STRUCTURAL GEOLOGY OF THE

CHRISTIANSBURG AREA,

MONTGOMERY COUNTY,

VIRGINIA

by

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INTRODUCTION

Location and Accessibility

The study area (Figure 1), is in central Montgomery County, Virginia, and includes approximately the southern third of the 1965 United States Geological Survey 7.5-minute Blacksburg, Virginia, and the northern third of the 1965 7.5-minute Riner, Virginia, quadrangles. The area is bounded by meridians 80° 22' 30" and 80° 27' 00" on the east and west, by parallel 37° 9' 50" on the north and by the Max Meadows fault trace on the south; it comprises about 19 square miles. The town of Christiansburg, Virginia, is in the central part of the mapped area.

Accessibility to the area is good. U.S. Highway 460 runs north from Christiansburg and U.S. Highway 460 Bypass (the Christiansburg Bypass) provides exposures of rocks not seen in surface outcrops. Other north-south roads include Virginia State Route 8, Montgomery County Routes 661, 723, and 720. East-west roads are Interstate 81, U.S. Highway 11-460, and Montgomery County Routes 666 and 662. In addition, the Norfolk and Western Railway right-of-way, various farm roads, telephone, power, and gas line rights-of-way, provide access to most areas.

Topography and Drainage

The Christiansburg area lies within the Valley and Ridge physiographic province. The highest point, about 2540 feet, is atop Rose Hill, south of Christiansburg. The lowest elevation, about 1580 feet, is where Wilson Creek leaves the area along the eastern edge of the map (Plate 1). The maximum relief is nearly 1000 feet. The topography in the southern part of the area consists of linear, steep-sided ridges,

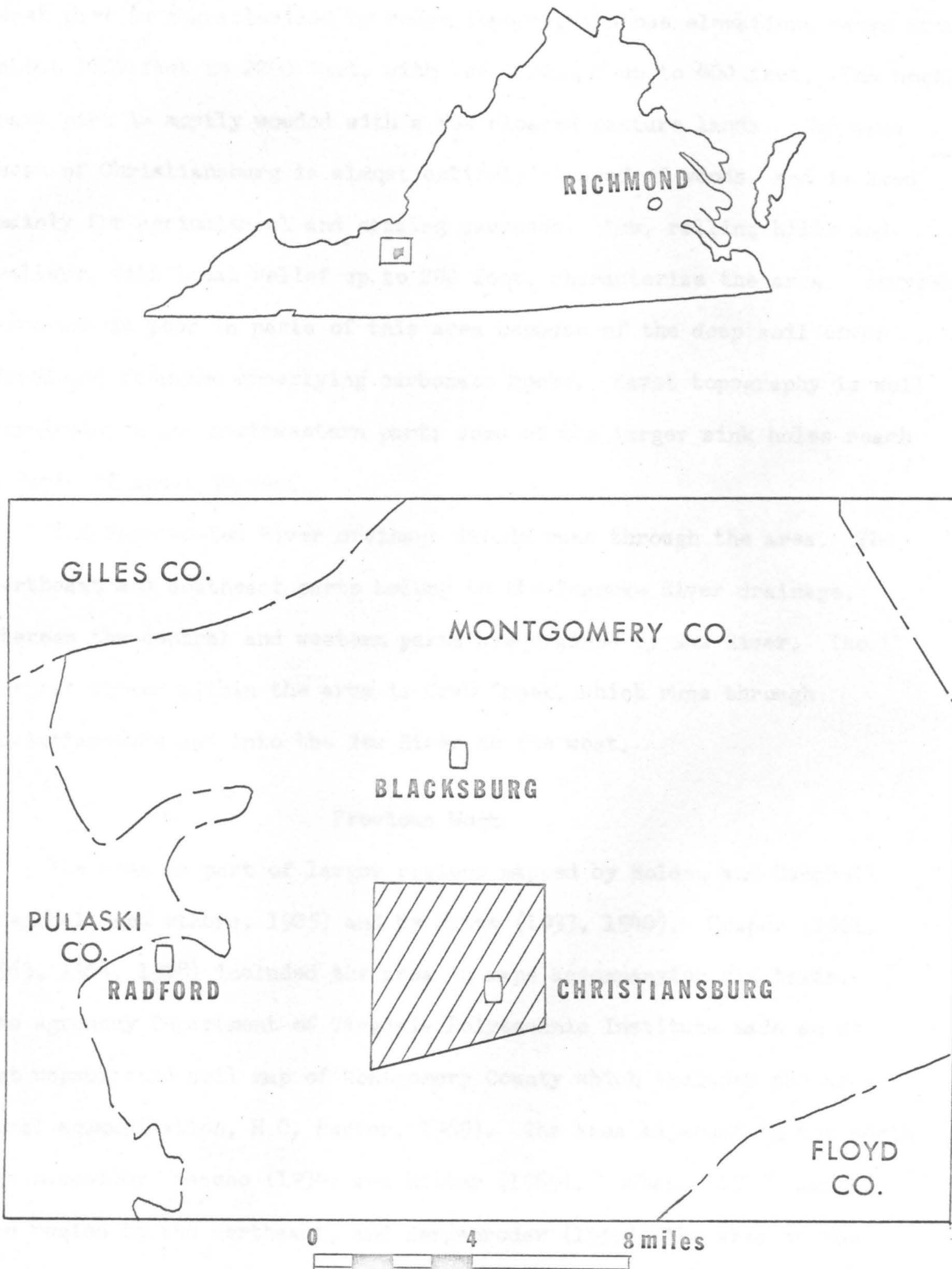


Figure 1. Location of the study area.

and hills which are developed on the Cambrian Rome shale. The northeast part is characterized by rough topography whose elevations range from about 1600 feet to 2200 feet, with local relief up to 400 feet. The northeast part is mostly wooded with a few cleared pasture lands. The area west of Christiansburg is almost entirely cleared of woods, and is used mainly for agricultural and grazing purposes. Low, rolling hills and valleys, with local relief up to 200 feet, characterize the area. Bedrock exposure is poor in parts of this area because of the deep soil cover developed from the underlying carbonate rocks. Karst topography is well developed in the northwestern part; some of the larger sink holes reach a depth of about 30 feet.

