COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

GEOLOGY OF THE SALEM QUADRANGLE, VIRGINIA

ROGER V. AMATO

REPORT OF INVESTIGATIONS 37

VIRGINIA DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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GEOLOGY OF THE SALEM QUADRANGLE, VIRGINIA

by

ROGER V. AMATO[1]

ABSTRACT

The Salem quadrangle is located in Roanoke County, Virginia and is centered around the City of Salem. The quadrangle is underlain by rocks ranging in age from Precambrian to Early Mississippian with an aggregate thickness of at least 12,000 feet. However, these strata do not represent a complete sedimentary sequence as they occur in four imbricated thrust sheets.

The Blue Ridge thrust sheet on the southeast contains Precambrian metamorphic and Lower Cambrian clastic rocks which have been thrust over the Rome Formation. The Max Meadows thrust sheet consists wholly of Lower Cambrian Rome strata which have been tightly squeezed into a series of drag folds. The Salem thrust sheet contains Upper Cambrian Elbrook strata which are also tightly folded. The rocks northwest of the Salem fault range in age from Upper Cambrian to Mississippian. This thrust sheet includes the Catawba syncline and two complementary structures, an anticline and a syncline, to the southeast.

Crushed rock, sand, shale, and building stone have been quarried from the Salem quadrangle, although only shale and sand are currently produced for building materials. Potential mineral resources include sand and gravel, lightweight aggregate, and crushed stone.

INTRODUCTION

The Salem 7.5-minute quadrangle (Plate 1) is located in north-central Roanoke County in southwestern Virginia (Figure 1). It encompasses an area of approximately 58 square miles and is bounded by latitudes 37°15′ and 37°22′30″ north and by longitudes 80°00′ and 80°07′30″ west. The quadrangle is mainly in the Valley and Ridge physiographic province, except for a small part which lies in the Blue Ridge province.

Much of the mapped area is urban and suburban including the City of Salem, a small part of the City of Roanoke, and

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[1] Earth Satellite Corporation, Geosciences and Environmental Applications Division, Washington, D. C. 20006.

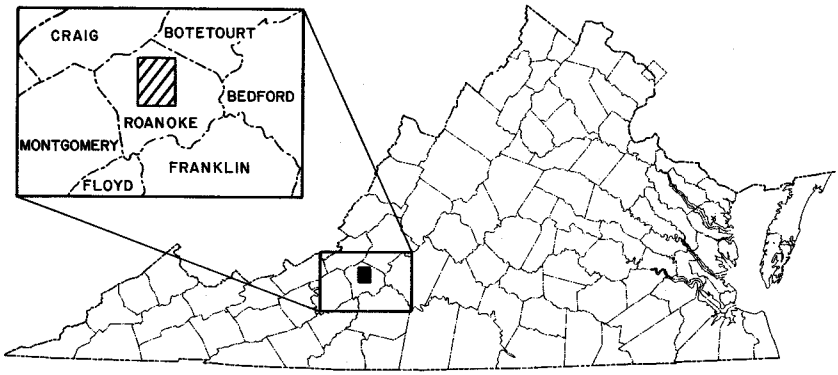

Figure 1. Index map showing location of the Salem quadrangle.

several small outlying communities. Most of the area is readily accessible from paved roads except for the mountainous northern and southern extremities, where dirt roads and trails provide limited access. Roanoke Valley comprises a wide central strip of the mapped area and serves as a funnel for transportation into southwestern Virginia. Interstate Highway 81, U. S. Highways 11 and 460, and the Norfolk and Western Railway are

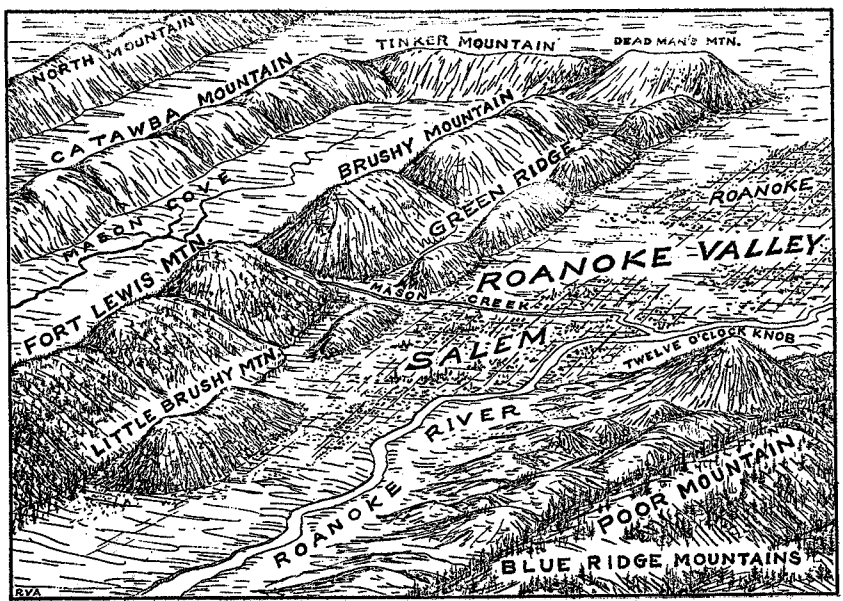

Figure 2. Northeastward view showing the physiographic features of the Salem quadrangle.

located along this valley. The chief north-south road in the Salem quadrangle is State Highway 311 which passes through Mason gap between Fort Lewis and Brushy mountains.

The major topographic features of the quadrangle (Figure 2) include Catawba Mountain, Fort Lewis Mountain, Brushy Mountain, Little Brushy Mountain, Green Ridge, Twelve O'Clock Knob, and the Roanoke Valley. The highest elevation of 3,082 feet is on a peak of Fort Lewis Mountain; the lowest elevation is slightly less than 960 feet where the Roanoke River leaves the area.

The crest of Fort Lewis Mountain averages about 2,900 feet while that of Brushy Mountain is somewhat lower, ranging from 2,000 to 2,300 feet. The two mountains are divided by a conspicuous gap through which Mason Creek flows toward its confluence with the Roanoke River several miles farther south. Fort Lewis and Brushy mountains are underlain by Mississippian and Devonian clastic formations of the Catawba syncline. Little Brushy Mountain lies south of Fort Lewis Mountain and is held up by Silurian sandstones which form the limbs of an overturned anticline. Although the highest point on Little Brushy Mountain is only 1,926 feet above sea level, it stands out as a prominent knob-like hill above the surrounding Roanoke Valley. Green Ridge begins about 2 miles northeast of Little Brushy Mountain and is held up by Silurian sandstones which are a continuation of the same anticlinal structure as that of Little Brushy Mountain. Twelve O'Clock Knob is a prominent feature of the Blue Ridge south of Salem and is held up by Lower Cambrian clastics and Precambrain metamorphic rocks. (Twelve O'Clock Knob is not labeled on Plate 1. Most of it is in the adjacent Bent Mountain quadrangle; however, its slopes extend for about 1 mile into the southwest part of the quadrangle.)

The Roanoke River flows eastward across the mapped area and drains all of it. The flood plain of the river averages about two-thirds of a mile in width and contains a thick veneer of alluvial fill. Roanoke Valley includes the river flood plain plus the wide, relatively level area on either side which is underlain by shales and carbonates of the Rome and Elbrook formations. The area north of the Roanoke River is drained by Horners Branch, Gish Branch, Mason Creek, and Peters Creek; the area to the south is drained by several small streams including Mill Creek.

It is estimated that only 5 percent of the bedrock in the Salem quadrangle is exposed. Colluvial deposits, which cover a significant part of the area, are notable along the lower slopes of Fort Lewis and Brushy mountains, Green Ridge, and Little Brushy Mountain, and on the northern slope of Twelve O'Clock Knob. Alluvial terrace deposits cover most of the surface adjacent to the Roanoke River including much of the City of Salem. Exposures of bedrock in the river channel indicate that it is presently a degrading stream. Most beds of the tributary streams contain deposits of sand, gravel, and boulders. Also, extensive urban and suburban development in the area has further covered rock outcrops. In general, the best bedrock exposures occur in the higher elevations of the mountains, along some of the deeper stream cuts, and in roadcuts.

The Salem area was mapped in reconnaissance by Butts (1933, 1940) for the geologic map of the Appalachian Valley of Virginia. Woodward (1932) included this area in his geologic survey of the Roanoke area. Latta (1956) discussed ground-water occurrence in the Roanoke-Salem district; however, his formation names and contacts were based on Woodward's (1932) report. Campbell and others (1925) named the Salem fault from exposures northwest of the city. Portions of the Salem quadrangle were also described in several unpublished theses. Field investigations for this report were done during the summer and fall of 1967.

The writer wishes to thank W. D. Lowry of Virginia Polytechnic Institute and State University who gave valuable suggestions concerning field work and text writing, C. G. Tillman for his assistance in fossil identification, and William Hazlett who assisted in field mapping and measuring stratigraphic sections. Appreciation is also due Carl Kuehn of the Virginia Department of Highways for providing drill-hole data from highway projects in the Salem area and to the Virginia Division of Mineral Resources and Earth Satellite Corporation for their assistance in preparing the text and maps for publication.

STRATIGRAPHY

PRECAMBRIAN ROCKS

Virginia Blue Ridge Complex

Greenish-gray, garnetiferous augen gneiss of Precambrian age is exposed on the eastern and northern slopes of Twelve O'Clock Knob where it constitutes the hanging wall of the Fries

fault (Plate 1). It has been thrust over the Unicoi Formation of Lower Cambrian age along the eastern slope and over the Rome Formation along the southeastern base of the knob. This unit lies in a belt of igneous and metamorphic rocks of Precambrian age that are shown on the geologic map of Virginia (Virginia Division of Mineral Resources, 1963) as the Virginia Blue Ridge Complex. Foliation in the gneiss has a northeasterly strike and a southeasterly dip of 10 to 30 degrees. The gneiss weathers to a dark-brown micaceous soil and forms few outcrops. It is best exposed along a road which forks to the left (when facing southward) from State Road 694 near the base of Twelve O'Clock Knob. Good exposures are also present along State Road 694 and in some of the deeper stream beds of Twelve O'Clock Knob. Diabase dikes cut the gneiss at several places, but were not mapped and are not shown on Plate 1.

