian- to Lower Ordovician-age rocks bounded on the northwest by the gently southeast-dipping St. Paul fault. The St. Paul fault is equivalent to the Hunter Valley fault mapped by other workers to the southwest of this study area (Henika, 1988; Nolde and Diffenbach, 1988), in the sense that it is the structural break between Cambrian- and Ordovician-age rocks in the hanging wall, and overturned Devonian-, Mississippian-, and Pennsylvanian-age rocks in the footwall. Numerous thrust faults of limited stratigraphic offset occur within this thrust sheet in dolomite of the Honaker Formation (Figure 8); dolomite breccia associated with these faults is extensive enough locally to constitute a separate map unit. The breccia (Figure 8) is easily broken with a pick or shovel; local farmers have long used this ready-made crushed stone for road metal. A series of northeast-trending open folds that includes the herein named Castlewood anticline and Red Oak syncline post-dates much of the faulting in the St. Paul sheet, and contributes to a chaotic map pattern.



a

b

Figure 8. (a) Outcrop photograph showing a thrust fault within the Honaker dolomite, exposed in crushed-stone borrow pit (Reference Locality 13); (b) close-up of carbonate rock breccia in the footwall block at the same locality.

The Honaker sheet is a homoclinal southeast-dipping sequence of Cambrian- to Upper Ordovician-age rocks that is imbricated by a series of thrusts in the lower part, southeast of the Honaker fault. The Copper Creek thrust sheet overrides the Honaker sheet in the southeast corner of Carbo quadrangle.

The Clinchport fault is a regionally extensive fault system that carries Rome Formation rocks in the hanging wall, and has been interpreted to include the Honaker and St. Clair faults in Virginia, and the Whiteoak Mountain and Taylor Ridge faults in Tennessee and Georgia (Harris, 1965). Within the area of this study, the name Clinchport is assigned only to a fault segment in southern St. Paul quadrangle; this particular fault passes into the Rome Formation outcrop belt east of Castlewood, and can no longer be mapped because of poor exposure. There does not appear to be a fault between the Rome and the adjacent Honaker limestone on the northwest flank of the Castlewood anticline in the vicinity of Castlewood. However, north of Carterton, this belt of Rome has been thrust northwestward over younger rocks on the herein named Dumps fault. Southeast of the Clinch River in Carbo quadrangle, another belt of Rome Formation rocks has been thrust over younger rocks by the Honaker fault. The Dumps fault and the Honaker fault emerge northeast of the zone of imbricate faulting that underlies southeastern St. Paul quadrangle (Plate 1). In a regional sense, both of these faults could be considered part of the Clinchport fault system.

Vibroseis data and data from the Gulf Russell Price #1 well, located just south of the mapped area, provide insight into the geometry of rock units in the subsurface beneath Carbo and St. Paul quadrangles. An interpretive cross section based on these data and on data from wells in the plateau portion of northern St. Paul quadrangle is given in Section B-B", Plate 1. Other interpretations of the data are possible, especially with respect to details of upper level structures in the vicinity of the structural front, but fundamentally, the interpretation shown in Section B-B", Plate 1 is consistent with geophysical data from the subsurface and with the surface geology. The St. Paul fault merges at depth with the subhorizontal Pine Mountain fault, which rides on a footwall of Devonian-age shale. The structurally complex St. Paul sheet, and at least the northwestern portion of the Honaker sheet, are underlain by a subhorizontal stratigraphic sequence extending downward from Devonian shale at the level of the Pine Mountain fault, to crystalline basement at a depth of about 16,800 feet. The subhorizontal package of rocks below the Pine Mountain fault extends southeastward beyond the limits of the mapped area and terminates at a southeast-dipping tectonic ramp.

ECONOMIC GEOLOGY

King W. Troensegaard

Coal constitutes the primary economic resource of Carbo and St. Paul quadrangles; mines are currently producing from the Jawbone, Upper Banner, Splash Dam, and Hagy coal beds. Mining is conducted by contour removal, auger, and underground methods. Generally, the coal names used in this report are the same names used in Wise County (Nolde and Diffenbach, 1988; Nolde and others, 1988). Local usage, where it differs from the Wise County terminology, is shown in parentheses after the Wise County name.

The Jawbone coal is approximately 260 feet above the upper Lee quartzarenite. In the vicinity of Virginia City, St. Paul quadrangle, and along Chaney Creek and Hurricane Fork in Carbo quadrangle, the Jawbone is currently being mined in the subsurface. In the Virginia City area, structural repetitions locally have developed coal bed thickness in excess of 20 feet.

The Raven coal (5 to 30 inches) and the Aily (Hogwallow) coal (16 to 38 inches) occur approximately 160 and 300 feet, respectively, above the Jawbone. These coals have been mined by contour stripping and auger mining in the highlands above Virginia City and, to a limited extent, in Robinette, Honey Branch, Hamlin Branch, Chaney Creek, and Hurricane Branch Hollows.

The Kennedy (Widow Kenndey) coal ranges in thickness from 16 to 30 inches, and is directly above the McClure sandstone, about 150 feet above the Aily. The Kennedy has been extensively strip-mined in northeastern Carbo quadrangle and, to a lesser extent, north of Virginia City, and in Hamlin Branch and Chaney Creek Hollows.

The Lower Banner coal is 24 to 36 inches thick within the mapped area, and crops out about 200 feet above the Kennedy. The Lower Banner has been mined extensively throughout its extent in Carbo and St. Paul quadrangles, by underground and surface methods. The Upper Banner coal bed (24 to 36 inches thick) is about 180 feet above the Lower Banner. Historically, the Upper Banner supplied coal used in the coking operations in the town of Dante. The Splash Dam seam or seams are from 5 to 50 feet above the Upper Banner. While these coals have seldom been mined by themselves, they have been surface mined with the Upper Banner where practical.

The Hagy (Edwards) coal is approximately 160 feet above the Splash Dam; the interval between these two coals is occupied by a homogeneous, iron-nodule-bearing siltstone that forms distinctive smooth "high-walls" and road cuts. The Hagy is currently being mined on Sandy Ridge in St. Paul quadrangle, where the coal averages 24 inches in thickness. The Norton coal occurs about 300 feet above the Hagy and is the uppermost coal in the mapped area. The Norton has been mined in a few small operations but is not of sufficient areal extent to be an important producer.

At the time of publication there are three producing natural gas wells and one shut-in gas well within the St. Paul and Carbo quadrangles. The wells are located on the Pine Mountain thrust sheet and produce from the Mississippian-age Bluestone Formation and Greenbrier Limestone.

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REFERENCE LOCALITIES

1, 2, 3) Highwall exposures of high-angle faults associated with the Dorton Hollow fault zone.

4) Good exposures of the Greenbrier Limestone and related karst features are present throughout Sinkhole Valley.

5) Good exposure of Mccrady and Price sandstone, siltstone, and shale in the trough of the Sinkhole Valley syncline.

6) Good exposure of structurally complex Rome Formation carbonate rock and interbedded shale.

7) Carbonate breccia developed in Honaker limestone along the footwall of the Honaker fault.

8) Good exposure of the Nolichucky Formation; a detailed description of this section is given by Derby (1965).

9) Good exposure of mudstone and siltstone of the Rome Formation; this locality has yielded trilobite fossils.

10) Carbonate breccia developed in the chaotic zone comprising the imbricated northwest limb of the Castlewood anticline.

11) Well-exposed sequence of limestone beds in the lower part of the Honaker Formation.

12) Sequence of outcrops across a Honaker limestone "horse block" along the footwall of the Honaker fault.

13) Fault within the Honaker dolomite is exposed in a borrow pit.

14) At this locality the Honaker fault is exposed in a pavement outcrop of brecciated Honaker limestone.

15) Carbonate rock breccia is exposed along the northwest-dipping southeast limb of the Red Oak syncline. This fault may be the westward projection of the Honaker fault over the Castlewood anticline.

16) Exposure of a fault beneath the overturned upper quartzarenite of the Lee Formation.