The Roanoke-New River drainage divide runs through the area. The northeast and southeast parts belong to the Roanoke River drainage, whereas the central and western parts are drained by New River. The largest stream within the area is Crab Creek, which runs through Christiansburg and into the New River to the west.

Previous Work

The area is part of larger regions mapped by Holden and Campbell (Campbell and others, 1925) and by Butts (1933, 1940). Cooper (1961, 1963, 1964, 1968) included the area in maps accompanying his texts. The Agronomy Department of Virginia Polytechnic Institute made an as yet unpublished soil map of Montgomery County which includes the area (oral communication, H.C. Porter, 1969). The area adjacent to the north was mapped by Waesche (1934) and Ritter (1969). Eubank (1967) mapped the region to the northeast, and Hergenroder (1957), the area to the west. Dietrich (1954) mapped the leading edge of the Max Meadows fault block south of Christiansburg, Virginia.

STRATIGRAPHY

General Statement

The rocks exposed in the Christiansburg area are Paleozoic sediments ranging in age from Lower Cambrian to Upper Ordovician (Figures 2 and 3). Adjacent to the west are strata of Silurian-Devonian age and less than 2 miles to the north are Mississippian rocks that form Price Mountain. The rocks within the area constitute part of five separate fault blocks: the Max Meadows fault block on the south, the Saltville fault block exposed in windows through the Pulaski thrust sheet in the central part of the area, the Pulaski fault block on the north, which is broken by the Salem fault to form the Salem fault block, and the Catawba fault block on the northeast. In the formational descriptions which follow, reference will be made to the blocks on which the formation occurs as there are differences in lithology in rocks of comparative age on the Saltville, Pulaski-Salem and Catawba fault blocks (Figure 4).

The oldest rock exposed is the Lower Cambrian Rome formation. It consists of olive, maroon and tan shales with lesser amounts of dolomite and sandstone. This rock constitutes all of the Max Meadows fault block within the area and it has been thrust northwest over the younger Elbrook formation.

The Middle and Upper Cambrian Elbrook Formation is present in the Pulaski and Salem fault blocks, and is represented by a sequence of interbedded limestone and dolomite with minor amounts of chert. Locally the Elbrook Formation on the Pulaski fault block has been much fractured and brecciated and an estimate of the thickness of the Elbrook is difficult. On the Salem fault block the Elbrook is at least 1000 feet thick in the

System	Formation	Columnar Section	Thickness in Feet
ORDOVICIAN	Martinsburg Formation		800±
	Liberty Hall equi.		50+
	Ordovician limestones		355
	disconformity		
	Upper Knox Formations		1000±
CAMBRIAN	Copper Ridge Formation		1000±
	pre-Copper Ridge dolomite		1000±
	major fault		
	Rome Formation (Max Meadows block)		uncertain

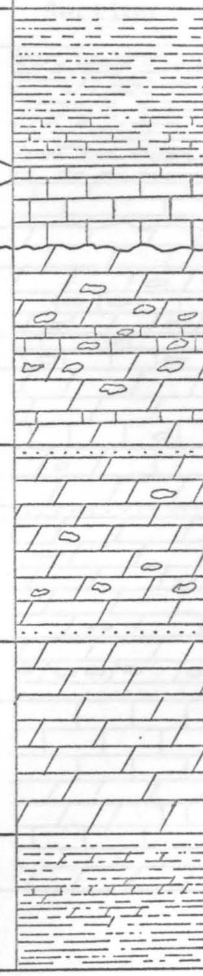
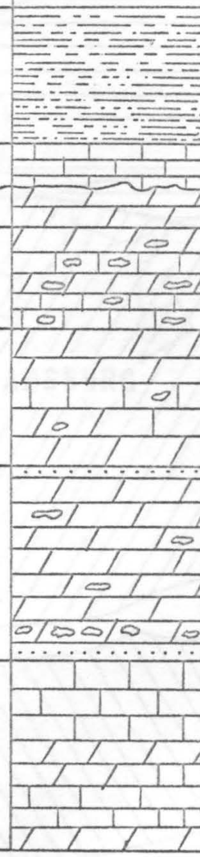


Figure 2. Columnar section of the bedrock formations of the Saltville fault block exposed in the Christiansburg, Virginia area. The Rome Formation is included although it is a part of the Max Meadows fault block.

System	Formation	Columnar Section	Thickness in Feet
ORDOVICIAN	Liberty Hall Formation		700 ±
	Ordovician limestones		250 ±
	Mascot-Kingsport fms.		200 ±
	Longview Formation		500 ±
	Chepultepec Formation		700 ±
CAMBRIAN	Copper Ridge Formation		1000 ±
	Elbrook Formation		1000 +



Pulaski Fault

Figure 3. Columnar section of the bedrock formations of the Pulaski and Salem fault blocks exposed in the Christiansburg, Virginia area.