CAMBRIAN SYSTEM

Units belonging to the Cambrian System in the Salem quadrangle include the Unicoi Formation, Rome Formation, Elbrook

Table 1.—Geologic formations in the Salem guadrangle, Virginia.

Age	Name	Character	Approximate thickness in feet
Quaternary	Alluvium	Clay, silt, sand, and small amounts of gravel.	0-30
	Terrace deposits	Coarse gravels, sand, and clay.	0-50
Mississippian	Price Formation	Tan to light-red, coarse-grained, arkosic sandstone; gray to dark-red shale containing some plant fossils. Cloyd Member: conglomerate composed predominantly of subangular to rounded pebbles, granules, and coarse grains of white quartzite, vein quartz, and some rock fragments (lower part).	500

Age	Name	Character	Approximate thickness in feet
Devonian	Chemung Formation	Gray and dark-brown, medium- to thick-bedded, fine- to medium-grained, fossiliferous and micaceous sandstone with interbedded dark-gray to olive shale; grayish-red conglomerate and dark-maroon red beds.	1000-1500
	Brallier Formation	Grayish-green shale and siltstone interbedded with gray and dark-brown, fine- to medium-grained sandstone; mostly olive- to dark-gray shale with thin beds of siltstone and fine-grained sandstone in lower part.	500-1500
	Millboro Shale	Dark-gray to black, fissile shale with interbedded medium-gray siltstone.	300-500
	Needmore Formation	Olive and brown, fissile, fossiliferous shale.	100-200
	Huntersville Formation	Light- to dark-gray chalcedonic chert with interbedded green glauconitic claystone and siliceous shale.	50±
Silurian	Keefer Sandstone	Mostly light-gray to white, medium- to thick-bedded, medium- to coarse-grained orthoquartzite; locally conglomeratic; thin beds of interbedded siltstone and shale.	125-185

Age	Name	Character	Approximate thickness in feet
Silurian	Rose Hill Formation	Light- to medium-gray, thin- to medium-bedded, medium- to coarse-grained orthoquartzite and dark-brown and maroon hematite-cemented sandstone with interbedded maroon to dark-green shale and light-gray to black siltstone; locally, pebble conglomerate.	45-85
	Tuscarora Formation	White to light-gray, medium- to thick-bedded, subangular to subrounded, medium-grained to conglomeratic orthoquartzite; coarse pebble conglomerate at base.	10-45
Ordovician	Martinsburg Formation	Mostly gray to tan shale and siltstone with grayish-green sandstone in upper part; mostly dark-gray and brown, calcareous shale with interbedded fossiliferous limestone in lower part.	200-1600
	Bays Formation	Olive-gray to brown, medium- to thick-bedded, fine-grained sandstone with interbedded grayish-green to dark-red and maroon siltstone and shale.	75-420
	Edinburg Formation	Gray to black calcareous shale and limestone; sparsely fossiliferous.	970±
—— ? —— Cambrian	Knox group	Light- to medium-gray, medium- to thick-bedded, fine-grained dolomite containing light-gray to white chert, dark-gray, thin-bedded limestone, and quartzose sandstone.	?

Age	Name	Character	Approximate thickness in feet
Cambrian	Elbrook Formation	Chiefly light-gray to dark bluish-gray, thin-bedded, fine-grained dolomite; some dark bluish-gray magnesian limestone and light-green to dark-gray shale; red shale rare.	1000±
	Rome Formation	Red, green. gray, purple, and buff shale and siltstone with interbedded light- to dark bluish-gray, thin- to medium-bedded limestone and dolomite; nodular black chert in some dolomite beds.	2000±
	Unicoi Formation	Medium- to thick-bedded conglomerate, conglomeratic and feldspathic sandstone, light-gray to tan quartzite, buff to gray siliceous shale, and amygaloidal basalt.	1600±
Precambrian	Virginia Blue Ridge Complex	Greenish-gray, garnetiferous augen gneiss.	?

Formation, and part of the Knox Group (Table 1). The Hampton and Erwin formations of the Chilhowee Group, which overlie the Unicoi Formation in the general region, do not crop out in the quadrangle. However, a thick sequence of shales and thin-bedded sandstones near the top of Twelve O'Clock Knob just south of the area may be part of the Hampton. Dietrich (1954) mapped both Hampton and Erwin strata along the flanks of Poor Mountain which lies to the southwest of the Salem area. The Shady Formation, which in normal succession in this general region of Virginia occurs between the Erwin and Rome formations, has not been identified in the Salem quadrangle and is interpreted to be absent due to faulting.

Unicoi Formation

The Unicoi is the only formation of the Chilhowee Group that is exposed within the mapped area. It crops out in the

southwest corner of the Salem quadrangle along the west and north slopes of Twelve O'Clock Knob, where it is well exposed along State Road 694 and also in some of the larger stream valleys near the base of the knob. The total thickness of the formation in the mapped area is not known as both its upper and lower limits are defined by thrust faults. Shufflebarger (1953), however, measured a thickness of 1,600 feet in the fault block along State Road 694 in the Salem and adjacent Bent Mountain quadrangles which was field checked by the writer (Appendix, Section 1).

The Unicoi Formation is composed chiefly of medium- to thick-bedded conglomerate, quartzite, feldspathic sandstone, thin-bedded siliceous shale, and amygdaloidal basalt. The conglomerate beds are a few inches to about 5 feet thick and are moderately coarse with grains averaging about 1 inch across. The quartzites are typically light gray and tan and fine to medium grained. The sandstones are medium to coarse grained, feldspar-rich, and locally grade into conglomeratic beds. The shales are buff to gray and contain thin, dark-gray and black laminae. Locally, cross-bedding and cut-and-fill structures are well developed in the sandstone and shale. In places the formation is veined with pure quartz. Several diabase dikes that cut the augen gneiss also cut the Unicoi but were not mapped and are not shown on Plate 1.

Rome Formation

The Rome Formation occurs in the southern half of the quadrangle as a wide northeasterly-trending belt. The outcrop width ranges from about 1 mile between Twelve O'Clock Knob and the Roanoke River to more than 3 miles near the eastern border of the map. The Rome is well exposed along State Road 639 south of its junction with State Road 760 along the western base of Twelve O'Clock Knob. The complete thickness of the formation in this area cannot be determined because the unit has been thrust northwestward over the Elbrook Formation by the Max Meadows fault and is overridden on the southeast by rocks of the Blue Ridge thrust sheet. Because this structural position persists regionally, little is known of the maximum thickness of the Rome in the Roanoke-Salem area; however, it is estimated to be about 2,000 feet thick in the Salem quadrangle.

The Rome is a heterogeneous formation composed of red, green, gray, purple, and buff shale and siltstone with interbedded limestone and dolomite. The shales and siltstones are fine-grained, fissile, and generally siliceous. Although the dark red shales are the most characteristic lithology, they constitute only about a third of the exposed formation. The red shale occurs with beds of green, gray, and buff shale and siltstone. Mudcracks and ripple marks are present on some bedding surfaces. The argillaceous beds are highly fractured at most outcrops and well-developed joint systems occur in places. Some of the fractures and joints are sealed with white calcite.

Limestone and dolomite compose at least a third of the Rome Formation in the mapped area and they closely resemble the carbonates of the younger Elbrook Formation. They are thin to medium bedded and where freshly exposed ranged from light to dark-bluish gray. Most are fine grained and where weathered they tend to be shaly. Nodules of black chert are present in some of the thicker dolomite beds. The limestone and dolomite beds are fractured and brecciated and contain numerous small calcite veins.

Several zones of tectonic breccia occur within the Rome Formation near the northern edge of the outcrop belt. These zones are associated with the Max Meadows fault along which Rome has been thrust over Elbrook strata. Cooper and Haff (1940) and Cooper (1970) noted that the breccia occurs as three basic types: a zone closest to the Rome Formation composed mainly of macerated shale and phyllite, an intermediate zone of crush conglomerate composed of subangular fragments of both Rome and Elbrook lithologies in a matrix of finely ground rock flour, and a third zone nearest to the Elbrook consisting chiefly of crushed and fractured blocks of limestone and dolomite (autobreccia). The best exposures of the breccia zones occur along parts of the southern bank of the Roanoke River in the western part of the quadrangle and at the junction of State Highway 117 (Peters Creek Road) and State Road 625 near the east margin of the map.

The Rome Formation is nonresistant and underlies the low and gentle topography in the south part of Roanoke Valley. The interbedded lithologies and the numerous drag folds and minor faults within the formation result in a characteristic topography consisting of long low ridges and hills with intervening valleys

both of which follow the strike of the beds. The Rome weathers readily to a reddish-brown soil which is usually full of small buff, gray, and pink shale chips. Some of the thicker carbonate beds locally form karst topography.

Elbrook Formation

The Elbrook Formation crops out in a wide northeasterly-trending belt near the center of the quadrangle. The Salem fault terminates the Elbrook belt on the north and the belt is terminated to the south by the Max Meadows fault. Exposures of the Elbrook in the area are generally poor; a few good exposures are (1) along the banks of the Roanoke River, (2) in the old Salem municipal quarry in North Salem, (3) along Mason Creek, and (4) around the water tower hill in the middle of Salem. As both the lower and upper boundaries of the Elbrook within the quadrangle are defined by thrust faults, the complete thickness of the formation is not known, but it is estimated to be about 1,000 feet or more.

The Elbrook Formation is made up chiefly of thin- to medium-bedded dolomite, but also contains some magnesian limestone and shale. The dolomite is fine grained and light- to dark-bluish gray. The thinner beds of dolomite are lighter in color and usually contain interbeds of shaly dolomite. The magnesian limestones are mostly dark-bluish gray and thicker than the dolomites. Most of the limestones in the Elbrook contain thin laminations of dolomite which tend to weather out as buff-gray crenulations in the darker limestone.