17) Lee Formation "horse block" has been breached by Honey Branch: gently southeast-dipping, right-side-up Norton siltstone at stream level is in the footwall. Overturned, moderately southeast-dipping upper Lee Formation quartzarenite in the hanging wall outcrops on both sides of the hollow, about 100 feet above the stream.

18) The St. Paul fault is exposed in a road cut. This cut has proven very unstable because of fault-related fractures in Honaker limestone in the hanging wall.

19) Intensely deformed Rome Formation shale in the hanging wall of the Clinchport fault is exposed in a road cut (westbound side of US Highway 19), and in a bank on the eastbound side of the highway. The trace of the fault crosses highway immediately to the north.

20) Northwesternmost thrust that reaches the surface in the mapped area is exposed in road cut. Norton Formation rocks in hanging wall and footwall are right-side-up.

21) The St. Paul fault rimming a fenster is exposed at the railroad tunnel portal. A photograph and description of this outcrop appears in Campbell (1899).

22) St. Paul fault on the edge of a small fenster is exposed in a railroad cut.

23) Exposure of the fault beneath the overturned, upper Lee Formation quartzarenite on the detached southeast limb of the Stone Mountain syncline.

SYSTEM and SERIES	FORMATION AND MEMBER	COAL THICKNESS	DESCRIPTION
QUATERNARY	ALLUVIUM, COLLUVIUM, TERRACE DEPOSITS		Unconsolidated stratified deposits of clay, silt, and sand; pebble- and cobble-size material present locally. Unconsolidated non-stratified deposits of angular cobbles and boulders, with interstitial sand, silt, and clay. Unconsolidated stratified deposits of rounded pebbles, cobbles, and boulders supported in a silt or sand matrix.
PENNSYLVANIAN, MIDDLE	WISE FORMATION		Siltstone and coal. Siltstone, medium-gray to pale-brown, thin- to medium-bedded. About 100 feet of section is exposed in the mapped area.
	GLADEVILLE SANDSTONE		Sandstone, very-light-gray to white, fine- to coarse-grained, locally conglomeratic, thin- to very-thick-bedded, locally cross-bedded; quartzose. Thickness: 0 - 40 feet.
	NORTON FORMATION: NORTON COAL	20-48	
	EAGLE SHALE MEMBER		Sandstone, siltstone, shale, and coal. Sandstone, light-gray to white, medium- to coarse-grained, conglomeratic at base, medium-bedded, locally cross-bedded; contains large fragments of plant fossils. Siltstone, medium- to dark-gray, laminated; contains nodules of siderite. Shale, medium- to dark-gray, ripple-bedded, platy; equivalent to the Eagle Shale of White (1885).
	HAGY COAL	18-24	
	SPLASH DAM COAL	10-35	Siltstone, sandstone, and coal. Siltstone, medium-gray, laminated to very-thin-bedded, siderite nodules and lenses common. Sandstone, light-gray to white, medium-grained, very-thin- to thick-bedded, locally trough-cross-bedded; feldspathic and micaceous. Thickness: 320 - 380 feet.
	UPPER BANNER COAL	24-80	
	LOWER BANNER COAL	24-36	Sandstone, siltstone, shale, and coal. Sandstone, light-gray, fine- to medium-grained, laminated to medium-bedded, cross-bedded, feldspathic and micaceous. Siltstone, medium-gray, laminated, contains siderite nodules. Shale, dark-gray to black, platy. Thickness: 240 - 300 feet.
	KENNEDY COAL	16-36	Sandstone, siltstone, and shale. McClure Sandstone Member, light-gray to white, fine- to coarse-grained, thin- to medium-bedded, feldspathic and micaceous, quartz-pebble conglomerate at base. Siltstone, medium-gray, laminated. Shale, light-gray, poorly indurated. Thickness: 40 - 100 feet.
	McCLURE SANDSTONE MEMBER		
	AILY COAL	16-38	
	RAVEN COAL	5-30	Siltstone, sandstone, shale, and coal. Siltstone, medium- to dark-gray, laminated; nodules and lenses of siderite common. Sandstone, light- to medium-gray, fine-grained, thin- to medium-bedded, feldspathic and micaceous; fragments of plant fossils common, conglomerate lenses present locally. Shale, dark-gray, laminated. Thickness: 270 - 420 feet.
	JAWBONE COAL	5-85	
	COUNCIL SANDSTONE MEMBER		
	TILLER COAL	0-41	Sandstone, siltstone, and coal. Sandstone, light- to medium-gray, medium-grained, thin- to thick-bedded, feldspathic and micaceous. Siltstone, medium-gray, laminated. Thickness: 220 - 340 feet.
PENNSYLVANIAN, LOWER	LEE FORMATION, MIDDLESBORO MEMBER: UPPER QUARTZARENITE		Quartzarenite, very-light-gray to white, fine- to coarse-grained, medium- to very-thick-bedded with tabular cross-beds; quartz-pebble conglomerate lenses common. Thickness: 150 - 200 feet.
	UPPER HORSEPEN COAL	7-10	Siltstone, shale, sandstone, and coal. Siltstone, medium- to dark-gray, laminated, carbonaceous and micaceous. Shale, dark-gray. Sandstone, medium-gray, very-fine- to medium-grained, thin- to medium-bedded; quartz-pebble conglomerate lenses rare. Coal beds average 18 inches thick. Thickness: 430 - 730 feet.
	WAR CREEK COAL	17-18	
	LOWER HORSEPEN COAL	18-19	
	LOWER QUARTZARENITE		Quartzarenite, very-light-gray to white, fine- to coarse-grained, thin- to very-thick-bedded, cross-bedded; quartz-pebble conglomerate lenses common. Thickness: 150 - 200 feet.
	POCAHONTAS FORMATION: BURTONS FORD COAL	30-64	Sandstone, siltstone, and coal. Siltstone, medium- to dark-gray, laminated, carbonaceous; abundant plant fossils, *Neuropteris pocahontas*. Sandstone, medium- to dark-gray, very-fine-grained, thin-bedded; micaceous. Very poorly exposed within mapped area. Thickness: approximately 300 feet.
	(POCAHONTAS #3)	29-340	
MISSISSIPPIAN, UPPER	BLUESTONE FORMATION		Shale, siltstone, and sandstone. Shale, grayish-red, greenish-gray, and grayish-black; locally calcareous. Siltstone, medium-gray, very-thin- to thin-bedded, micaceous. Sandstone, medium- to dark-gray, very-fine-grained, thin- to medium-bedded; conglomerate lenses locally present at base of sandstone. Thickness: approximately 500 feet.
	HINTON FORMATION: TALLERY SANDSTONE MEMBER		Quartzarenite, light-gray to pale orange, fine- to medium-grained, thick-bedded to massive, large-scale, low-angle cross-stratification pebbly conglomerate near base. Thickness: 40 - 100 feet.
	MIDDLE RED MEMBER		Siltstone, mudstone, shale, limestone, and sandstone. Siltstone, mudstone, and shale, light-gray in lower part and dark-gray to grayish-red in upper part. Mudstone, greenish-gray, calcareous; grades into dark-gray micritic limestone. Sandstone, light- to medium-gray, fine-grained, thin- to medium-bedded. This coal bed present near base of unit. Thickness: approximately 550 feet.
	STONY GAP SANDSTONE MEMBER		Sandstone, light-gray, fine- to medium-grained, tabular- to planar-cross-bedded, some beds contain small shale clasts; interbedded with medium-gray shale. Thickness: approximately 220 feet.
	BLUEFIELD FORMATION		Shale and siltstone, grayish-yellow to grayish-olive, laminated to thin-bedded; locally abundant brachiopods. Base of section truncated by faulting; less than 100 feet exposed northwest of St. Paul fault, St. Paul quadrangle.
MISSISSIPPIAN, LOWER	GREENBRIER LIMESTONE		Limestone, light- to medium-gray, thin-bedded to massive, micritic, locally abundant fossils; grayish-red, shaley limestone and calcareous shale are present in the upper part of the section. About 430 feet of section is exposed in the Sinkhole Valley syncline, Carbo quadrangle.
	MACCRADY AND PRICE FORMATION		Maccrady Formation: siltstone and shale. Siltstone, grayish-red to greenish-gray, very-thin- to medium-bedded. Shale, grayish-red, laminated to very-thin-bedded; interbedded with siltstone. Price Formation: siltstone, sandstone, and shale. Siltstone, light-olive-gray, thin- to medium-bedded. Sandstone, medium-gray, fine-grained, medium- to thick-bedded. Shale, greenish-gray, laminated to thin-bedded, interbedded with sandstone and siltstone. Thickness: approximately 200 feet.
DEVONIAN	CHATTANOOGA SHALE		Shale and siltstone. Shale, medium-gray to black, very-fine-grained, laminated to thin-bedded. Siltstone, medium-gray to grayish-yellow, thin-bedded. Dominantly shale in the lower portion, interbedded shale and siltstone in the upper portion. Approximately 1000 feet of section is exposed southeast of Weaver Creek fault, Carbo quadrangle.