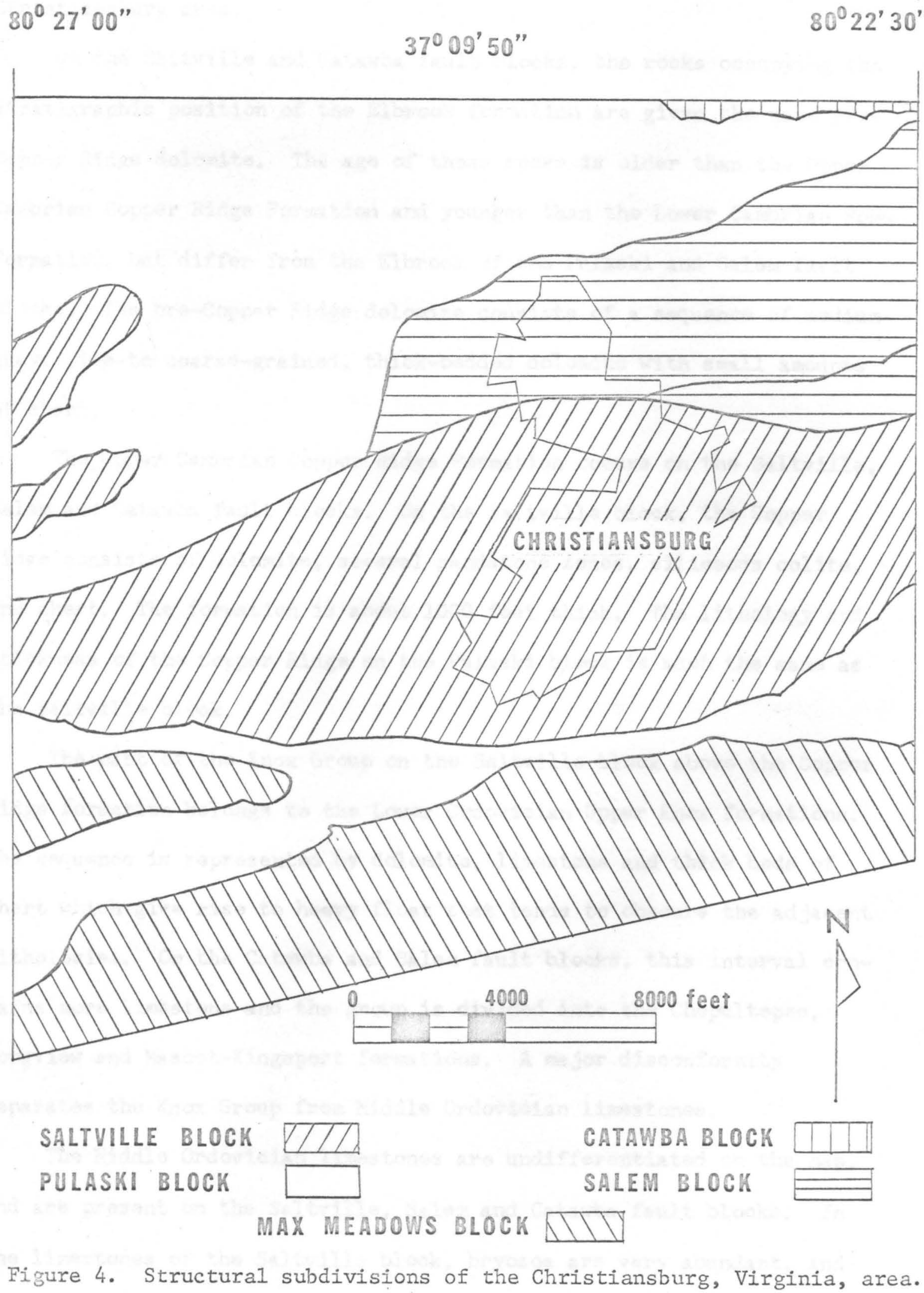


Figure 4. Structural subdivisions of the Christiansburg, Virginia, area.

Christiansburg area.

On the Saltville and Catawba fault blocks, the rocks occupying the stratigraphic position of the Elbrook formation are given the name pre-Copper Ridge dolomite. The age of these rocks is older than the Upper Cambrian Copper Ridge Formation and younger than the Lower Cambrian Rome Formation, but differ from the Elbrook of the Pulaski and Salem fault blocks. The pre-Copper Ridge dolomite consists of a sequence of medium-gray, fine-to coarse-grained, thick-bedded dolomite with small amounts of chert.

The Upper Cambrian Copper Ridge Formation occurs on the Saltville, Salem and Catawba fault blocks. On the Saltville block, the Copper Ridge consists of dolomite, several sandstone zones, siliceous oolite, and chert. The formation is about 1000 feet thick. The lithology and thickness of the Copper Ridge on the Pulaski block is much the same as the Saltville block.

The part of the Knox Group on the Saltville block above the Copper Ridge Formation belongs to the Lower Ordovician Upper Knox formations. The sequence is represented by dolomite, limestone and thick beds of chert which give rise to heavy float that tends to obscure the adjacent lithologies. On the Catawba and Salem fault blocks, this interval contains more limestone and the group is divided into the Chepultepec, Longview and Mascot-Kingsport formations. A major disconformity separates the Knox Group from Middle Ordovician limestones.

The Middle Ordovician limestones are undifferentiated on the map, and are present on the Saltville, Salem and Catawba fault blocks. In the limestones of the Saltville block, bryozoa are very abundant, and represent a reefy facies. The thickness is about 350 feet. On the Catawba block, the Middle Ordovician limestones are less fossiliferous, and in the map area are only about 100 feet thick, though they thicken appreciably to the northeast (Gilbert, 1953, Eubank, 1967).

On the Catawba block these limestones are overlain by the Middle Ordovician Liberty Hall Formation which occurs north of the Salem fault where it is represented by a weathered olive-to dark-tan shale. On the Saltville block, the shaly facies of the Liberty Hall was not found. However, the massive and thick-bedded reefy Middle Ordovician limestones are overlain by about 50 feet of dark and light-gray, banded limestone, which may be a much more limy equivalent of the shaly Liberty Hall. This unit is bounded on the north by the Willow Springs fault which forms the edge of the Christiansburg window. The apparent absence of the shaly facies of the Liberty Hall in the Saltville block indicates that it was either never deposited in this area or else was removed by movement along the Pulaski fault. One very small isolated patch of the shaly Liberty Hall was found on the Pulaski fault block adjacent to the north side of the Christiansburg window, west of the Christiansburg sewage disposal plant.

The Middle to Upper Ordovician Martinsburg Formation, exposed along the western edge of the area in windows through the Pulaski thrust sheet, consists of weathered olive and brown shale with interbeds of slabby limestone.

The youngest deposits within the area are alluvium and colluvium of Pleistocene-Recent age. Rounded pebbles and cobbles of quartzite and vein quartz of the type found in the Blue Ridge are found locally throughout the area.