The shales in the formation range from light green to dark gray and are thin to medium bedded. They have little resistance to weathering and are rarely exposed. Most of the shale beds are highly fractured and in some places show fracture cleavage. Red shale similar to that found in the Rome Formation is present in the Elbrook along State Highway 419 near Dalewood Avenue.

Because of the thin-bedded and brittle nature of the rocks and their position between two major thrusts, the Elbrook strata are highly brecciated and deformed into folds cut by minor faults. Most of the thicker beds are highly brecciated and contain numerous small, calcite-filled fractures. The white veins in the dark-gray limestones and dolomites give the unit its characteristic appearance. Several zones of tectonic breccia (Cooper, 1970, p. 180) and crush conglomerate occur within

the unit near the trace of the Salem fault. The tectonic breccias in the Elbrook consist of angular to subrounded, crushed and sheared fragments of dolomite and limestone in a matrix of finely ground, calcareous rock flour. The size of the fragments varies greatly with pieces up to 10 inches across occurring in some zones. The best exposure of the breccia is in the Salem municipal quarry along State Road 631 about a half mile east of State Highway 311. A massive zone about 10 feet thick is present along the top of the southern wall of the quarry and several smaller zones occur near the base of the wall. These tectonic breccia zones are nearly always close to the leading edge of the Salem fault and seem to occupy definite stratigraphic horizons, most of which are between thick beds of limestone or dolomite. The quarry lies about 400 feet south of the trace of the fault.

The Elbrook Formation, which is relatively nonresistant to weathering, underlies much of the low topography of the Roanoke Valley. The numerous sinkholes and springs in the Elbrook belt indicate that considerable underground drainage exists. The formation weathers to a thick red residual soil composed mostly of clay. Some pieces of chalcedonic chert occur locally in the soil.

CAMBRIAN AND ORDOVICIAN ROCKS

Knox Group

The Knox group is present in a small, triangular fault slice along Interstate Highway 81 near the east boundary of the area. The slice of Knox is bounded on the north by a reverse fault and on the south by a probable southern branch of the same fault. Edinburg shale occurs in fault contact above and below the Knox.

The Knox group consists of light- to medium-gray, fine-grained dolomite with interbedded dark-gray limestone and quartzose sandstone. The dolomite is medium to thick bedded and contains thin interbeds and small nodules of light-gray to white chert. The limestones are generally thin bedded and contain thin laminations of more resistant dolomite which together weather to a straticulate pattern. Sandstone beds ranging in thickness from a few inches to about 2 feet are exposed along the road leading from Interstate Highway 81 to Loch Haven Club near the east edge of the map. The sandstones

are calcite-cemented and are very friable where weathered. The Knox weathers to a thick, light-brown soil which is strewn with small blocks of chert.

ORDOVICIAN SYSTEM

Edinburg Formation

The Edinburg Formation is exposed in the quadrangle in three belts: Catawba Valley in the northwestern corner, the Green Ridge belt, and the southern limb of the east-northeastward-trending syncline east from Little Brushy Mountain. The thickness of the formation in this area is indeterminable as the lower contact has been concealed by faulting. Woodward (1932, p. 48) gives a thickness of about 970 feet in Catawba Valley in the northwest flank of the Catawba syncline about 2 miles north of the Salem quadrangle; this is probably a reasonable estimate of the thickness in the Salem area.

The Edinburg Formation consists of gray to black calcareous shale and limestone, which is the Liberty Hall unit of Cooper and Cooper (1946, p. 78). The lower part is predominantly dark-gray, sparsely fossiliferous shale whereas the upper part is thin-bedded, argillaceous limestone. Most exposures exhibit fracture cleavage which attests to the incompetence of the unit under deforming stresses. The cleavage appears to be of the axial-plane type and in most places has dips of 50 to 60 degrees to the southeast. The rocks are so highly fractured in some places that the bedding is hardly discernible. Many of the larger fractures are filled with white calcite.

Relatively fresh exposures of the Edinburg appear to be thick bedded or massive; however, weathering tends to show up its true thin-bedded character. Outcrops of the formation generally weather to light gray or chocolate brown whereas its residual soil is usually light brown and contains numerous small, gray or tan shale chips.

Bays Formation

The Bays Formation crops out in four roughly parallel belts in the quadrangle (Plate 1) : along the northern foot of Catawba Mountain, along the foot of Green Ridge, and on the northern and southern flanks of the east-northeastward-trending syncline east from Little Brushy Mountain. The outcrop pattern of the

Bays serves as a key in the delineation of the structure between the Salem fault and the Catawba syncline.

The thickness of the Bays Formation differs considerably within the area. The Green Ridge belt ranges from about 75 to 150 feet thick, but the Bays is not exposed for about 3 miles along this belt because of faulting. Thickness in the syncline east from Little Brushy Mountain ranges from about 200 feet on Little Brushy Mountain to 420 feet in the northwest flank of the syncline near the east border of the area. At least some of the variations in thickness are due to repetitions and deletions of strata by minor folding and faulting. Some of this structural disturbance is evident in exposures near Hanging Rock and along Interstate Highway 81 between State Highway 311 and State Road 705.

The Bays Formation consists largely of olive-gray to brown sandstone with interbedded siltstone and shale. Where exposed, the base of the formation is a coarse-grained sandstone that is locally conglomeratic. Medium- to thick-bedded, fine-grained sandstones are the predominant lithology. The sandstones are commonly argillaceous and show numerous small spots of brown limonite on freshly broken surfaces. Some of the sandstone beds are slightly calcareous. The siltstones and shale in the Bays range in color from grayish green to dark red and maroon. Most of the siltstone beds tend to occur in the lower half of the formation. Some contain thin interbeds of bentonite. Hergenroder (1966, p. 31) noted at least four bentonite horizons in the upper part of the formation. The dark red and maroon siltstones are the most conspicuous lithology in the outcrops and tend to occur near the bottom and top of the formation. Some of the siltstones are sheared locally, showing a crude fracture cleavage.

Martinsburg Formation

The Martinsburg Formation is present in three parallel northeasterly-trending belts. The wider and thicker belt forms the trough of the syncline east of Little Brushy Mountain; the second lies in the Green Ridge belt north of the syncline, and the third lies along the north flank of Catawba Mountain. The thickness of the formation differs greatly in this area. A continuously exposed, but probably incomplete, section from the top of the Bays to the base of Silurian sandstones crops out

along State Highway 116 near Hanging Rock; it is only about 200 feet thick. Nichol (1959) measured a total of 1,594 feet of Martinsburg along State Highway 311 on the northwest slope of Catawba Mountain.

The Martinsburg Formation consists of calcareous shale, siltstone, sandstone, and limestone. The lower part is mainly dark-gray and brown calcareous shale with closely spaced interbeds of fine- to coarse-grained limestone. The limestone beds range in thickness from about 1 to 10 inches. Thin beds tend to be coarsely crystalline and fossiliferous whereas the thicker beds are finer grained and argillaceous. Some of the limestones are almost entirely "fossil hash" and contain a rich fauna of brachiopods, bryozoans, and trilobites.

The upper part of the Martinsburg Formation consists mostly of gray to tan shales and siltstones with grayish-green sandstones. The sandstones become increasingly more abundant toward the top of the sequence and are generally unfossiliferous. Some of the siltstones and shales adjacent to the Salem fault are highly sheared even to a point where bedding is unrecognizable. Many of the fractures in the thicker beds of shale and limestone have been sealed with white calcite.

The Martinsburg Formation is the most fossiliferous unit within the mapped area. Much of the formation was mapped by the occurrence of shale chips which show a profusion of fine-ribbed brachiopods and bryozoans on their weathered surfaces. The well known uppermost Martinsburg marker horizon, the *Orthorhynchula* zone, was not identified in any of the exposures in the area.

SILURIAN SYSTEM

Tillman (1963) used the names Tuscarora, Rose Hill, and Keefer for the Silurian formations on the northwest limb of the Catawba syncline, and Hazlett (1968) applied these names to the Green Ridge section that is exposed at Carvins Cove dam about 2.5 miles east of the Salem quadrangle. The writer examined the outcrops on the northwest limb of the Catawba syncline along State Highway 311 and in the Carvins Cove sections and believes the three Silurian lithologies correlate well with those that are exposed along Mason Creek near Hanging Rock (Appendix, Section 2). Thus, the names Tuscarora Formation, Rose Hill Formation, and Keefer Sandstone are used in this report (Table 1).

The Silurian sandstones crop out in three belts in the quadrangle (Plate 1): the thickest section occurs along Catawba Mountain where it forms part of the northeast flank of the Catawba syncline; the Green Ridge belt is an overturned succession that forms part of the southeast flank of the Catawba syncline; and a short belt caps Little Brushy Mountain. The three Silurian formations are traceable along Green Ridge to Hanging Rock, where complex faulting appears to have both offset and deleted part of the sequence. As no Rose Hill beds were found west of Mason Creek, the sandstones in the western part of the Silurian belt are either Tuscarora or Keefer. The presence of a persistent coarse basal conglomerate in the western Green Ridge section hints that this may be Tuscarora whereas the unit capping Little Brushy Mountain which lacks this conglomerate may be Keefer. For mapping purposes the Tuscarora and Rose Hill formations are combined as a single map unit, and the Keefer is mapped as a single unit with the younger Huntersville Formation.

Tuscarora Formation

The Tuscarora is 9 feet thick at Hanging Rock and Nichol (1959) measured 44 feet of the formation along State Highway 311 atop Catawba Mountain just north of the Salem quadrangle. Hazlett (1968) noted a thickness of 18 feet at Carvins Cove dam about 2.5 miles east of the quadrangle.