SYSTEM and SERIES	FORMATION AND MEMBER	DESCRIPTION
SILURIAN	CLINCH SANDSTONE	Quartzarenite, white, medium- to coarse-grained, thick-bedded, cross-stratified, well-indurated, quartz-pebble conglomerate lenses locally present. Section truncated by faulting; approximately 75 feet of section exposed.
ORDOVICIAN, MIDDLE AND UPPER	MIDDLE AND UPPER ORDOVICIAN LIMESTONE FORMATIONS: RED LIMESTONE AND SHALE UNIT	Limestone, reddish-gray, yellowish-gray, and medium-gray, fine- to medium-grained, thin- to medium-bedded; shale interbeds common. Thickness: approximately 300 feet.
	NON-CHERTY LIMESTONE UNIT	Limestone, medium- to dark-gray, locally reddish-gray, fine- to coarse-grained, thin- to medium-bedded in the lower part, thin-bedded and flaggy in the upper part. Thickness: approximately 550 feet.
	CHERTY LIMESTONE UNIT	Limestone, light- to medium-gray, micrite and grainstone, fine- to coarse-grained, thin- to thick-bedded; contains abundant nodules of black chert. Thickness: approximately 430 feet.
	BLACKFORD FORMATION	Mudstone, limestone, and dolomite. Mudstone, grayish-red or greenish-gray, laminated to thin-bedded, calcareous. Limestone, yellowish-gray, fine-grained, thin-bedded, contains nodules of grayish-white chert. Dolomite, greenish-gray, very-fine-grained, laminated to thin-bedded, argillaceous, pebbly dolomite at base of unit. Thickness: 90 feet.
ORDOVICIAN, LOWER	MASCOT AND KINGSPORT FORMATIONS	Dolomite, white to light-gray, some grayish-pink beds near the top of unit, very-fine- to coarse-grained and saccharoidal, thin- to medium-bedded; contains abundant white-weathering chert nodules. Thickness: approximately 1150 feet.
	CHEPULTEPEC AND COPPER RIDGE FORMATIONS	Dolomite and sandstone. Dolomite, light- to medium-gray, thinly laminated near base of section, medium- to dark-gray or grayish-brown, locally mottled higher in the section, very-fine- to medium-grained and saccharoidal, thin-bedded to massive; flat-pebble conglomerate beds common, petroliferous, white-weathering chert prominent in residuum. Sandstone, light-yellowish-brown (fresh) or moderate-brown (weathered), medium- to coarse-grained, thin- to medium-bedded; calcite cement readily leached by weathering, leaving a porous, friable quartz-sandstone residuum. Thickness: approximately 1200 feet.
CAMBRIAN, UPPER	MAYNARDVILLE LIMESTONE	Limestone, medium- to dark-gray, argillaceous-ribbon-banded. Thickness: 60 feet.
	NOLICHUCKY FM.: UPPER SHALE UNIT	Shale, siltstone, and limestone. Shale, grayish-green to grayish-olive. Siltstone, yellowish-brown to grayish-orange, thin- to medium-bedded, locally glauconitic. Limestone, medium- to dark-gray, thin-bedded and shaley. Unit is dominantly shale. Thickness: 175 feet.
	MIDDLE LIMESTONE	Limestone, medium- to dark-gray, medium- to thick-bedded, locally argillaceous-ribbon-banded; section contains several flat-pebble conglomerate beds; grayish-olive shale interbedded with limestone. Thickness: 50 feet.
	LOWER SHALE UNIT	Shale, limestone, and siltstone. Shale, grayish-green to grayish-olive, interbedded with limestone. Limestone, medium-gray to dark-gray, thin-bedded and slabby or argillaceous-ribbon-banded, some beds contain glauconite, flat-pebble conglomerate beds common. Siltstone, yellowish-brown to grayish-orange, thin-bedded, locally interbedded with shale; some beds contain glauconite. Limestone constitutes about 50 percent of the section. Thickness: 290 feet.
CAMBRIAN, MIDDLE	HONAKER FORMATION: UPPER LIMESTONE UNIT	Limestone, light-gray, very-fine-grained, thick-bedded to massive in the lower portion, argillaceous-ribbon-banded in the upper portion. Thickness: southeast of the Honaker fault, about 220 feet. Unit thickens to the west; more than 300 feet of section exposed in thrust sheets northwest of the Honaker fault (equivalent to Maryville Limestone).
	DOLOMITE UNIT: DOLOMITE	Dolomite and shale: dolomite, dark-gray to black, with pinkish tinge where fresh, medium- to coarse-grained, thick-bedded to massive; argillaceous-ribbon-banded limestone and mottled limestone-dolomite common northwest of the Honaker fault. Thickness: southeast of the Honaker fault, about 600 feet. Unit thins to the west; less than 200 feet of section is exposed in the western thrust sheets of Carbo and St. Paul quadrangles. Shale, greenish-gray, laminated to thin-bedded, grayish-red shale present locally; shale unit occurs as much as 50 feet thick, and constitutes less than 30 percent of the section; structural complexity and poor exposure preclude tracing individual carbonate beds over large distances. Thickness: southeast of the Honaker fault, 20 - 30 feet; 50 - 60 feet in western thrust sheets (equivalent to Rogersville Shale).
	SHALE	
	DOLOMITE	
	LOWER LIMESTONE UNIT	Limestone, light- to medium-gray, very-fine-grained, argillaceous-ribbon-banded in the lower portion, thick-bedded above, thin shale interbeds near the bottom of the section. Thickness: about 250 feet southeast of the Honaker fault; thickens to more than 300 feet in western thrust sheets (equivalent to Rutledge Limestone).
CAMBRIAN, LOWER	ROME FORMATION	Shale, siltstone, sandstone, dolomite, and limestone. Shale and siltstone, greenish-gray or grayish-red, thinly laminated to very-thin-bedded; mesoscopic folds present in most outcrops. Sandstone, greenish-gray, fine- to medium-grained, thin-bedded. Dolomite, dark-gray, fine- to medium-grained, massive. Limestone, light-gray, weathering to rusty-orange, argillaceous-ribbon-banded. Limestone and dolomite occur in discontinuous zones up to 50 feet thick, and constitute less than 30 percent of the section; structural complexity and poor exposure preclude tracing individual carbonate beds over large distances. In each outcrop belt of Rome Formation within the mapped area, the base of the unit is truncated by faulting; approximately 500 feet of section is exposed.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES

GEOLOGY OF ST. PAUL AND CARBO QUADRANGLES, VIRGINIA

Nick H. Evans

INTRODUCTION

St. Paul and Carbo 7.5-minute quadrangles are located in southern Dickenson, eastern Wise, and northwestern Russell Counties, Virginia, and have a combined area of about 120 square miles (Plate 1). The northern portion of these quadrangles contains almost horizontal, coal-bearing, Pennsylvanian-age strata of the Appalachian Plateaus physiographic province. The Alleghenian structural front, northwest limit of the Valley and Ridge physiographic province, trends diagonally from southwest to northeast through the center of the area. Along the front, imbricated Cambrian- and Ordovician-age rocks have been thrust-faulted on top of overturned and imbricated Silurian-, Devonian-, Mississippian-, and Pennsylvanian-age rocks. Structural complexity decreases southeastward from the structural front; in southeastern Carbo quadrangle, Cambrian- to Upper Ordovician-age rocks form a gently southeast-dipping sequence that is overridden by the Copper Creek thrust sheet.