Cambrian System

Rome Formation

Name and Age

The Rome Formation was named by E.A. Smith (1890) for outcrops near Rome, Georgia. It is the oldest formation exposed in the area, and was assigned an age of Lower to Middle Cambrian on the basis of sparsely occurring fossils (Butts, 1940).

Distribution and Thickness

The Rome Formation which occurs in the southern part of the area has been thrust northwest over the Middle to Upper Cambrian Elbrook Formation. The main trace of the Max Meadows fault, which separates these formations, roughly parallels Interstate 81 and the Appalachian Power Company high tension line, south of Christiansburg. A large detached mass of Rome lies about 1500 feet north of the main fault trace in the southwest part of the area. A cemetery just north of Cemetery Ford, along Montgomery County Road 661, is located on the crest of a hill capped by Rome. Small patches of Rome lie east and west of U.S. Highway 460 in the northern part of the area. They are probably klippen of Rome left behind as the main body of the Max Meadows fault block was eroded back to its present position.

The thickness of the Rome was not determined because the unit is bounded by fault contacts and also because the beds may be repeated by folding and faulting. Dietrich (1954) gives no estimate of the thickness of the Rome south of Christiansburg, probably for the same reasons.

Description

The topography developed on the Rome Formation is characterized by long strike ridges and valleys. This topography is easy to recognize in aerial photographs. The Rome is a heterogeneous formation composed of variegated red, green, olive and buff-colored shales and siltstones with interbeds of limestone and dolomite. The shales are fine-grained, fissile and generally siliceous. Although the beds are folded, fractured and faulted in places, the red and green shales crop out in belts which can be followed for several hundred feet. The shales weather into small chips which are scattered abundantly over the reddish-brown soil. Carbonate rock makes up at least a third of the Rome in the Salem area (Amato, 1968), but is not so abundant in the Christiansburg area. The carbonates which are light-to medium-gray, fine-grained, and thin-to medium-bedded dolomite, resemble those of the Elbrook Formation.

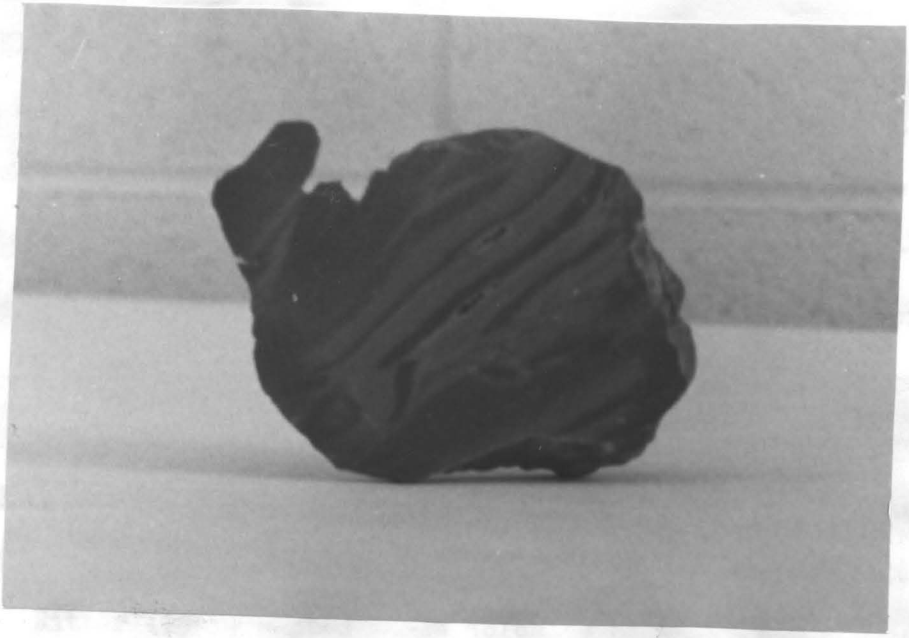
A ledge of fine-grained, thinly laminated jasperoid-like quartz runs for about 2500 feet along the crest of a hill on the Teel farm, about 1700 feet south-southeast of Interstate 81 and about 1500 feet east of the western boundary of the map (Plate 2A). The laminations are cross-bedded and highly contorted in places. No reliable in-place outcrops were found, but abundant float, up to boulder-size, is present. This ledge ends abruptly on the southwest, apparently cut off by leading edge of the Max Meadows fault block. Several old prospect pits were found in a wooded area along the crest of the hill.

Tectonic breccia occurs in limited amounts along the Rome-Elbrook contact. The best exposure is about 150 feet south of the Interstate 81-Virginia Route 8 interchange at the entrance to the Frontage Road. The breccia exposed at this location represents the three types of Max Meadows breccia described by Cooper and Haff (1940).

Plate 2.

A. Thinly laminated jasperoid-like quartz found in the Rome Formation near the leading edge of the Max Meadows fault. The laminations are cross-bedded and highly contorted in places. Speciman measures about three inches in diameter.

B. Tectonic breccia which occurs in isolated zones throughout the Elbrook Formation on the Pulaski fault block. These breccia zones are most common on the Pulaski block north of the Christiansburg window. This locality is adjacent to the Triangle Bowling Lanes along Virginia Route 114.



Elbrook Formation

Name and Age

The Elbrook Formation was named by G. W. Stose (1906) after the town of Elbrook, Franklin County, Pennsylvania. Butts (1940) assigned the Elbrook a Late Middle Cambrian age and stated that it probably extended into the Upper Cambrian. The age of the Elbrook in the Christiansburg area is uncertain due to lack of fossil evidence. A few specimens of the Stromatolite Cryptozoon were found by the writer in the limestones. In the Blacksburg area, J.R. Derby (1966) collected Llanoaspis modesta, Pemphigaspis and Terranovella dorsalis from shaly dolomite near the top of the Elbrook. He noted that these beds are equivalent to the Nolichucky Formation. Ritter (1969) mapped these dolomite beds below the basal Copper Ridge sandstone as "Dolomites of Uncertain Age."