The Tuscarora Formation is a white to light-gray, medium- to thick-bedded orthoquartzite. The unit ranges in texture from a coarse conglomerate to a medium-grained sandstone and consists almost entirely of subangular to subrounded quartz grains. A coarse pebble conglomerate occurs at the base; it contains clasts which measure more than 1 inch in longest dimension. Several local interbeds of conglomeratic sandstone were also noted. Locally, the formation exhibits cross-lamination. Although this is one of the more structurally competent units in the area, it is highly jointed and sheared with fracture cleavage developed locally near its base. Also, large slickensided areas that are well exposed at Hanging Rock attest to the possibility that at least part of the unit has been removed by faulting. This faulting probably accounts for the variable thickness of the formation in the southeast limb of the Catawba syncline. The Tuscarora weathers to a gray sandy soil and

its outcrop belts are characteristically strewn with large blocks of sandstone. Much of the colluvial material found along the slopes of Green Ridge was derived from this formation.

Rose Hill Formation

The distribution of the Rose Hill Formation in the area is considerably more limited than that of the Tuscarora and Keefer formations. It is well exposed at Hanging Rock where a 45-foot thickness was measured (Appendix, Section 2). Tillman (1963) lists 83 feet of Rose Hill in the Catawba Mountain section (Catawba quadrangle) and Hazlett (1968) lists 43 feet at Carvins Cove (Roanoke quadrangle).

The Rose Hill Formation consists of thin- to medium-bedded orthoquartzites and hematite-cemented sandstones with interbedded shales and siltstones. The orthoquartzites are light to medium gray and generally medium to coarse grained, locally grading into pebble conglomerates. The hematite-cemented beds are dark brown and maroon, thin, and medium grained. The interbeds of shale are varicolored, ranging from maroon to dark green, and make up about one-fourth of the formation. Thin beds of light-gray to black siltstones also occur. The Rose Hill Formation is less resistant than both the underlying Tuscarora and overlying Keefer sandstones, and where present, forms a small notch in the ridges that are held up by the Silurian clastics. The Rose Hill forms a grayish-brown soil which yields small pieces of hematite-cemented sandstone.

LOWER DEVONIAN AND MIDDLE SILURIAN ROCKS

The Keefer Sandstone (Middle Silurian) and the overlying Huntersville Formation (Lower Devonian) are combined as a single map unit, Lower Devonian and Middle Silurian rocks (Plate 1). An important break occurs in the quadrangle between the two formations. This hiatus is present throughout most of the Catawba syncline, although probable Keyser Formation (Upper Silurian and/or Lower Devonian) and Ridgeley Sandstone (Lower Devonian) crop out in adjacent quadrangles (mainly in the northwest limb of the syncline). Tillman (1963) described 10 feet of probable Keyser unconformably overlain by 30 feet of Ridgeley Sandstone or Rocky Gap Sandstone along State Highway 311, 0.4 mile north of the Salem quadrangle near the southeast base of Catawba Mountain; however, none was found in the mapped area.

Keefer Sandstone

The Keefer Sandstone is best exposed along Mason Creek near Hanging Rock where a 128-foot section was measured (Appendix, Section 2). Tillman (1963) lists 184 feet of Keefer along State Highway 311 on the southeast slope of Catawba Mountain (Catawba quadrangle), and he used quotation marks around the name because the unit is much thicker there than at its type locality and probably spans a greater time interval than the type Keefer. Hazlett (1968) measured 260 feet of the formation at Carvins Cove dam (Roanoke quadrangle).

The Keefer Sandstone consists mostly of medium- to coarse-grained, light-gray to white orthoquartzite that is medium to thick bedded with local cross-lamination. Many of the bedding planes are coated with a brown limonitic stain. Thin beds of light-gray siltstone and shale are interbedded with the thicker sandstone in the unit. Some of the sandstones are locally conglomeratic with clasts up to half an inch across. The thicker beds in the formation tend to be highly jointed and fractured. Weathered exposures of the Keefer usually are tan or light orange.

Huntersville Formation

The Huntersville Formation consists of light- to dark-gray chalcedonic chert with interbeds of green glauconite-rich claystone and siliceous shale. The chert is medium to thin bedded, although much of it occurs in knotty beds of irregular thickness. The glauconite beds are only a few inches thick and are rarely seen in weathered outcrops. A temporary excavation northeast of the junction of Interstate Highway 81 and State Road 619 exposed at least three glauconitic interbeds. Small green chips in the Huntersville soil, however, indicate that such beds probably are fairly continuous in the formation. A few thin beds of gray and tan siliceous shale were also noted between some of the thicker chert beds. The formation averages about 50 feet in thickness. Outcrops of the Huntersville are usually stained dark brown, and the formation weathers to gray, clay-rich soil containing numerous chert fragments.

DEVONIAN SYSTEM

Needmore Formation

The Needmore Formation is combined with the overlying Millboro Shale as a single unit for mapping purposes. The

Needmore is exposed on the northwest flank of the Catawba syncline along State Highway 311 where the Millboro appears to conformably overlie it. The Needmore is poorly exposed in the Salem quadrangle and crops out only in a few stream cuts and along State Highway 311 at Mason Cove. The Needmore occurs in a thin belt along the south base of Fort Lewis and Brushy mountains and in a wide belt in Mason Cove along the southern base of Catawba Mountain. It ranges in thickness from about 100 to 200 feet. The Needmore Formation consists of olive and brown, fissile, fossiliferous shales. The formation weathers to a light-brown clay soil containing abundant shale chips.

Millboro Shale

The Millboro Shale is poorly exposed in the Salem quadrangle and crops out only along State Highway 311 at Mason Cove and in a few stream cuts. It occurs along the southern bases of Fort Lewis, Brushy, and Catawba mountains. The formation is about 300 to 500 feet thick.

The Millboro Shale consists of dark gray to black, fissile shale with a few medium-gray, interbedded siltstones. It is mostly noncalcareous and pieces cleave readily into thin, shiny, black plates. The black shale weathers rapidly to light-gray and yellow shale chips which are abundant in the Millboro residual soil.

Brallier Formation

The Brallier Formation is present in two wide belts along the flanks of Fort Lewis and Brushy mountains, where it is estimated to range from about 500 to 1,500 feet in thickness. The formation is well exposed at Hanging Rock along State Highway 311 where the beds are overturned and in fault contact with the Chemung Formation. Although this fault is not well exposed elsewhere, it appears likely that it is responsible for the abbreviated thickness of the Brallier along the south flank of the Catawba syncline.

The Brallier Formation consists of a thick sequence of sparsely fossiliferous grayish-green shales and siltstones interbedded with gray and dark-brown sandstones. The lower part of the formation is mostly olive- to dark-gray, micaceous shale with some thin beds of siltstone and fine-grained sandstone. The sandstones are fine- to medium-grained, dark-colored gray-

wackes or subgraywackes. In general the sandstones become more abundant in the middle and upper parts of the formation. The Brallier erodes to a series of small, linear hills that are well expressed on aerial photographs. The formation weathers to a soil that is littered with orange to grayish-brown, silty shale chips.

Chemung Formation

The Chemung Formation crops out in a wide belt along the upper slopes of Fort Lewis and Brushy mountains, and is well exposed along Mason Creek and State Highway 311 in the water gap that divides these two ridges. It is estimated to be approximately 1,000 to 1,500 feet thick.

The Chemung Formation consists mostly of gray and dark-brown fossiliferous sandstones with interbedded dark-gray to olive shales. Grayish-red conglomerate and dark-maroon red beds crop out in the upper part of the section. The lower gradational contact with the underlying Brallier Formation was placed where thin-bedded shale, siltstone, and sandstone changed to medium- and thick-bedded shale, siltstone, and sandstone. The lower part of the formation is thinner bedded and more shaly with sandstones increasing in number and thickness toward the top. The fossil-rich beds are calcareous and range in thickness from several inches to about 2 feet. The sandstones are generally micaceous and fine- to medium-grained, although they contain some thin layers of pebble conglomerate which occurs locally as scour fillings. The formation is medium to thick bedded and many of the thicker sandstones near the top show abundant cross-bedding.

MISSISSIPPIAN SYSTEM

Price Formation

The Price Formation is exposed on the northwest flank of the Catawba syncline where its outcrop belt forms the dip slope along part of the southeast side of Fort Lewis and Brushy mountains. The quartzose sandstones and conglomerates in the formation make it one of the best ridge-formers in the area. It is well exposed along many of the dirt roads and fire trails on the crests of Fort Lewis and Brushy mountains. The maximum thickness of the unit in the area is about 500 feet; much of the upper part has been removed by erosion.

The Price Formation is largely nonmarine conglomerates, sandstones, and shales. The basal Cloyd Member, 5 to 30 feet thick, is a conglomerate composed predominantly of subangular to rounded pebbles, granules, and coarse grains of white quartzite, vein quartz, and some rock fragments in a clay matrix. The average size of the pebbles is about 1 inch in diameter, but cobbles as large as 3 inches across were noted. The Cloyd conglomerate grades upward to coarse-grained, arkosic sandstones and shales. The sandstones are medium to thick bedded and range from tan to light red. Cross-bedding is abundant in many of the thicker sandstone beds. The shales are gray to dark red and occur in relatively thin layers. Plant fossils were noted in some of the shale beds. The formation weathers to a thin, light-brown, sandy soil which is strewn with large sandstone blocks. The Price and Chemung formations are the source of most of the colluvium which covers the lower slopes of Fort Lewis and Brushy mountains.

QUATERNARY SYSTEM

More than 95 percent of the bedrock of the Salem quadrangle is covered by deposits of residual soil, alluvium, and colluvium of Quaternary and possible Tertiary age. The residual soils are best developed over carbonate bedrock such as limestone and dolomite in the Rome and Elbrook formations. The carbonate residuum is commonly over 50 feet thick, although the thickness may vary considerably in a small area. The residual soils are thinnest over sandstones and quartzites (0 to 5 feet) and somewhat thicker over shales (0 to 20 feet).

Colluvium is present along the slopes of all ridges which are capped by sandstone or quartzite. Some of the larger colluvial deposits such as those along the slopes of Twelve O'Clock Knob and Fort Lewis Mountain are at least 50 feet thick and extend beyond the topographic base of the mountain. The colluvium is composed mainly of coarse gravel and angular cobbles in a matrix of fine sand and clay, although subangular boulders 1 to 6 feet in diameter are common.