Field work for this study was conducted from 1986 to 1988. Geology was mapped at a scale of 1:24,000, providing much greater detail than earlier maps published at smaller scales (Campbell, 1899; Giles, 1921; Eby, 1923; Butts, 1933). This project has provided considerable insight regarding stratigraphic relations and geologic structure in this part of southwest Virginia.

STRATIGRAPHY

A detailed description for each map unit is given in the columnar section. Additional points related to stratigraphy are discussed below.

Complex faulting and folding in the Rome Formation (Figure 1) within the study area rendered accurate measurement of stratigraphic sections in this unit impractical. Carbonate rocks within the Rome were not mapped separately because of poor exposure and the apparent lenticular nature of those units. As a result, the map pattern of the Rome Formation rocks is not very informative with respect to geologic structures within the unit.

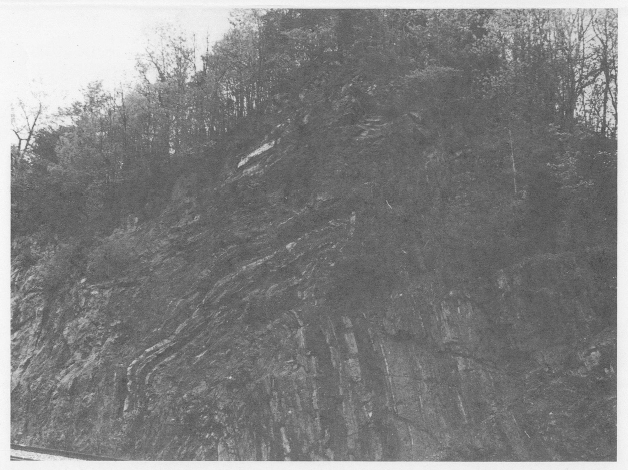


Figure 1. Anticline outlined by carbonate beds within the Rome Formation (Reference Locality 6).

Campbell (1899) recognized that the area between Castlewood and Cleveland contains a facies transition zone for rocks stratigraphically above the Rome Formation and below the Nolichucky shales. Southwest of Castlewood, this interval has a lower limestone unit (Rutledge), a shale unit (Rogersville), and an upper limestone unit (Maryville); these units were mapped northeastward along strike from type localities in the Appalachian Valley of eastern Tennessee by earlier workers (Campbell, 1894; Brent, 1963). Northeast of Cleveland, this stratigraphic interval is mapped as Honaker Formation, and is predominantly dolomite, with subordinate limestone at the top and bottom (Figure 2). The type locality of the Honaker Formation is at Honaker, about ten miles northeast of Carbo quadrangle (Campbell, 1897). Farther northeast along strike, in Giles County, Virginia, the Honaker consists almost entirely of dolomite (Figure 3; Shultz and others, 1986).

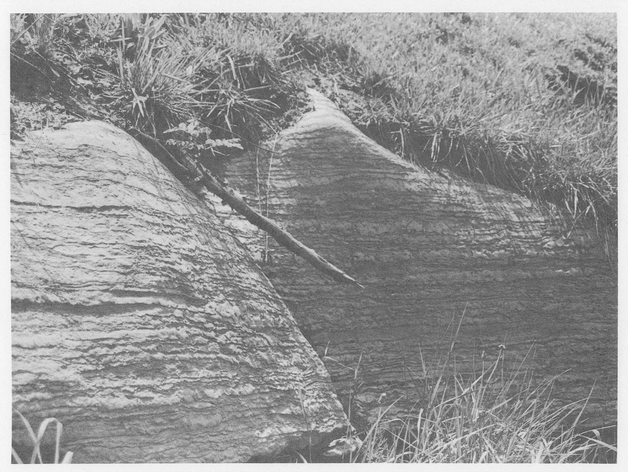


Figure 2. Argillaceous, ribbon-banded limestone typical of the lower part of the Honaker Formation.

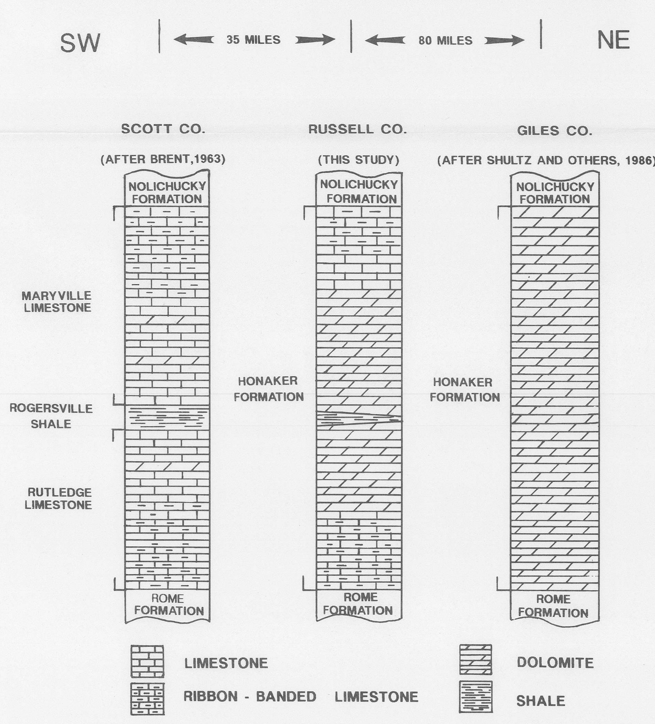


Figure 3. Stratigraphic columns representing the Honaker Formation (this study), and equivalent units along strike to the southwest and northeast of the study area.

In this study, the rocks in the stratigraphic interval between the Rome and the Nolichucky Formations are assigned to four units in the Honaker Formation: lower limestone, middle dolomite, shale, and upper limestone. This assemblage of rock types is similar to the package at the type locality at Honaker. The overall thickness of the Honaker section is about 1100 to 1200 feet throughout the mapped area, but from northwest to southeast among different thrust sheets, and northeast along strike within a given thrust sheet, the proportion of dolomite in the section increases and the thickness of the shale interval decreases. These trends are consistent with the map pattern portrayed on Big A Mountain quadrangle (Miller and Meissner, 1977) and Honaker quadrangle (Meissner and Miller, 1981); both quadrangles are northeast of Carbo quadrangle.

Limestone stratigraphically above the Blackford Formation in southeastern Carbo quadrangle was assigned to three unnamed map units on the basis of lithologic characteristics that could be recognized in the field. Units defined by Cooper (1945) for Middle Ordovician limestone in this strike-belt could not be mapped at 1:24,000 scale.

Mississippian-age rocks throughout the mapped area are for the most part overturned and poorly exposed. Rigorous stratigraphic treatment of these rocks on the basis of outcrops in this area was not practical; thickness estimates take into account information from drill logs of wells northwest of the Allegheny structural front. The drill logs are on file at the Virginia Division of Mineral Resources.

The Lee Formation in Carbo and St. Paul quadrangles contains two persistent ridge-forming quartzarenite units separated by about 600 feet of shale, siltstone, and coal (Figure 4). In keeping with the original lithostratigraphic definition of the Lee (Campbell, 1894), the top of the Lee Formation was mapped as the top of the uppermost quartzarenite. The Bee Rock Sandstone and Hensley Members of the Lee were not mapped in this area. Gathright (1964) and Whitlock and others (1988) have shown that the Bee Rock grades by facies transition from a quartzose sandstone into the feldspathic McClure Sandstone Member of the Norton Formation west of the area of this study. Siltstone and coal below the McClure and above the uppermost quartzarenite of the Middlesboro Member of the Lee were mapped as lower Norton Formation. These rocks are equivalent to the Hensley Member of the Lee, mapped by others southwest of this study area.