Distribution and Thickness

The Elbrook Formation is present only on the Pulaski and Salem fault blocks. In the southern part of the area, the Elbrook frames the south edge of the Christiansburg window and farther south is in fault contact with the overriding Max Meadows fault block. Farther north, the Elbrook is in contact with parts of the northern edge of the Christiansburg window. This belt of Elbrook is on the Pulaski fault block and runs from the western edge of the area eastward to about the Christiansburg sewage disposal plant. East of the disposal plant, the Elbrook is on the Salem fault block, also adjacent to the north edge of the Christiansburg window.

The thickness of the Elbrook is uncertain, as it is bounded by faults south of the Christiansburg window. North of the window, the Elbrook on the Pulaski fault block is probably very thin as it is highly fractured and brecciated as if the Pulaski fault plane is not far below the surface.

Description

The Elbrook in the Christiansburg area consists of dark-blue to light-gray, fine-grained, thin-to medium-bedded dolomite; buff-colored, thin-to medium-bedded, shaly dolomite, and blue, fine-grained, medium-to thick-bedded limestone. The dolomite and limestone are calcite-veined, and a large percent of the beds are fractured and brecciated. Shaly beds are poorly exposed, but weathered chips of shale are found in the soil. The Elbrook which crops out in the northern part of the area has been severely fractured and faulted to form large blocks in chaotic attitudes. Zones of tectonic breccia containing large blocks of limestone and dolomite are common in the unit (Plate 2B). Oolitic texture can be seen in the thick-bedded Elbrook limestones along the Norfolk and Western Railway about 2000 feet southeast of the Montgomery County Route 661 crossing. The breccia is composed of angular to subrounded fragments of limestone and dolomite in a matrix of calcareous rock flour. A pronounced karst topography has developed on the Elbrook in the northwest corner of the map area.

Exposures of Elbrook along the Max Meadows fault are not numerous, but the rock does not seem to be as broken as to the north. Several isolated outcrops of highly fractured, bedded chert are present in the Elbrook adjacent to the contact with the southern edge of a large, detached mass of Rome. The chert occurs about 1100 feet south-southwest of a gate across the Frontage Road paralleling Interstate 81. This rock was examined in thin section and found to be microcrystalline chert with zones of siliceous oolites. It was possibly derived from the younger Copper Ridge

Formation.

Limestone from the Elbrook was quarried and burned for agricultural use in a small quarry just upstream from a dam across Crab Creek, at Cemetery Ford, Montgomery County Road 661 (H.D. Christman, oral communication, June, 1969). The rock on the quarry face consists of a blue, fine-grained, laminated limestone.

Pre-Copper Ridge Dolomite

Name and Age

The name pre-Copper Ridge dolomite is given to a succession of dolomite underlying the Copper Ridge Formation on the Saltville and Catawba fault blocks. This dolomite occupies the stratigraphic position of the Elbrook Formation on the Pulaski and Salem fault blocks, but is sufficiently different in lithology from the Elbrook to warrant the use of this name. In the Blacksburg area, Ritter (1969) calls this unit "Dolomites of Uncertain Age" and assigns them to the Middle-Upper Cambrian.

Distribution and Thickness

The pre-Copper Ridge dolomite is poorly exposed in a belt running approximately east across the map area and through the town of Christiansburg, Virginia. The unit which forms the crest of the Christiansburg anticline (Plate 1) in the Saltville fault block, is exposed in the Christiansburg window. This dolomite also occurs on the Catawba fault block (Ritter, 1969), but is not present on the part of the Catawba block exposed within the map area.

A total thickness cannot be given because the unit forms the core of the Christiansburg anticline and is poorly exposed. Ritter (1969) estimates a thickness of at least 1900 feet on the Catawba fault block to the north. On the Saltville block, calculations from the width of the outcrop belt indicate a thickness of at least 1000 feet.

Description

The best exposure of the pre-Copper Ridge dolomite was in an open trench along U.S. Highway 11, west of Christiansburg, which has since been refilled. The rock is a light-to medium-gray, fine-to coarse-grained, thick-bedded dolomite. The general absence of limestone in this unit serves to distinguish it from the Elbrook. Ritter (1969) reports large masses of algal chert and silicified algal structures in these dolomites on the Catawba block just north of the map area. As stated previously, Derby (1966) collected fossils of Nolichucky age in the upper part of this unit near Blacksburg, Virginia.

Copper Ridge Formation

Name and Age

E.O. Ulrich (1911) proposed the name "Copper Ridge chert" for exposures along Copper Ridge, Knox County, Tennessee, but later changed the name to "Copper Ridge dolomite" (Ulrich, 1924). Aronson (1966) used the name "Copper Ridge formation" for carbonates in the Blacksburg area. This unit extends into the Christiansburg area; therefore the name Copper Ridge Formation will be used. The dolomitic facies of the Copper Ridge is correlated with the limestone facies of the Conococheague. Although the unit in the Christiansburg area is mapped as Conococheague on the Geologic Map of Virginia (1963), very little limestone was seen. Consequently, the name Copper Ridge Formation is preferred. The Copper Ridge is the oldest formation in the Knox Group, which was named by Stafford (1856) for a thick sequence of limestone and dolomite in Knox County, Tennessee. The age of the Copper Ridge is Upper Cambrian (Butts, 1940).

Distribution and Thickness

The Copper Ridge Formation occupies two belts which run east-northeast across the central part of the area. These two belts which are separated by the pre-Copper Ridge dolomite, represent the northwest and southeast flanks of a major anticline in the Saltville fault block. This anticline is referred to herein as the Christiansburg anticline. A thickness of about 1000 feet for the Copper Ridge Formation on the flanks of the Christiansburg anticline is shown in the structure sections (Plate 1).