Alluvial deposits composed of large water-worn boulders occur along most of the Roanoke Valley and along the valleys of most of the major streams in the quadrangle. These deposits are mapped as *Alluvium* and *Terrace Deposits*.

Terrace Deposits

The older terraced alluvial deposits (Figure 3) are mainly along the higher elevations of the Roanoke Valley and along Mason Creek. At least three distinct terraces can be recognized

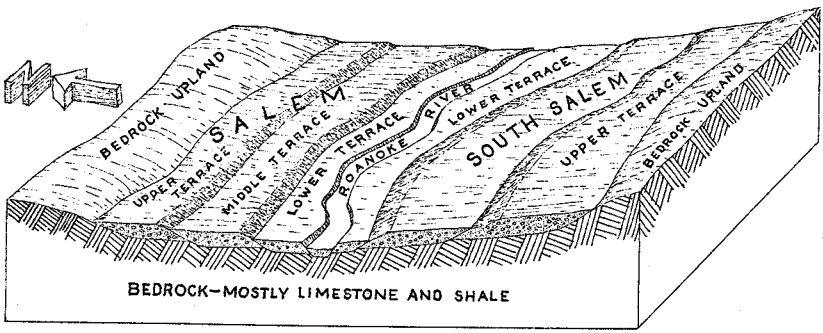

Figure 3. Block diagram showing the development of alluvial terraces along Roanoke River in the Salem area.

on both the north and south sides of the Roanoke River; a lower terrace adjacent to the river and tributary streams and middle and upper terraces were mapped as one unit (Plate 1). The terraced alluvial deposits are much coarser than the flood-plain alluvium and contain thick lenses of gravel in a matrix of silt and clay.

Alluvium

The alluvium includes present channel and flood-plain deposits, and alluvial-fan deposits. The present river and stream-channel deposits are predominantly silt and sand with scattered gravel-bar deposits. Periodic floods alter these deposits and add considerable amounts of sediment and debris to the lower elevations along the river and larger streams. Thickness of the alluvial deposits ranges from a few feet to a maximum of 30 feet. Twelve feet of alluvium was measured in a water well drilled in Salem near the junction of State Roads 630 and 631 (W. D. Lowry, personal communication, 1968).

STRUCTURE

BLUE RIDGE THRUST SHEET

Poor Mountain and Fries Faults

Two distinct faults occur in the Blue Ridge thrust sheet in the mapped area—the *Poor Mountain fault,* along which clastics

of the Lower Cambrian Unicoi Formation have been thrust northwestward over the younger Rome Formation, and the *Fries fault,* along which Precambrian metamorphic rocks have been thrust over the Unicoi and Rome formations (Plate 1). The Blue Ridge sheet occurs only in the southwestern corner of the quadrangle where it forms the northern tip of a prominent salient. The trace of the Poor Mountain fault bounds the northwest side of this salient and the Fries fault trace bounds the northeast side. The structure of the Blue Ridge thrust sheet in the mapped area is anticlinal and is probably a northeastern continuation of the Poor Mountain anticline from the south.

The Poor Mountain fault extends eastward from its type area in the adjacent Bent Mountain quadrangle along the base of Poor Mountain to just south of the mapped area, where it abruptly swings northward to form the salient around the northwest side of Twelve O'Clock Knob. Rocks of the Unicoi Formation form the sole of the thrust within the quadrangle. The trace of the fault is very sinuous because of the low dip of the fault plane (5 to 10 degrees southeastward) and the deeply dissected topography of the overthrust Unicoi rocks. Much of the fault is covered by colluvial deposits on the lower slopes of Twelve O'Clock Knob and detailed mapping of the trace is difficult. However, in places where the fault is exposed, such as along Mill Creek and several other small streams which drain Twelve O'Clock Knob, the fault contact is marked by a wide zone of breccia. This tectonic breccia is for the most part brecciated quartzite which has been recemented by limonite. Limonite-rich zones occur locally in the brecciated rock and some have been prospected on the western slope of Twelve O'Clock Knob.

The Fries fault extends from its type area in Grayson County, Virginia, to the south base of Poor Mountain and Twelve O'Clock Knob (Dietrich, 1954). At the north base of the knob (Plate 1), the trend of the fault trace abruptly changes from a northerly to a southeasterly direction where it forms the northeast side of the Blue Ridge thrust sheet in this area.

Where the Fries fault separates Precambrian gneiss from Rome shale on the north, the fault surface is nearly flat. However, where the fault separates the gneiss from Chilhowee rocks, as along the east side of Twelve O'Clock Knob, the fault

surface appears to be steep. The contact between the gneiss and the Unicoi is not well exposed and the degree of deformation along the fault zone is not known within the mapped area.

MAX MEADOWS THRUST SHEET

Max Meadows Fault

The Max Meadows thrust sheet is bounded on the northwest by the Max Meadows fault and on the south by the Poor Mountain and Fries faults. Only the Rome Formation is exposed in the sheet, which has been thrust northwestward over the Elbrook Formation of the Salem thrust sheet. As the Elbrook overlies the Rome in the stratigraphic succession in the mapped area, the stratigraphic displacement of the Max Meadows fault is relatively small. However, low dip of the fault plane and a zone of tectonic breccia along the leading edge of the fault suggest considerable horizontal movement. The Max Meadows sheet is broken by a series of small imbricate faults which repeat the strata in the sheet.

The Max Meadows fault extends across the Salem quadrangle in a northeasterly direction from the point where the Roanoke River enters the area on the west. The trace of the fault extends aong the south edge of the river valley to a point in the community of South Salem from which it continues across the river and the City of Salem. Between Mason Creek and the east edge of the map the fault trace swings northward to form a small salient which coincides with a smaller northward bulge of the Salem fault trace.

Because of the poor exposure and similarity of lithologies of the hanging wall and footwall of the fault, the trace is difficult to locate accurately. A zone of tectonic breccia and crush conglomerate is exposed at the leading edge of the fault in places along the Roanoke River in the western part of the area and at the intersection of State Highway 117 and State Road 625 near the eastern border of the map. The fault trace is obscure between Roanoke River and Mason Creek where urban development has covered most of the bedrock exposures.

At the northernmost extension of the Blue Ridge thrust sheet, the exposed Max Meadows sheet is about 1 mile wide whereas near the east edge of the Salem quadrangle it is about 4 miles wide. The Rome beds have a northeasterly to easterly strike and mainly a southeasterly dip. Cross laminations and

other primary features indicate that most of the beds in the Max Meadows thrust sheet are right side up, especially those near the leading edge of the fault. The strata in this sheet are highly deformed into a series of tight drag folds which are broken in places by small reverse faults. Most of the larger folds are synclinal with the adjacent anticlinal limbs broken by fault and fracture zones. Some of the folds are steeply overturned to the northwest. The fold axes appear to follow the strike of the fault trace, bending from a northeasterly strike along Roanoke River to an easterly strike between Salem and the east edge of the map. The reverse faults and fracture zones also parallel the fold axes. The large number of these faults in the Max Meadows thrust sheet suggest that it may consist of a series of small imbricated fault blocks which have repeated the Rome Formation over the entire width of the major thrust sheet. This repetition may account for the unusually wide belt of the Rome which is estimated to be about 2,000 feet thick in this area.

SALEM THRUST SHEET

Salem Fault

Campbell and others (1925, p. 276) named the Salem fault for exposures north of Salem where the Elbrook Formation has been thrust northwestward over formations ranging in age from Middle Ordovician to Late Devonian. The Salem thrust sheet is bounded on the north by the Salem fault and on the south by the Max Meadows fault. Exposures of the Salem sheet in the quadrangle contain only the Cambrian Elbrook Formation, but younger formations crop out in the block in places both to the east and west of this area. The Elbrook is highly brecciated in most places near the leading edge of the fault and several zones of tectonic breccia occur in the formation. This breccia is well exposed in the old Salem municipal quarry on State Road 631. Geopetal evidence noted in the area indicates that the beds, including primary structures exposed in the Elbrook along the Roanoke River, Gish Branch, just east of State Road 117, and along State Road 419, in the Salem thrust sheet are not overturned. The fault overrides the Edinburg Formation in the eastern part of the mapped area and rapidly picks up stratigraphic displacement to the west. The youngest unit overridden by the fault is the Brallier Formation of Devonian age.

In its type area the Salem fault is undoubtedly a low-angle thrust. In 1967 the City of Salem drilled a test water well along Mason Creek near the junction of State Roads 630 and 631. The drill site was 530 feet south and 12 feet higher in elevation than the leading edge of the fault exposed in the creek. W. D. Lowry (personal communication, 1968) reports the following well information:

Overburden	0-12 feet
Elbrook dolomite	12-369 feet
Black shale, probably Edinburg Formation	369-410 feet
Dolomite, probably Elbrook	410-428 feet
Black shale, Edinburg Formation	428-456 feet

From this data, the angle of dip of the Salem fault in this area was calculated to be 38°. The black shale encountered between 369 and 410 feet is believed to be a slice of the Edinburg which was picked up during faulting and the main fault plane probably occurs at the 428-foot depth. The calculated dip of the fault is only a few degrees less than the dip of the Elbrook beds along Mason Creek and elsewhere along the fault trace, indicating that the Salem fault in this area is essentially a bedding plane thrust.

AREA NORTH OF SALEM FAULT

Catawba Syncline

The Catawba syncline is one of the largest synclinal folds in the Virginia part of the Appalachians, extending from near Blacksburg northeast to the vicinity of Fincastle, a distance of about 35 miles. Its width ranges from 6 to almost 8 miles. The syncline plunges steeply at both ends and is highly asymmetric with the southeast flank overturned along most of its length. The Catawba syncline includes all the strata in about the northern half of the quadrangle.