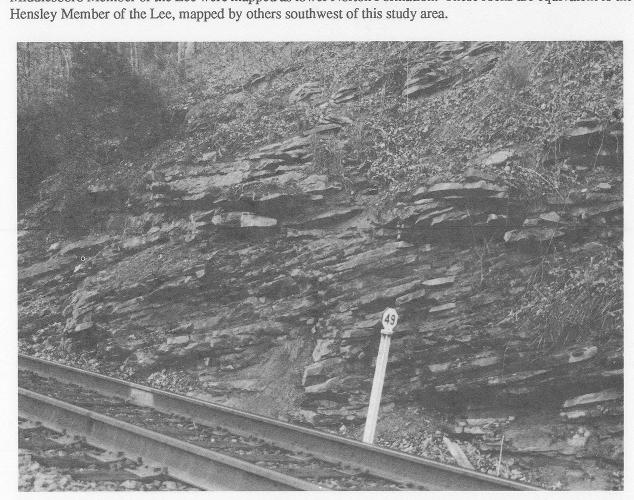


Figure 4. Cross-bedded quartzarenite in the Lee Formation: at this locality in southwest St. Paul quadrangle, the beds are right-side up and nearly horizontal.

The Norton Formation contains at least five prominent feldspathic sandstone units in addition to the McClure. The Gladeville Sandstone is a quartzose unit that occurs stratigraphically above the Norton Formation and below the Wise Formation in northwestern St. Paul quadrangle. On the topographically high points in the north-central part of the mapped area, the Gladeville either is not present, or has undergone a facies transition into a more feldspathic sandstone. The boundary between the Norton and Wise Formations elsewhere is placed at the base of the Dorchester coal; this coal is not present within the mapped area.

The most useful stratigraphic marker in the Pennsylvanian-age section of this area is a 1-inch-thick gritty parting in the Upper Banner coal, thought to be volcanogenic. In thin section, the material is predominantly kaolinite, but also contains needles of zircon, plagioclase feldspar, and quartz. The kaolinite could be a product of chemical alteration of biotite. This marker has been recognized in the Upper Banner coal throughout the southwest Virginia coalfields, and probably is present elsewhere beyond the limits of the Upper Banner, at the same stratigraphic level in the Norton Formation.

STRUCTURE

Four major structural blocks or thrust sheets are present in the mapped area: the Pine Mountain, St. Paul, Weaver Creek, and Honaker. Each carries a distinct structural style.

In the northwest portion of the mapped area, the Pine Mountain sheet contains flat-lying or gently-dipping Pennsylvanian-age sandstone, shale, and coal of the Appalachian Plateaus. At the structural front, Mississippian- and Pennsylvanian-age rocks of the Pine Mountain sheet have been folded into the asymmetric Stone Mountain syncline along the footwall of the St. Paul fault. Southwest of the mapped area, the Stone Mountain syncline was mapped as an intact structure on the southeast flank of the Powell Valley anticline from Big Stone Gap quadrangle northeastward through East Stone Gap, Fort Blackmore, and much of Dungannon quadrangles by Miller (1965), Henika (1988), Whitlock and others (1988), and Nolde and Diffenbach (1988). Throughout the area of this report, the overturned southeast limb of the Stone Mountain syncline has been detached and thrust northwestward along the Buffalo Mountain fault (Plate 1; Figure 5). Displacement on the Buffalo Mountain fault increases along strike from southwest to northeast across the mapped area. Across much of St. Paul quadrangle the detached overturned limb of the syncline has itself been imbricated along a subsidiary thrust, and folded into an open synform. Northwest of this "horse block" of overturned Lee Formation rocks, upright rocks of the Norton Formation have been thrust over flat-lying Norton rocks along another unnamed fault that, locally, imbricates the Jawbone coal (Figure 6). This has resulted in structural thickening of that seam southeast of Virginia City, in Robinette and Honey Branch Hollows, and probably elsewhere along strike. In northeastern Carbo quadrangle, the detached overturned limb of the Stone Mountain syncline has been thrust northwestward over flat-lying Norton Formation rocks; the limb is imbricated, and has been overridden by the Weaver Creek thrust sheet.

Figure 5. Outcrop photograph showing deformed Norton Formation shale beneath an overthrust block of overturned Lee Formation quartzarenite (Reference Locality 23).

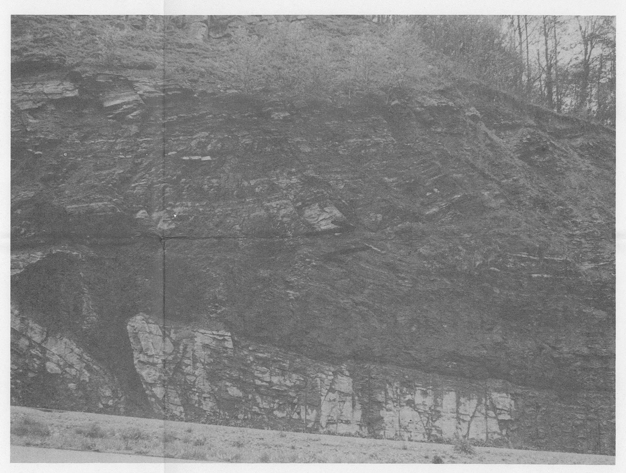
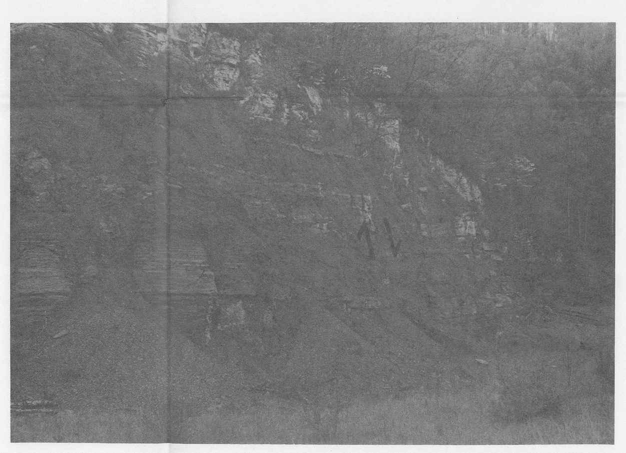


Figure 6. Outcrop photograph showing a thrust fault within the Norton Formation (Reference Locality 20).

The Weaver Creek thrust sheet comprises an asymmetric syncline of Devonian- and Mississippian-age rocks. This structure plunges beneath a northwest-trending, gently southeast-dipping segment of the St. Paul fault.

Rocks of the Pine Mountain and Weaver Creek sheets are cut by a series of northwest-trending high-angle faults that are not present southeast of the St. Paul fault. These faults have vertical displacements on the order of a few tens of feet and can be located with certainty only where the rock units on either side of the fault have sufficient dip to show offset of formational contacts in map view. Although the map indicates most of these faults are confined to the overturned rocks adjacent to the structural front, it is likely the faults extend northwestward into relatively flat-lying rocks to a greater extent than shown. The Dorton Hollow fault is a zone of high-angle faults that has been mapped across much of northwestern Carbo quadrangle on the basis of exposures in Lower Banner high-walls (Figure 7) and information from mine maps.

a



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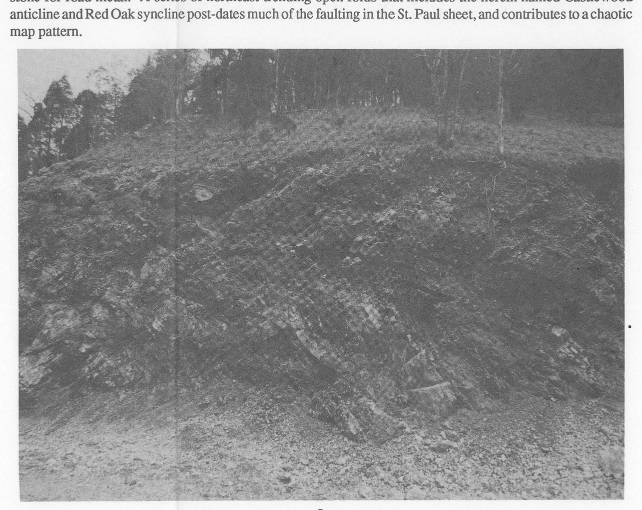
Figures 7a and 7b. Outcrop photographs showing high-angle faults in Lower Banner surface-mine highwalls (Reference Locality 2).