A small exposure of the Copper Ridge Formation occurs on the Salem fault block along the eastern boundary of the area where the Norfolk and Western Railway leaves the map area (Plate 1). This belt is cut off to the west by a well developed zone of tectonic breccia exposed along the railroad right-of-way. However this belt was traced some distance to the east by Dr. W. D. Lowry (oral communications, August, 1969). Northwest of the breccia zone, a belt of Copper Ridge, also of the Salem fault block, runs northeast roughly parallel to, and in between, Montgomery County Road 723 and the Norfolk and Western Railway. This belt intersects the north edge of the Christiansburg window in the vicinity of the Christiansburg sewage disposal plant. A thickness of about 1000 feet for this belt is shown on structure section B-B' (Plate 1). A small amount of Copper Ridge occurs in the northeast corner of the area on the Catawba fault block. This unit is a part of the belt mapped by Ritter (1969) and is cut off by the Ellett Road fault in the Christiansburg area (Plate 1).

Description

The Copper Ridge Formation is principally a light-to dark-gray, fine-to coarse-grained dolomite and siliceous dolomite. Although limestone may occur in the Copper Ridge elsewhere (Aronson, 1966), very little was noted in the Christiansburg area. The unit contains two distinct beds of quartzose sandstone and both oolitic and stromatolitic chert.

The sandstones in the Copper Ridge Formation occur at the base and at the top of the formation and are composed of light-gray to buff-colored, medium-to coarse grains of subrounded quartz and minor feldspar commonly cemented by dolomite. Though very hard where unweathered, the sandstone in most outcrops is friable and iron-stained as a result of the leaching out of carbonate cement. The lower sandstone is identified by the presence of siliceous oolite above it (Aronson, 1966; Derby, 1966), and is thicker than the upper one. The lower sandstone on the northwest flank of the Christiansburg anticline can be seen in a road cut on the east side of Montgomery County Road 661, 900 feet northwest of the intersection with U.S. Highway 11, west of Christiansburg. This bed, about 30 feet thick, forms a prominent ridge both to the northeast and southwest. Cross-beds indicate that it is right side up. The ridges formed by the upper and lower Copper Ridge sandstone beds readily define the structure of the Christiansburg anticline.

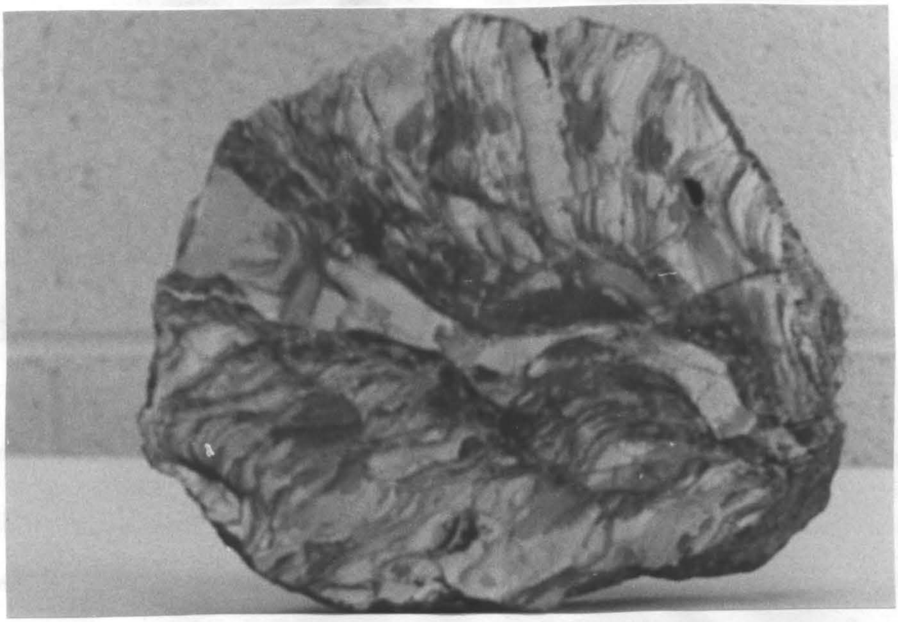
On the Salem fault block, the lower sandstone of the Copper Ridge Formation gives way to the underlying Elbrook Formation. The sandstone can be seen in a road cut on the northeast side of U.S. Route 460 Bypass, 1600 feet souteast of the bridge over Montgomery County Road 723. This cut is close to where Montgomery County Road 644 was located before construction of the bypass. Here the sandstone is a hard light-gray, quartzite which is probably overturned to the northwest. The upper sandstone, which gives way upward to the Ordovician Knox formations, is a weathered, iron-stained, medium-grained, friable sandstone.

Oolitic and stromatolic chert is especially abundant above the basal sandstone. Derby (1966) reports a bed of oolitic limestone 48 feet above the lower sandstone in his Geologic Section Number 18 in Washington County, Virginia, and states that oolitic chert is common at this horizon elsewhere in Virginia. In the Christiansburg area, the oolitic chert above the basal sandstone is light-to medium-gray and is made up of spheroidal ooliths about 1 mm in diameter. The ooliths have a dark gray rim and a lighter interior. The stromatolitic chert occurs up to cobble size and some specimens show excellent preservation of structure (Plate 3A). Both types of chert can be seen above the lower sandstone on the northwest flank of the Christiansburg anticline at the location along Montgomery County Road 661 northwest of its intersection with U.S. Highway 11 described above. The two types of chert rarely crop out, but are abundant as float.

Plate 3.

A. Stromatolitic chert float found above the lower Copper Ridge sandstone along Montgomery County Road 661. This specimen measures about six inches in diameter.

B. Banded limestone on the Saltville fault block which may be equivalent to the shaly facies of the Liberty Hall Formation. This limestone overlies the Middle Ordovician limestone inside the north edge of the Christiansburg window.



Ordovician System

Chepultepec Formation

Name and Age

The Lower Ordovician Chepultepec Dolomite was named by E.O. Ulrich (1911) for exposures just west of the town of Allgood (Chepultepec), Blount County, Alabama.