The northwest limb of the syncline north of the Salem quadrangle is bounded by the Pulaski fault of Butts (1933). The southeast limb in the mapped area is truncated by a fault just southeast of Green Ridge. Several other high-angle reverse faults further complicate this southeast limb. The Martinsburg Formation is abnormally thin and appears to be faulted over the Silurian rocks. The Millboro and Needmore formations are in probable fault contact with the Brallier

Formation, and the lower part of the Brallier has been thrust over Chemung strata. The oldest unit in the syncline in the mapped area is the Edinburg Formation (Middle Ordovician) and the youngest strata belong to the Price Formation (Lower Mississippian).

The strata exposed in the Catawba syncline in this area generally strike about N. 60° E. except at a point midway between Little Brushy Mountain and Hanging Rock, where the strike bows gently southward to form a small recess. Near Hanging Rock the strike continues in a northeasterly direction. The irregular trend of the axial trace of the syncline is probably the result of differential lateral compression during the folding of the structure. The oldest strata exposed on the northwest flank belong to the Elbrook Formation. The total stratigraphic thickness within the syncline is about 14,000 feet.

Hanging Rock Area

A high-angle reverse fault with a small stratigraphic displacement occurs between the Brallier and Chemung formations in at least part of the Salem area. The fault is well exposed on the west side of State Highway 311 just north of its junction with State Highway 116 at Hanging Rock. Woodward (1932) mapped this fault as a northern branch of the Salem fault which bifurcated from the main Salem fault near the northwest corner of Little Brushy Mountain. His map shows the fault extending in a northeasterly direction to about 4 miles east of Hanging Rock. Butts (1933) interpreted this same fault as originating from the Salem fault several miles to the southwest of Little Brushy Mountain and continuing eastward through Hanging Rock to about the same terminal point as that of Woodward (1932).

The good exposure of the fault at Hanging Rock is actually a zone of intense faulting, warping, and brecciation approximately 400 feet wide. The zone begins in the nearly vertical sandstones and shales of the Brallier Formation which become tightly folded and sheared. In places the less competent shales appear to have been squeezed into the cores of small tight folds in the thicker sandstone beds. The footwall of the fault is made up of thick-bedded sandstones in the Chemung Formation which are much less deformed. North of the fault zone, the overturned Chemung beds change to a normal northwest dip and then to horizontal at the trough of the Catawba syncline.

The fault is difficult to trace either east or west of the Hanging Rock exposure. Most of the contact between the Brallier and Chemung formations is covered by colluvial debris along the lower slopes of Fort Lewis Mountain. A few exposures along some of the deeper stream cuts west of Hanging Rock show some structural complexity, but they are considerably smaller than the zone at Hanging Rock. The main criterion for continuing the fault to the west was the narrow width of the Brallier outcrop belt. The Brallier in the northwest flank of the Catawba syncline is at least 1,500 feet thick whereas it is ony about 600 to 1,000 feet thick along the southeast limb in this area.

Little Brushy Mountain—Green Ridge Area

An anticline extends from along the southeast base of Green Ridge southwesterly to just north of Little Brushy Mountain. It is an intermediate fold between the Catawba syncline and the syncline that extends northeasterly from Little Brushy Mountain. The anticline is overturned to the northwest and its limbs are separated by a northeastward-trending fault. The axis of the fold is irregular and at the west end of Little Brushy Mountain the fold turns sharply to the south and plunges under the Salem fault.

The oldest exposed unit in the fold is the Edinburg Formation (Middle Ordovician), although it is possible that the fault slice of Knox group at the eastern edge of the map may be part of the anticline. The youngest strata in the anticline belong to the Chemung Formation (Upper Devonian). Probably the most puzzling feature of this structure is the relative thinness of its constituent formations. The same units that crop out in the northwest limb of the Catawba syncline are considerably thicker, as are the Bays and Martinsburg in the syncline extending northeast from Little Brushy Mountain. These thinned strata may be due to partial erosion of a small persistent positive area between two basins of deposition or they may be the result of deletion by faulting. It is possible that several high-angle reverse faults, parallel to the strike of these formations, were developed during the tight folding of the anticline and that the planes of these faults form the actual contacts of the thinner rock units. The high-angle reverse fault that extends along the axis of the fold either dies out in Lower Devonian shales west of Little Brushy Mountain or continues southwestward under the Salem thrust sheet.

Another high-angle reverse fault extends from the western side of Little Brushy Mountain to the vicinity of Hanging Rock. The fault either terminates in the small structural complex near the southwest corner of Little Brushy Mountain or continues southwestward under the Salem thrust sheet. It appears to extend in a northeasterly direction from Little Brushy Mountain to near the intersection of Interstate Highway 81 and State Highway 311. The fault probably dies out in the Edinburg shales east of State Highway 311, or it may merge with the fault at the south base of Green Ridge.

Between State Road 705 and State Highway 311 the fault has moved a small anticlinal fold that is developed in the Bays and Edinburg formations over the northwest limb of the north-northeasterly-trending syncline east of Little Brushy Mountain. On Little Brushy Mountain, the fault has moved moderately southeastward-dipping strata of Upper Ordovician and Silurian age on the hanging wall over similar age strata which have a very low southeasterly dip. The location of the fault is uncertain from Little Brushy Mountain to State Road 705 as both the hanging wall and footwall are in the Martinsburg Formation.

A syncline extends in a northeasterly direction across the central part of the map area from the west edge of Little Brushy Mountain to a point about 2 miles east of the quadrangle. West of Little Brushy Mountain, the syncline is presumably covered by overthrust strata of the Salem fault. The youngest strata exposed in the axial portion of the syncline belong to the Martinsburg Formation except on Little Brushy Mountain, where Silurian and Lower Devonian rocks overlie the Martinsburg on the northwest limb. The oldest unit in the syncline is the Edinburg Formation of Middle Ordovician age. The outline of the structure is well defined by the outcrop belt of the Bays Formation.

The syncline is highly asymmetric with the southeast limb overturned to the northwest. East of Little Brushy Mountain, the Salem fault trace closely follows the strike of the syncline. The sinuous axial trace of the fold may be the result of differential compression caused by the overriding of the Salem fault. The syncline plunges gently to the southwest with an average dip of about 5°.

Between State Highway 311 and the west edge of the map, the northwest limb of the syncline is complicated by minor faulting and folding. The strike of the Bays Formation is in

a northerly direction across Interstate Highway 81 and then changes to an easterly direction to State Road 311, where it forms a small plunging anticline on this limb. The anticline is terminated by a reverse fault on the north and east.

Minor Folds

Most of the stratigraphic units in the southern one-third of the quadrangle have been tightly compressed into a series of small folds. These folds range in width from a few feet to a thousand feet or more and some probably extend for a considerable distance laterally. The best development of these folds is in the shales and thin-bedded carbonates of the Rome and Elbrook formations. However, small folds are present to a lesser degree in the Unicoi, Edinburg, Bays, and Martinsburg formations. Some minor warping and gentle folding also occur in the Devonian shales of the Catawba syncline.

Although the examination of minor folds was limited by few good exposures, they probably are present in the Rome and Elbrook formations throughout the area. Nearly all large exposures of the Rome Formation show continuous tight folding. The typical "Rome topography" of small linear ridges and hills indicates that these folds continue horizontally to form a mass of contorted strata. Folds in the Rome are best exposed along the east side of State Road 639 about 1.5 miles south of the Roanoke River, along Mason Creek, and in a few places near the east edge of the mapped area. Folds in the Elbrook strata appear to be much broader and contain more faults and fractures than those in the Rome. Attitudes of Elbrook beds along Mason Creek and Gish Branch indicate folds between 500 and 1,500 feet wide.

Most of the minor folds in the area are asymmetric with the axial planes having dips of between 40 and 80° SE. Some of the folds are recumbent with the overturned limb dipping southeast. The axial traces of several of the larger folds in the Rome were plotted using bedding attitudes and aerial photographs. These axes strikingly parallel the leading edge of the Max Meadows fault except near the trace of the Fries and Poor Mountain faults where they seem to bend slightly northward.

Cleavage is common in many of the folds in the Rome. Some of the cleavage remains at a constant or nearly constant

dip angle across the fold and appears to be of the axial-plane type. Fracture cleavage occurs in the strata of a number of the folds where thin shale beds are sandwiched between thicker and more competent siltstone and shale beds. Some of this is probably slip cleavage resulting from the adjustment of the structurally imcompetent beds to the tight folding. Flowage of these weak beds occurs in the cores of some of the tightest folds.

ECONOMIC GEOLOGY

CLAY AND SHALE

Shale is produced from a quarry on the southwest slope of Little Brushy Mountain, about 0.1 mile northeast of State Road 619 (Plate 1, active quarry, number 1). The quarry is operated by the Old Virginia Brick Company, Inc., to supply raw material for the manufacture of common brick at their plant in Salem. Most of the quarry is in Millboro Shale, which has been intensely folded and faulted and is deeply weathered, although some shale of the Brallier Formation has also been excavated.

Evaluation data for four clay and shale samples from the Salem quadrangle were reported by Calver, Smith, and Le Van (1964). Potential uses of raw materials from these localities is shown in Table 2. Also, some noncalcareous shales in the Rome, Millboro, and Brallier formations may have potential use for lightweight aggregate.

SAND AND GRAVEL

The Arrow Sand Company quarries sandstone from the Unicoi Formation at the north end of Twelve O'Clock Knob southwest of Salem, about 1.3 miles southeast of the intersection of State Roads 639 and 760 (Plate 1, active quarry, number 2). It is crushed and used for construction purposes.

Sand was also mined from an abandoned quarry along Interstate Highway 81 approximately 0.3 mile west of State Highway 311 (Plate 1, abandoned quarry, number 4). It was quarried from highly weathered pyritic sandstone in the Bays Formation.

The abundant sand and gravel in the alluvial terraces along the Roanoke River are potential sources of aggregate for concrete and road construction. However, removal of the large percentage of clay in much of this material would probably make it generally uneconomical for such use unless large deposits of relatively clean and well-sorted gravel could be found.

Table 2.—Potential uses of clay materials from the Salem quadrangle (data compiled from Calver, Smith, and Le Van, 1964).