The structurally complex St. Paul sheet contains Cambrian- to Lower Ordovician-age rocks bounded on the northwest by the gently southeast-dipping St. Paul fault. The St. Paul fault is equivalent to the Hunter Valley fault mapped by other workers to the southwest of this study area (Henika, 1988; Nolde and Diffenbach, 1988), in the sense that it is the structural break between Cambrian- and Ordovician-age rocks in the hanging wall, and overturned Devonian-, Mississippian-, and Pennsylvanian-age rocks in the footwall. Numerous thrust faults of limited stratigraphic offset occur within this thrust sheet in dolomite of the Honaker Formation (Figure 8); dolomite breccia associated with these faults is extensive enough locally to constitute a separate map unit. The breccia (Figure 8) is easily broken with a pick or shovel; local farmers have long used this ready-made crushed stone for road metal. A series of northeast-trending open folds that includes the herein named Castlewood anticline and Red Oak syncline post-dates much of the faulting in the St. Paul sheet, and contributes to a chaotic map pattern.



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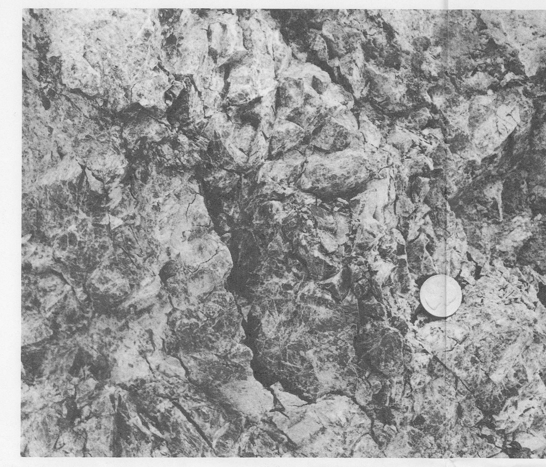

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Figure 8. (a) Outcrop photograph showing a thrust fault within the Honaker dolomite, exposed in crushed-stone borrow pit (Reference Locality 13); (b) close-up of carbonate rock breccia in the footwall block at the same locality.

The Honaker sheet is a homoclinal southeast-dipping sequence of Cambrian- to Upper Ordovician-age rocks that is imbricated by a series of thrusts in the lower part, southeast of the Honaker fault. The Copper Creek thrust sheet overrides the Honaker sheet in the southeast corner of Carbo quadrangle.

The Clinchport fault is a regionally extensive fault system that carries Rome Formation rocks in the hanging wall, and has been interpreted to include the Honaker and St. Clair faults in Virginia, and the Whiteoak Mountain and Taylor Ridge faults in Tennessee and Georgia (Harris, 1965). Within the area of this study, the name Clinchport is assigned only to a fault segment in southern St. Paul quadrangle; this particular fault passes into the Rome Formation outcrop belt east of Castlewood, and can no longer be mapped because of poor exposure. There does not appear to be a fault between the Rome and the adjacent Honaker limestone on the northwest flank of the Castlewood anticline in the vicinity of Castlewood. However, north of Carterton, this belt of Rome has been thrust northwestward over younger rocks on the herein named Dumps fault. Southeast of the Clinch River in Carbo quadrangle, another belt of Rome Formation rocks has been thrust over younger rocks by the Honaker fault. The Dumps fault and the Honaker fault emerge northeast of the zone of imbricate faulting that underlies southeastern St. Paul quadrangle (Plate 1). In a regional sense, both of these faults could be considered part of the Clinchport fault system.

Vibroseis data and data from the Gulf Russell Price #1 well, located just south of the mapped area, provide insight into the geometry of rock units in the subsurface beneath Carbo and St. Paul quadrangles. An interpretive cross section based on these data and on data from wells in the plateau portion of northern St. Paul quadrangle is given in Section B-B", Plate 1. Other interpretations of the data are possible, especially with respect to details of upper level structures in the vicinity of the structural front, but fundamentally, the interpretation shown in Section B-B", Plate 1 is consistent with geophysical data from the subsurface and with the surface geology. The St. Paul fault merges at depth with the subhorizontal Pine Mountain fault, which rides on a footwall of Devonian-age shale. The structurally complex St. Paul sheet, and at least the northwestern portion of the Honaker sheet, are underlain by a subhorizontal stratigraphic sequence extending downward from Devonian shale at the level of the Pine Mountain fault, to crystalline basement at a depth of about 16,800 feet. The subhorizontal package of rocks below the Pine Mountain fault extends southeastward beyond the limits of the mapped area and terminates at a southeast-dipping tectonic ramp.

ECONOMIC GEOLOGY

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Coal constitutes the primary economic resource of Carbo and St. Paul quadrangles; mines are currently producing from the Jawbone, Upper Banner, Splash Dam, and Hagy coal beds. Mining is conducted by contour removal, auger, and underground methods. Generally, the coal names used in this report are the same names used in Wise County (Nolde and Diffenbach, 1988; Nolde and others, 1988). Local usage, where it differs from the Wise County terminology, is shown in parentheses after the Wise County name.

The Jawbone coal is approximately 260 feet above the upper Lee quartzarenite. In the vicinity of Virginia City, St. Paul quadrangle, and along Chaney Creek and Hurricane Fork in Carbo quadrangle, the Jawbone is currently being mined in the subsurface. In the Virginia City area, structural repetitions locally have developed coal bed thickness in excess of 20 feet.

The Raven coal (5 to 30 inches) and the Aily (Hogwallow) coal (16 to 38 inches) occur approximately 160 and 300 feet, respectively, above the Jawbone. These coals have been mined by contour stripping and auger mining in the highlands above Virginia City and, to a limited extent, in Robinette, Honey Branch, Hamlin Branch, Chaney Creek, and Hurricane Branch Hollows.

The Kennedy (Widow Kenndey) coal ranges in thickness from 16 to 30 inches, and is directly above the McClure sandstone, about 150 feet above the Aily. The Kennedy has been extensively strip-mined in northeastern Carbo quadrangle and, to a lesser extent, north of Virginia City, and in Hamlin Branch and Chaney Creek Hollows.

The Lower Banner coal is 24 to 36 inches thick within the mapped area, and crops out about 200 feet above the Kennedy. The Lower Banner has been mined extensively throughout its extent in Carbo and St. Paul quadrangles, by underground and surface methods. The Upper Banner coal bed (24 to 36 inches thick) is about 180 feet above the Lower Banner. Historically, the Upper Banner supplied coal used in the coking operations in the town of Dante. The Splash Dam seam or seams are from 5 to 50 feet above the Upper Banner. While these coals have seldom been mined by themselves, they have been surface mined with the Upper Banner where practical.

The Hagy (Edwards) coal is approximately 160 feet above the Splash Dam; the interval between these two coals is occupied by a homogeneous, iron-nodule-bearing siltstone that forms distinctive smooth "high-walls" and road cuts. The Hagy is currently being mined on Sandy Ridge in St. Paul quadrangle, where the coal averages 24 inches in thickness. The Norton coal occurs about 300 feet above the Hagy and is the uppermost coal in the mapped area. The Norton has been mined in a few small operations but is not of sufficient areal extent to be an important producer.

At the time of publication there are three producing natural gas wells and one shut-in gas well within the St. Paul and Carbo quadrangles. The wells are located on the Pine Mountain thrust sheet and produce from the Mississippian-age Bluestone Formation and Greenbrier Limestone.

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REFERENCE LOCALITIES

1, 2, 3) Highwall exposures of high-angle faults associated with the Dorton Hollow fault zone.

4) Good exposures of the Greenbrier Limestone and related karst features are present throughout Sinkhole Valley.

5) Good exposure of Mccrady and Price sandstone, siltstone, and shale in the trough of the Sinkhole Valley syncline.

6) Good exposure of structurally complex Rome Formation carbonate rock and interbedded shale.

7) Carbonate breccia developed in Honaker limestone along the footwall of the Honaker fault.