Distribution and Thickness

A small exposure of the Chepultepec Formation occurs in the northeast corner of the area as a continuation of a belt on the Catawba fault block mapped by both Eubank (1967) and Ritter (1969). The outcrop belt intersects the trace of the Colonial Gas Company pipeline about 1400 feet north-northwest of the point where the pipeline crosses Montgomery County Road 723 (the Ellett Road) and continues due west until terminated by the Ellett Road fault (Plate 1). Ritter (1969) gives a thickness of 400 feet for this belt of Chepultepec, but only about 100 feet is present where it is cut off by the Ellett Road fault. Outcrops of dolomite with interbedded limestones, which are a part of the Salem fault block, are located along Montgomery County Road 723 northeast of Christiansburg, Virginia. These beds are in contact with the Copper Ridge and Longview formations and are presumed to be Chepultepec.

Description

The Chepultepec Formation consists of light-to medium-gray, medium-grained, thin-to medium-bedded dolomite interbedded with medium-to dark-gray, fine-grained, thin-bedded limestone. Within the map area the Chepultepec on the Catawba fault block is primarily dolomite with small amounts of blocky, nodular chert. The diagnostic fossil, Fineklnburgia, was not seen, but a few longitudinal sections of snails were seen on weathered bedding surfaces. Within the map area, the Chepultepec on the Salem fault block is also mostly dolomite, but contains beds of dark-gray, thin-bedded, limestone about in the middle of the unit.

Longview Formation

Name and Age

The Lower Ordovician Longview Formation was named by E.O. Ulrich (1924) for exposures near the town of Longview, Shelby County, Alabama.

Distribution and Thickness

The Longview Formation occurs on the Catawba fault block in a narrow, poorly exposed belt in the northeast corner of the map area where it is terminated by the Ellett Road fault. This belt runs west-southwest, close to the Colonial Gas Company pipeline, and is a part of the belt described by Eubank (1967) and Ritter (1969). Ritter (1969) gives the thickness as about 100 feet, but this formation thins down to approximately 50 feet before it is cut off by the Ellett Road fault. The Longview also crops out on the Salem fault block along the northwest side of Montgomery County Road 723 northeast of Christiansburg, Virginia. The best outcrops of this belt can be seen in a hillside pasture along Montgomery County Road 723, about 1500 feet northeast of U.S. Highway 460 Bypass.

Description

The Longview Formation of the Catawba block contains blue-gray, medium-gray, thin-to medium-bedded limestone and light-gray, blocky-weathering chert. The chert is evident principally as float in this area.

Lecanospira and small trochospirally coiled gastropods occur on the weathered surfaces of the limestone, and impressions of Lecanospira and Syntrophynella were found in chert by Ritter (1969) in this belt farther northeast. The writer did not find any fossils in the limited outcrops.

The Longview of the Catawba block along Montgomery County Road 723 is composed of light-gray, fine-grained to saccharoidal, medium-bedded dolomite and interbedded medium-to dark-gray, medium-grained, thin-bedded limestone. The weathered surfaces of the dolomite are almost white in color. They contain beds, up to 6 inches thick, of rounded dolomite and limestone clasts, and a light-tan detrital chert. Impressions of snails were found in the limestones.

Mascot-Kingsport Formation

Name and Age

The Mascot and Kingsport Formations were named by John Rodgers (1943) for dolomites of Lower Ordovician age in Hancock and Grainger Counties Tennessee.

Distribution and Thickness

The Mascot-Kingsport Formation occurs on the Catawba fault block along Montgomery County Road 723 in the northeast corner of the area. It is a continuation of the belt described by Eubank (1967) and Ritter (1969). The unit is terminated by the Ellett Road fault and very little of the formation is present within the Christiansburg area. The outcrop belt is poorly exposed and the thickness uncertain. Eubank (1967) states that the thickness of the Upper Knox dolomites ranges from a feather edge up to 350 feet according to the relief developed on the Lower-Middle Ordovician disconformity.

Description

The Mascot-Kingsport Formation consists of medium-gray, coarse-grained, medium-to thick-bedded dolomite. Light gray chert nodules and light tan, bedded chert are present locally. Eubank (1967) reports that in the area to the northeast, the relief on the surface of the disconformity between the Upper Knox formations and the overlying Middle Ordovician limestones is at least 360 feet along a strike distance of 3.3 miles.

Upper Knox Formations

Name and Age

In the Christiansburg window, the name Upper Knox formations applies to an undifferentiated sequence of dolomites, limestones, and chert above beds identified as the Copper Ridge Formation and below the Lower-Middle Ordovician disconformity. These rocks are a part of the Saltville fault block. On the Catawba and Salem blocks, the succession of rocks in this stratigraphic position are mapped as the Lower Ordovician Chepultepec, Longview, and Mascot-Kingsport formations. In the Christiansburg window, the Upper Knox formations have been mapped as one unit partly because of poor exposure, but largely because of differences in lithology from rocks of equivalent age in the Catawba and Salem blocks.

Distribution and Thickness

The Upper Knox formations in the Christiansburg window comprise a belt running east-northeast across the central part of the map area. The outcrop belt ranges in width from 900 to 1800 feet, and is a part of the northwest flank of the Christiansburg anticline. A smaller exposure of Upper Knox is present on the southeast flank where it is in contact with the Pulaski fault block along the southern edge of the Christiansburg window. A thickness of about 1100 feet is shown on the structure sections (Plate 1).

Description

The Upper Knox formations consist of light-to medium-gray, fine-to medium-grained, medium-bedded dolomite, and at least locally, are interbedded with medium-to dark-blue-gray, fine-grained, thin-bedded limestone. Large areas of this belt are heavily littered with medium-gray to light-tan, blocky, chert float. The chert rarely crops out, but the large amount of float indicates a much greater percent of chert in the rocks than those of similar age on the Catawba and Salem blocks.

Outcrops of interbedded limestone and dolomite containing elongate, dark gray, chert clasts are located in a farm yard on the east side of Montgomery County Road 661, about 0.4 mile from its intersection with U.S. Highway 11, west of Christiansburg. These beds are just above the Copper Ridge Formation and are probably equivalent to the Chepultepec Formation. Limestones of the Longview type are located southwest of U.S. Highway 11 west of Christiansburg at the intersection of Montgomery County Road 662 and a dirt road leading northeast back to U.S. Highway 11. These limestones are blue-gray, medium-bedded and contain dolorhombs and impressions of snails weathering out on the exposed bedding surfaces. Impressions of Lecanospira in blocks of chert are found at about this same horizon elsewhere along this belt.