Repository Number*	Location	Formation	Sample Interval	Potential Use
R-1863	Abandoned quarry on the north side of State Road 912 just east of the intersection with State Highway 311	Millboro	Sample across 95 feet of dark-gray shale	None
R-1864	Same as R-1863	Millboro	Sample across 55 feet of olive-gray shale	Common brick
R-1865	Bank of small pond on the north side of State Road 912 and about 0.2 mile east of the intersection with State Highway 311	Residual clay	Representative of exposure of clay, 5 feet in height, sampled for a distance of 95 feet	Possible as constituent of common brick
R-1927	Old Virginia Brick Company, Inc. quarry just northeast of State Road 619 about 0.4 mile north of Interstate Highway 81	Millboro	Composite of shale from company stockpile believed to be representative of shale in quarry	Brick

*Samples are on file in the Virginia Division of Mineral Resources repository where they are available for examination.

CRUSHED AND BROKEN STONE

Aggregate for road building and concrete has been obtained from two abandoned quarries in the quadrangle: (1) the old Salem municipal quarry on the south side of State Road 631 (Plate 1, abandoned quarry, number 5) that produced limestone and tectonic breccia from the Elbrook Formation along the leading edge of the Salem fault and (2) a quarry along State Road 628 and Interstate Highway 81 about 0.2 mile from the junction of State Road 628 and State Highway 116 (Plate 1, abandoned quarry, number 3) that produced thin-bedded limestone and siltstone from the Edinburg Formation.

BUILDING STONE

Building stone has been obtained for local use from the Elbrook Formation, Silurian and Devonian sandstones, and large boulders in alluvial deposits.

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APPENDIX

STRATIGRAPHIC SECTIONS

Section 1: Twelve O'Clock Knob

Along State Road 694 on NE slope of Twelve O'Clock Knob, Salem quadrangle, Roanoke County (uppermost part in adjacent Bent Mountain quadrangle); strike approximately N.55°E., dip approximately 30°SE.; after Shufflebarger (1953).

		Thickness Feet
Unicoi and Hampton formations		
	Quartzite; pebbly quartzite and sandstone	360
Unicoi Formation (1,500 feet)		
14	Shale and sandstone, olive, micaceous; gray and blue laminated	70
13	Shale, drab-gray, micaceous; interbedded quartzose layers	155
12	Sandstone, red, micaceous; contains coarse grains of blue quartz	10
11	Conglomerate, gray, buff-weathering, arkosic	40
10	Shale, similar to unit 13	20
9	Sandstone and shale, gray, thin-bedded; arkosic sandstone; interbeds of bluish-gray shale and micaceous mudrock	70
8	Shale, dirty-brown, fissile; contains thin quartzose beds	60
7	Quartzite, arkosic; coarse conglomerate at base contains pebbles 1 inch in diameter.	45
6	Amygdaloid, mud-colored, deeply weathered; contains oblate cavities lined with small acicular crystals	200
5	Diabase, dark-green, fine-grained; columnar jointing well exhibited	150
4	Amygdaloid; dark-green where fresh	5
3	Shale, red and olive	200
2	Sandstone and conglomerate, intensely rolled and shattered; contains weathered diabase and thin, weathered amygdaloid near top	125
1	Crushed arkosic sandstone; half quartz grains and half feldspar at base of interval	450

Fault; Unicoi Formation arkose thrust upon Rome Formation

Section 2: Mason Creek

Along Mason Creek near Hanging Rock, Salem quadrangle, Roanoke County; section begins about 1,000 feet south of the junction of State Highway 311 and State Road 630 and is measured northward for about 200 feet; strike approximately N50°E., dip 56 to 59° SE.; overturned.

		Thickness Feet
Huntersville Formation (not exposed along creek, but may be seen about 200 feet to the northeast).		
Keefer Sandstone (128.0 feet)		
19	Sandstone, light-gray to tan, medium- to coarse-grained; some interbeds of conglomerate, medium- to thick-bedded; some crossbedding; weathers medium gray with orange and brown stains	54.8
18	Shale and siltstone, dark-gray to maroon, highly fractured and cleaved with interbeds of medium-grained, light-gray sandstone; weathers to medium gray	3.2
17	Sandstone, light-gray, medium- to coarse-grained, medium bedded with some cross-bedding, weathers to tan and light brown	29.0
16	Siltstone, light-gray, thin-bedded; weathers to medium gray; upper boundary undulates slightly, may be small unconformity	0.5
15	Sandstone, light gray to white, medium- to coarse-grained; some thin interbeds of conglomerate, medium- to thick-bedded, locally cross-bedded, highly jointed and fractured; weathers to tan and medium gray, some iron staining along bedding planes	40.5
Rose Hill Formation (42.0 feet)		
14	Shale, dark-gray, very fissile; weathers to same color	0.5
13	Sandstone, light-gray, medium- to coarse-grained, silica-cemented, thick-bedded; weathers to light tan	5.2
12	Sandstone, dark gray, medium-grained; weathers to dark red brown	1.3
11	Thin- to medium-bedded sandstones and interbedded shales. Shales are gray to light grayish-green and range in thickness from one to ten inches. Sandstone is gray to dark red, medium-grained; weathers to dark brown. Shale weathers to light gray and buff	9.9
10	Sandstone, dark-gray to maroon, medium-grained, locally hematite-cemented, medium-bedded with thin interbeds of dark-gray shale; weathers to dark rusty brown with thin druses of limonite on exposed faces	5.2
9	Shale, dark-gray to brown, very fissile with lenses of maroon sandstone; weathers to light gray and reddish brown	2.3
8	Sandstone, dark-gray to brown, thin- to medium-bedded with interbeds of olive green shale and siltstone; weathers to dark rusty brown	4.9
7	Sandstone, medium-grained, hematite-cemented, medium-bedded	1.2

6 Sandstone, light-gray to grayish-green, medium- to coarse-grained; becomes coarser toward the top, grading into a conglomerate with clasts up to 0.25 inch across; mostly silica cemented; weathers to dark grayish-green .. 4.1

5 Shale, dark-gray to brown, very fissile, one 5-inch bed of medium-grained, light gray sandstone; weathers to dark red and green with black stains 4.0

4 Sandstone, light-gray, coarse-grained to conglomeratic, thin-bedded, flaggy, irregular bedding planes, silica-cemented; weathers to rusty brown, very friable 2.6

3 Conglomerate, light-gray, medium-bedded, contains clasts up to 0.5 inch in diameter, very hard and resistant, weathers to medium gray 0.8

Tuscarora Formation (9.2 feet)

2 Orthoquartzite, white to light-gray, coarse-grained to conglomeratic with pebbles ranging up to one inch in longest dimension; highly jointed, some fracture cleavage developed in upper part; numerous slickensides, very hard and resistant, weathers to light brown or tan 9.2

Martinsburg Formation

1. Sandstone, grayish-brown, thin-bedded, noncalcareous, unfossiliferous

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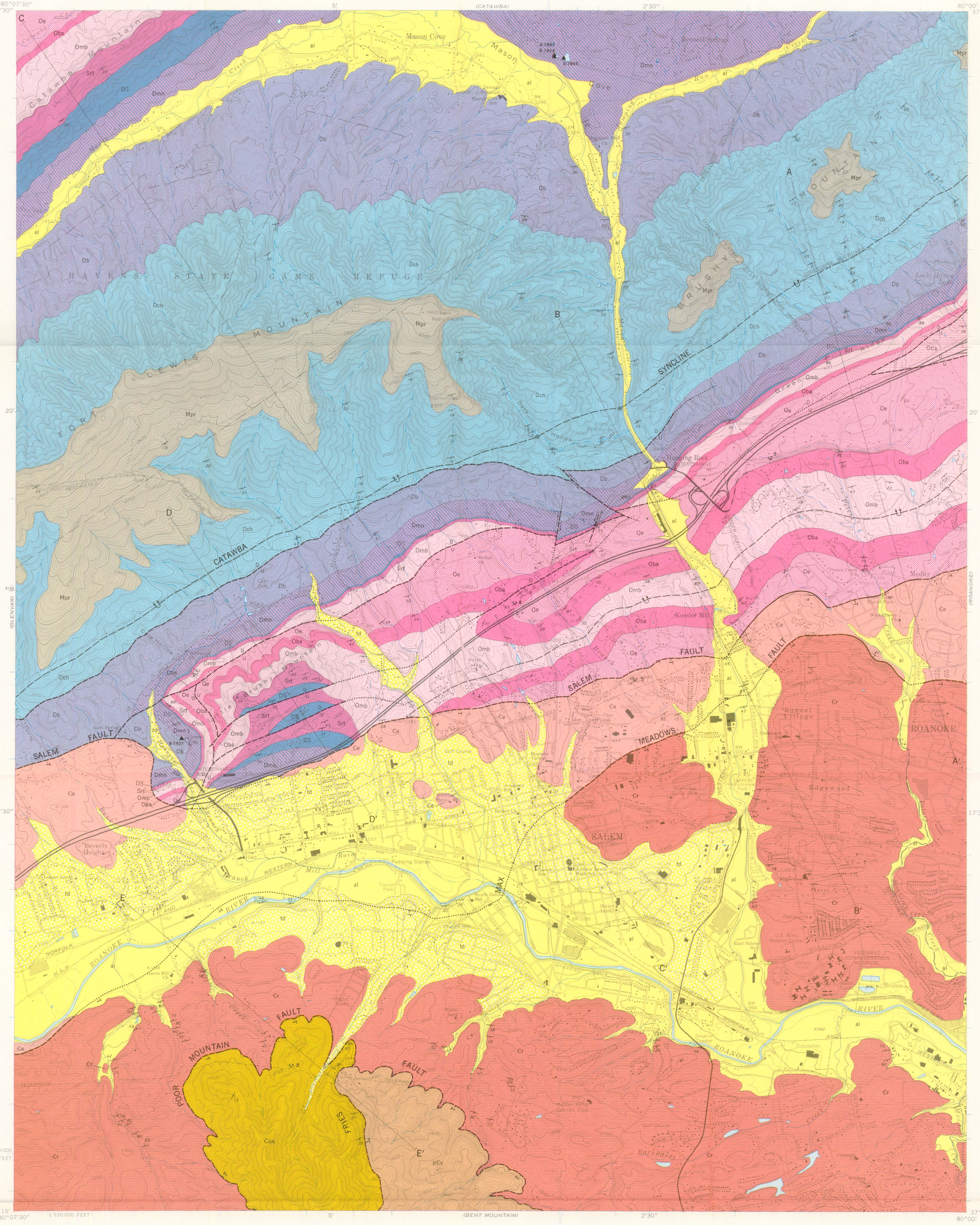
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



Base map from U. S. Geological Survey 1968, Salem Quadrangle, 7½-Minute Series

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GEOLOGIC MAP OF THE SALEM QUADRANGLE, VIRGINIA

Geology by Roger V. Amato

1974

MN GN 4° 71 MILS 0°34' 10 MILS

UTM GRID AND 1968 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET

VIRGINIA

QUADRANGLE LOCATION

EXPLANATION

CENOZOIC — QUATERNARY

al — Alluvium
Sand, silt, clay, and small amounts of gravel.

td — Terrace deposits
Coarse gravels, sand, and clay.