8) Good exposure of the Nolichucky Formation; a detailed description of this section is given by Derby (1965).

9) Good exposure of mudstone and siltstone of the Rome Formation; this locality has yielded trilobite fossils.

10) Carbonate breccia developed in the chaotic zone comprising the imbricated northwest limb of the Castlewood anticline.

11) Well-exposed sequence of limestone beds in the lower part of the Honaker Formation.

12) Sequence of outcrops across a Honaker limestone "horse block" along the footwall of the Honaker fault.

13) Fault within the Honaker dolomite is exposed in a borrow pit.

14) At this locality the Honaker fault is exposed in a pavement outcrop of brecciated Honaker limestone.

15) Carbonate rock breccia is exposed along the northwest-dipping southeast limb of the Red Oak syncline. This fault may be the westward projection of the Honaker fault over the Castlewood anticline.

16) Exposure of a fault beneath the overturned upper quartzarenite of the Lee Formation.

17) Lee Formation "horse block" has been breached by Honey Branch: gently southeast-dipping, right-side-up Norton siltstone at stream level is in the footwall. Overturned, moderately southeast-dipping upper Lee Formation quartzarenite in the hanging wall outcrops on both sides of the hollow, about 100 feet above the stream.

18) The St. Paul fault is exposed in a road cut. This cut has proven very unstable because of fault-related fractures in Honaker limestone in the hanging wall.

19) Intensely deformed Rome Formation shale in the hanging wall of the Clinchport fault is exposed in a road cut (westbound side of US Highway 19), and in a bank on the eastbound side of the highway. The trace of the fault crosses highway immediately to the north.

20) Northwesternmost thrust that reaches the surface in the mapped area is exposed in road cut. Norton Formation rocks in hanging wall and footwall are right-side-up.

21) The St. Paul fault rimming a fenster is exposed at the railroad tunnel portal. A photograph and description of this outcrop appears in Campbell (1899).

22) St. Paul fault on the edge of a small fenster is exposed in a railroad cut.

23) Exposure of the fault beneath the overturned, upper Lee Formation quartzarenite on the detached southeast limb of the Stone Mountain syncline.

SYSTEM and SERIES		FORMATION AND MEMBER		COAL THICKNESS	DESCRIPTION
QUATERNARY		ALLUVIUM, COLLUVIUM, TERRACE DEPOSITS			Unconsolidated stratified deposits of clay, silt, and sand; pebble- and cobble-size material present locally. Unconsolidated non-stratified deposits of angular cobbles and boulders, with interstitial sand, silt, and clay. Unconsolidated stratified deposits of rounded pebbles, cobbles, and boulders supported in a silt or sand matrix.
PENNSYLVANIAN	MIDDLE	WISE FORMATION			Siltstone and coal. Siltstone, medium-gray to pale-brown, thin- to medium-bedded. About 100 feet of section is exposed in the mapped area.
		GLADEVILLE SANDSTONE			Sandstone, very-light-gray to white, fine- to coarse-grained, locally conglomeratic, thin- to very-thick-bedded, locally cross-bedded; quartzose. Thickness: 0 - 40 feet.
		NORTON FORMATION	NORTON COAL	20-48	
			EAGLE SHALE MEMBER		Sandstone, siltstone, shale, and coal. Sandstone, light-gray to white, medium- to coarse-grained, conglomeratic at base, medium-bedded, locally cross-bedded; contains large fragments of plant fossils. Siltstone, medium- to dark-gray, laminated; contains nodules of siderite. Shale, medium- to dark-gray, ripple-bedded, platy; equivalent to the Eagle Shale of White (1885).
			HAGY COAL	18-24	
			SPLASH DAM COAL	10-35	
			UPPER BANNER COAL	24-80	Siltstone, sandstone, and coal. Siltstone, medium-gray, laminated to very-thin-bedded, siderite nodules and lenses common. Sandstone, light-gray to white, medium-grained, very-thin- to thick-bedded, locally trough-cross-bedded; feldspathic and micaceous. Thickness: 320 - 380 feet.
			LOWER BANNER COAL	24-36	Sandstone, siltstone, shale, and coal. Sandstone, light-gray, fine- to medium-grained, laminated to medium-bedded, cross-bedded, feldspathic and micaceous. Siltstone, medium-gray, laminated, contains siderite nodules. Shale, dark-gray to black, platy. Thickness: 240 - 300 feet.
			KENNEDY COAL	16-36	
			McCLURE SANDSTONE MEMBER		Sandstone, siltstone, and shale. McClure Sandstone Member, light-gray to white, fine- to coarse-grained, thin- to medium-bedded, feldspathic and micaceous, quartz-pebble conglomerate at base. Siltstone, medium-gray, laminated. Shale, light-gray, poorly indurated. Thickness: 40 - 100 feet.
			AILY COAL	16-38	
			RAVEN COAL	5-30	Siltstone, sandstone, shale, and coal. Siltstone, medium- to dark-gray, laminated; nodules and lenses of siderite common. Sandstone, light- to medium-gray, fine-grained, thin- to medium-bedded, feldspathic and micaceous; large fragments of plant fossils common, conglomeratic lenses present locally. Shale, dark-gray, laminated. Thickness: 270 - 420 feet.
			JAWBONE COAL	5-85	
			COUNCIL SANDSTONE MEMBER		
			TILLER COAL	0-41	Sandstone, siltstone, and coal. Sandstone, light- to medium-gray, medium-grained, thin- to thick-bedded, feldspathic and micaceous. Siltstone, medium-gray, laminated. Thickness: 220 - 340 feet.
	LOWER	LEE FORMATION, MIDDLESBORO MEMBER	UPPER QUARTZARENITE		Quartzarenite, very-light-gray to white, fine- to coarse-grained, medium- to very-thick-bedded with tabular cross-beds; quartz-pebble lenses common. Thickness: 150 - 200 feet.
			UPPER HORSEPEN COAL	7-10	
			WAR CREEK COAL	17-18	Siltstone, shale, sandstone, and coal. Siltstone, medium- to dark-gray, laminated, carbonaceous and micaceous. Shale, dark-gray. Sandstone, medium-gray, very-fine- to medium-grained, thin- to medium-bedded; quartz-pebble conglomerate lenses rare. Coal beds average 18 inches thick. Thickness: 430 - 730 feet.
			LOWER HORSEPEN COAL	18-19	
			LOWER QUARTZAERNITE		Quartzarenite, very-light-gray to white, fine- to coarse-grained, thin- to very-thick-bedded, cross-bedded; quartz-pebble conglomerate lenses common. Thickness: 150 - 200 feet.
		POCAHONTAS FORMATION	BURTONS FORD COAL	30-64	
			(POCAHONTAS #3)	29-340	Siltstone, sandstone, and coal. Siltstone, medium- to dark-gray, laminated, carbonaceous; abundant plant fossils, *Neuropteris pocahontas*. Sandstone, medium- to dark-gray, very-fine-grained, thin-bedded; micaceous. Very poorly exposed within mapped area. Thickness: approximately 300 feet.
MISSISSIPPIAN	UPPER	BLUESTONE FORMATION			Shale, siltstone, and sandstone. Shale, grayish-red, greenish-gray, and grayish-black; locally calcareous. Siltstone, medium-gray, very-thin- to thin-bedded, micaceous. Sandstone, medium- to dark-gray, very-fine-grained, thin- to medium-bedded; conglomeratic lenses locally present at base of sandstone. Thickness: approximately 500 feet.
		HINTON FORMATION	TALLERY SANDSTONE MEMBER		Quartzarenite, light-gray to pale orange, fine- to medium-grained, thick-bedded to massive, large-scale, low-angle cross-stratification pebbly conglomerate near base. Thickness: 40 - 100 feet.
			MIDDLE RED MEMBER		Siltstone, mudstone, shale, limestone, and sandstone. Siltstone, mudstone, and shale, light-gray in lower part and dark-gray to grayish-red in upper part. Mudstone, greenish-gray, calcareous; grades into dark-gray micritic limestone. Sandstone, light- to dark-gray, medium-grained, thin- to medium-bedded. Thin coal bed present near base of unit. Thickness: approximately 550 feet.
			STONY GAP SANDSTONE MEMBER		Sandstone, light-gray, fine- to medium-grained, tabular- to planar-cross-bedded, some beds contain small shale clasts; interbedded with medium-gray shale. Thickness: approximately 220 feet.
		BLUEFIELD FORMATION			Shale and siltstone, grayish-yellow to grayish-olive, laminated to thin-bedded; locally abundant brachiopods. Base of section truncated by faulting; less than 100 feet exposed northwest of St. Paul fault, St. Paul quadrangle.
MISSISSIPPIAN	LOWER	GREENBRIER LIMESTONE			Limestone, light- to medium-gray, thin-bedded to massive, micritic, locally abundant fossils; grayish-red, shaley limestone and calcareous shale are present in the upper part of the section. About 430 feet of section is exposed in the Sinkhole Valley syncline, Carbo quadrangle.
		MACCRADY AND PRICE FORMATION			Maccrady Formation: siltstone and shale. Siltstone, grayish-red to greenish-gray, very-thin- to medium-bedded. Shale, grayish-red, laminated to very-thin-bedded; interbedded with siltstone. Price Formation: siltstone, sandstone, and shale. Siltstone, light-olive-gray, thin- to medium-bedded. Sandstone, medium-gray, fine-grained, medium- to thick-bedded. Shale, greenish-gray, laminated to thin-bedded, interbedded with sandstone and siltstone. Thickness: approximately 200 feet.
DEVONIAN		CHATTANOOGA SHALE			Shale and siltstone. Shale, medium-gray to black, very-fine-grained, laminated to thin-bedded. Siltstone, medium-gray to grayish-yellow, thin-bedded. Dominantly shale in the lower portion, interbedded shale and siltstone in the upper portion. Approximately 1000 feet of section is exposed southeast of Weaver Creek fault, Carbo quadrangle.