PALEOZOIC

MISSISSIPPIAN

Mpr — Price Formation
Tan to light-red, coarse-grained, arkosic sandstone; gray to dark-red shale containing some plant fossils (upper part). Cloyd Member: conglomerate composed predominantly of pebbles, granules, and coarse grains of white quartzite, vein quartz, and some rock fragments (lower part).

DEVONIAN

Dch — Chemung Formation
Gray and dark-brown, medium- to thick-bedded, fine- to medium-grained, fossiliferous and micaceous sandstone with interbedded dark-gray to olive shale; grayish-red conglomerate and dark-maroon redbeds.

Db — Brallier Formation
Grayish-green shale and siltstone interbedded with gray and dark-brown, fine- to medium-grained sandstone; mostly olive- to dark-gray shale in lower part.

Dmn — Millboro Shale and Needmore Formation
Millboro: dark-gray to black, fissile shale with interbedded medium-gray siltstone. Needmore: olive and brown, fissile, fossiliferous shale.

DS — Lower Devonian and Middle Silurian rocks
Huntersville Formation: light- to dark-gray chert with interbedded green clagstone and shale. Keefer Sandstone: light-gray to white, medium- to thick-bedded, medium- to coarse-grained orthoquartzite; locally conglomeratic; thin beds of siltstone and shale.

SILURIAN

Srt — Rose Hill Formation and Tuscarora Formation
Rose Hill: light- to medium-gray, thin- to medium-bedded, medium- to coarse-grained orthoquartzite and dark-brown and maroon sandstone with interbedded maroon to dark-green shale and light-gray to black siltstone; locally, pebble conglomerate. Tuscarora: white to light-gray, medium- to thick-bedded, subangular to subrounded, medium-grained to conglomeratic orthoquartzite.

ORDOVICIAN

Omb — Martinsburg Formation
Gray to tan shale and siltstone with grayish-green sandstone in upper part; dark-gray and brown calcareous shale with fossiliferous limestone in lower part.

Oba — Bays Formation
Olive-gray to brown, medium- to thick-bedded, fine-grained sandstone with interbedded grayish-green to dark-red and maroon siltstone and shale.

Oe — Edinburg Formation
Gray to black calcareous shale and limestone; sparsely fossiliferous.

O€k — Knox group
Light- to medium-gray, medium- to thick-bedded, fine-grained dolomite containing light-gray to white chert, dark-gray, thin-bedded limestone, and quartzose sandstone.

CAMBRIAN

€e — Elbrook Formation
Light-gray to dark bluish-gray, thin-bedded, fine-grained dolomite; some dark bluish-gray magnesian limestone and light-green to dark-gray shale; red shale rare.

€r — Rome Formation
Red, green, gray, purple, and buff shale and siltstone with interbedded light- to dark bluish-gray limestone and dolomite; black chert in some dolomite beds.

€un — Unicoi Formation
Medium- to thick-bedded conglomerate, feldspathic sandstone, light-gray to tan quartzite, buff to gray siliceous shale, and amygaloidal basalt. (Map unit includes some diabase dikes.)

PRECAMBRIAN

p€v — Virginia Blue Ridge Complex
Greenish-gray, garnetiferous augen gneiss. (Map unit includes some diabase dikes.)

CONTACTS

Solid where exposed, dashed where approximate, dotted where covered

FOLDS

Overturned syncline—trace of fold

FAULTS

Solid where exposed, dashed where approximate, dotted where covered or inferred; tick mark indicates direction of dip; U, upthrown side; D, downthrown side; T, upper sheet; arrows indicate direction of relative movement

ATTITUDE OF ROCKS

- 50 Strike and dip of beds
- 85 Strike and dip of overturned beds
- Strike of vertical beds
- Horizontal beds

QUARRIES

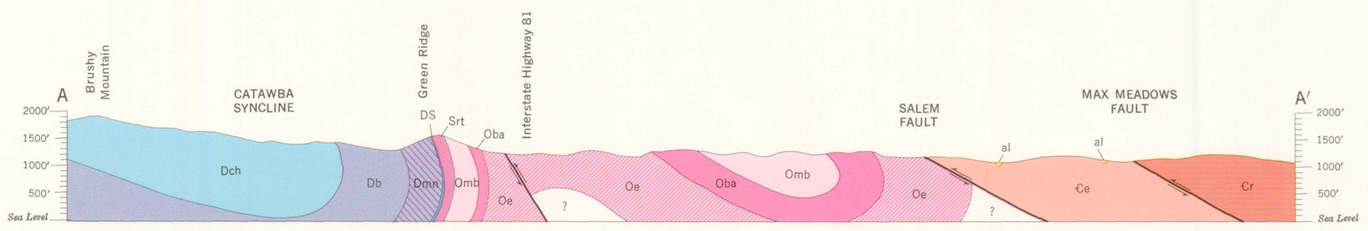
Active quarry
1. Old Virginia Brick Company, Inc. (shale)
2. Arrow Sand Company (sandstone)

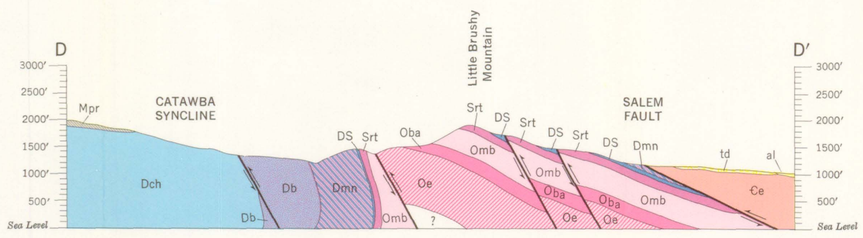
Abandoned quarry
3. Limestone and siltstone (crushed and broken stone)
4. Sand (sandstone)
5. Salem municipal quarry—limestone and breccia (crushed and broken stone)

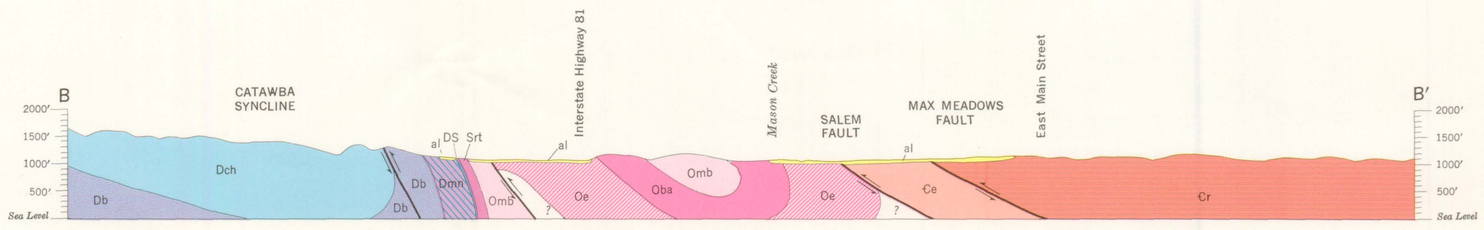
SAMPLE LOCATIONS

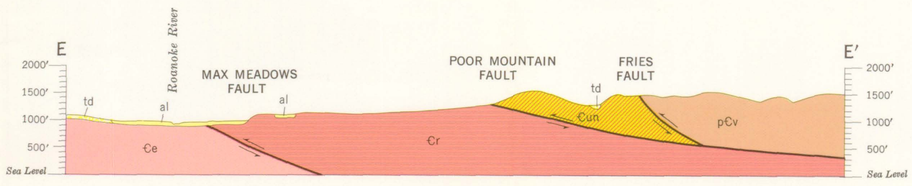
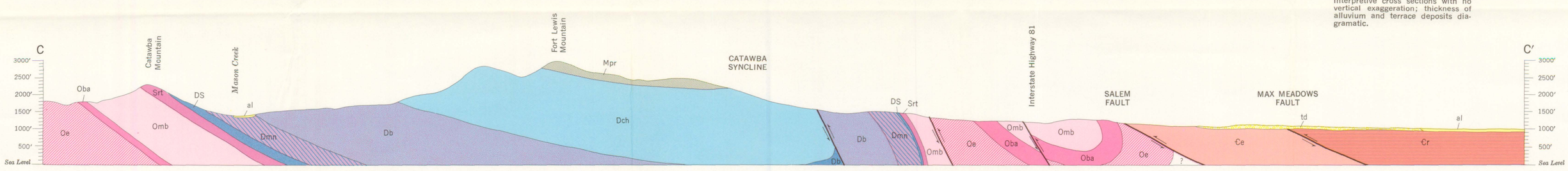
△ R-1863 Sampled lithology; R, repository number

▲ R-1927 Sample of raw material having potential commercial use; R, repository number









Interpretive cross sections with no vertical exaggeration; thickness of alluvium and terrace deposits diagramatic.