SYSTEM and SERIES		FORMATION AND MEMBER			DESCRIPTION
SILURIAN		CLINCH SANDSTONE			Quartzarenite, white, medium- to coarse-grained; thick-bedded, cross-stratified, well-indurated, quartz-pebble conglomerate lenses locally present. Section truncated by faulting; approximately 75 feet of section exposed.
ORDOVICIAN	MIDDLE AND UPPER	ORDOVICIAN LIMESTONE FORMATIONS	RED LIMESTONE AND SHALE UNIT		Limestone, reddish-gray, yellowish-gray, and medium-gray, fine- to medium-grained, thin- to medium-bedded; shale interbeds common. Thickness: approximately 300 feet.
			NON-CHERTY LIMESTONE UNIT		Limestone, medium- to dark-gray, locally reddish-gray, fine- to coarse-grained, thin- to medium-bedded in the lower part, thin-bedded and flaggy in the upper part. Thickness: approximately 550 feet.
			CHERTY LIMESTONE UNIT		Limestone, light- to medium-gray, micrite and grainstone, fine- to coarse-grained, thin- to thick-bedded, contains abundant nodules of black chert. Thickness: approximately 430 feet.
		BLACKFORD FORMATION			Mudstone, limestone, and dolomite. Mudstone, grayish-red or greenish-gray, laminated to thin-bedded, calcareous. Limestone, yellowish-gray, fine-grained, thin-bedded, contains nodules of grayish-white chert. Dolomite, greenish-gray, very-fine-grained, laminated to thin-bedded, argillaceous, pebbly dolomite at base of unit. Thickness: 90 feet.
	LOWER	MASCOT AND KINGSPORT FORMATIONS			Dolomite, white to light-gray, some grayish-pink beds near the top of unit, very-fine- to coarse-grained and saccharoidal, thin- to medium-bedded; contains abundant white-weathering chert nodules. Thickness: approximately 1150 feet.
ORDOVICIAN / CAMBRIAN	LOWER / UPPER	CHEPULTEPEC AND COPPER RIDGE FORMATIONS			Dolomite and sandstone. Dolomite, light- to medium-gray, thinly laminated near base of section, medium- to dark-gray or grayish-brown, locally mottled higher in the section, very-fine- to medium-grained and saccharoidal, thin-bedded to massive; flat-pebble conglomerate beds common, petroliferous, white-weathering chert prominent in residuum. Sandstone, light-yellowish-brown (fresh) or moderate-brown (weathered), medium- to coarse-grained, thin- to medium-bedded; calcite cement readily leached by weathering, leaving a porous, friable quartz-sandstone residuum. Thickness: approximately 1200 feet.
CAMBRIAN	UPPER	MAYNARDVILLE LIMESTONE			Limestone, medium- to dark-gray, argillaceous-ribbon-banded. Thickness: 60 feet.
	MIDDLE	NOLICHUCKY FM.	UPPER SHALE UNIT		Shale, siltstone, and limestone. Shale, grayish-green to grayish-olive. Siltstone, yellowish-brown to grayish-orange, thin- to medium-bedded, locally glauconitic. Limestone, medium- to dark-gray, thin-bedded and shaley. Unit is dominantly shale. Thickness: 175 feet.
			MIDDLE LIMESTONE		Limestone, medium- to dark-gray, medium- to thick-bedded, locally argillaceous-ribbon-banded; section contains several flat-pebble conglomerate beds; grayish-olive shale interbedded with limestone. Thickness: 50 feet.
			LOWER SHALE UNIT		Shale, limestone, and siltstone. Shale, grayish-green to grayish-olive, interbedded with limestone. Limestone, medium-gray to dark-gray, thin-bedded and slabby or argillaceous-ribbon-banded, some beds contain glauconite, flat-pebble conglomerate beds common. Siltstone, yellowish-brown to grayish-orange, thin-bedded, interbedded with shale; some beds contain glauconite. Limestone constitutes about 50 percent of the section. Thickness: 290 feet.
		HONAKER FORMATION	UPPER LIMESTONE UNIT		Limestone, light-gray, very-fine-grained, thick-bedded in the lower portion, argillaceous-ribbon-banded in the upper portion. Thickness: southeast of the Honaker fault, about 220 feet. Unit thickens to the west; more than 500 feet of section is exposed in thrust sheets northwest of the Honaker fault (equivalent to Maryville Limestone).
			DOLOMITE UNIT	DOLOMITE	Dolomite and shale: dolomite, dark-gray to black, with pinkish tinge where fresh, medium- to coarse-grained, thick-bedded to massive; argillaceous-ribbon-banded limestone and mottled limestone-dolomite common northwest of the Honaker fault. Thickness: southeast of the Honaker fault, about 600 feet. Unit thins to the west; less than 200 feet of section is exposed in the western thrust sheets of Carbo and St. Paul quadrangles. Shale, greenish-gray, laminated to thin-bedded; thin beds of dolomite present locally; shale unit occurs near the middle of the dolomite unit. Thickness: southeast of the Honaker fault, 20 - 30 feet; 50 - 60 feet in western thrust sheets (equivalent to Rogersville Shale).
				SHALE	
				DOLOMITE	
			LOWER LIMESTONE UNIT		Limestone, light- to medium-gray, very-fine-grained, argillaceous-ribbon-banded in the lower portion, thick-bedded above, thin shale interbeds near the bottom of the section. Thickness: about 250 feet southeast of the Honaker fault; thickens to more than 300 feet in western thrust sheets (equivalent to Rutledge Limestone).
	LOWER	ROME FORMATION			Shale, siltstone, sandstone, dolomite, and limestone. Shale and siltstone, greenish-gray or grayish-red, thinly laminated to very-thin-bedded; mesoscopic folds present in most outcrops. Sandstone, greenish-gray, fine- to medium-grained, thin-bedded. Dolomite, dark-gray, fine- to medium-grained, massive. Limestone, light-gray, weathering to rusty-orange, argillaceous-ribbon-banded. Limestone and dolomite occur in discontinuous zones up to 50 feet thick, and constitute less than 30 percent of the section; structural complexity and poor exposure preclude tracing individual carbonate beds over large distances. In each outcrop belt of Rome Formation within the mapped area, the base of the unit is truncated by faulting; approximately 500 feet of section is exposed.