<u>Middle Ordovician Limestones</u>

<u>Name and Age</u>

The Middle Ordovician limestones present on the Catawba fault block were divided by Gilbert (1953) into four formations: the New Market Limestone, the Whistle Creek Limestone, the Lincolnshire Limestone and the Botetourt Limestone. Within the Christiansburg window, the limestones of the Saltville fault block which lie disconformably on the Upper Knox formations have not been differentiated (Plate 1). Although Hergenroder (1957) assigned the names Lenoir Limestone and Fetzer Limestone to this same belt of limestones in the Radford area, no attempt is made to assign formational names to these limestones in the Christiansburg area until both the micro- and megafossils have been studied.

<u>Distribution and Thickness</u>

The Middle Ordovician limestones on the Catawba fault block crop out in a belt running northeast, southeast of Montgomery County Road 723 in the northeast corner of the map area. The limestones which belong to the belt mapped by Eubank (1967) and Ritter (1969) are overlain by the Liberty Hall Formation. All these Middle Ordovician units are terminated on the south by the Ellett Road fault. Ritter (1969) reports an exposed thickness of up to 200 feet, which compares favorably with a thickness of about 250 feet close to the Ellett Road fault.

The band of Middle Ordovician limestones on the Saltville block run generally east across the north-central part of the area where they constitute the steep to overturned north limb of the Christianburg anticline. The limestones also crop out sporadically in a belt along the western edge of the area about 2500 feet northwest of the main outcrop. In this second belt, the limestones are in part covered by Martinsburg shale and together they form a small northeast plunging anticline. An overturned section of Middle Ordovician limestone is exposed in Crab Creek at Cemetery Ford along Montgomery County Road 661. Also, along the north edge of the Christiansburg window southwest of the intersection of the road leading to the Round Meadow Country Club and Montgomery County Road 661, several large blocks of Middle Ordovician limestone are mixed in with blocks of Upper Knox dolomite in a fractured and faulted zone.

The thickness of the Middle Ordovician limestones in the Christiansburg area is about 350 feet.

Description

The Middle Ordovician limestones on the Catawba fault block are poorly exposed. The outcrops present are light-to medium-gray, fine-to medium-grained, and medium-bedded. They contain pebble-size intraformational clasts of limestone.

The Middle Ordovician limestones on the Saltville fault block are principally a reefy facies. Lithologically the section is different from that of the Catawba block. Until a study of the fossils of this reefy facies is made, no correlation with the units of the Catawba block is attempted.

The main band of Middle Ordovidian limestones is best exposed at three localities. The first is along the west side of the small stream which empties into Crab Creek west of Christiansburg, Virginia. This locality is about 1100 feet west of the entrance to the Christiansburg sewage disposal plant and south of the Norfolk and Western Railway right-of-way.

Although the actual contact with Knox dolomite is covered, dark gray, very coarse grained, thick-bedded to massive reefy limestones occur low in the sequence. Some of the reefy limestone beds are extremely fossiliferous; bryozoan and gastropod fragments weather in relief on the bedding surfaces. An excellent outcrop of this fossiliferous reef facies is located 600 feet west of the stream along the outcrop belt. The limestones above the reef facies are medium to dark blue-gray, fine-to coarse-grained, and thin to slabby bedded; they contain stringers and nodules of medium-to dark-gray chert.

The second exposure of the Middle Ordovician limestones is in a pasture about 1000 feet due east of the westernmost intersection of Montgomery County Road 662 and U.S. Highway 11, west of Christiansburg. A large sinkhole in the northeast corner of this intersection has developed in the limestones and marks the trace of their outcrop belt. Here the contact with the Knox dolomite and the lower reefy facies is covered, but the limestones higher in the sequence are similar to those described above.

The third and best exposed section of the Middle Ordovician limestones is representative of the belt exposed in the Christiansburg window. The rock crops out in a stream bed and strikes northeast with a nearly vertical dip. The section is described in the following geologic section.

Geologic Section 1. <u>In a stream bed, 200 feet west of a farm road, 0.5 mile southwest of the Christian Fellowship Evangelistic Tabernacle, U.S. Route 11, west of Christiansburg, Montgomery County, Virginia</u>

	Thickness Ft.	In.
Liberty Hall formation or Liberty Hall equivalent		
9. Limestone, fine-grained, light-to medium-gray, medium-bedded, weathers to light blue;		

interbedded with dark silty limestone which weathers to dark tan; banded; nodules and stringers of dark gray chert which weather to light tan and knobby relief; veins of white calcite up to 1/2 inch. Upper contact is edge of Christiansburg window.	47	0

Middle Ordovician limestones (355 feet)

8. Limestone, dark-gray, medium-grained, slabby, weathers light blue; medium-gray chert nodules; bryozoan fragments. Beds toward top of unit become contorted, calcite veins appear, less fossiliferous.	191	6
7. Covered	19	0
6. Limestone, medium-gray, medium to coarse-grained, medium-bedded, silicified bryozoan fragments weathering in relief; nodules of dark gray chert, calcite veins.	4	0
5. Covered	20	6
4. Limestone, medium-gray, medium-to coarse-grained, thin-to medium-bedded, slabby; similar to unit 6, but more thinly bedded or slabby	7	0
3. Covered	42	0
2. Limestone, medium-gray, medium-to coarse-grained, medium-to thick-bedded; interbedded with light-to medium-grained, recrystallized limestone; beds up to 4 inches thick contain bryozoan and gastropod fragments; medium-gray chert stringers up to 1.5 feet long; dark gray chert nodules containing dolorhomb cavities and pyrite; solution cavities; calcite veins up to 1/8 inch perpendicular and parallel to bedding; 19 feet from the base, a 2-foot layer of algal limestone containing large bryozoan fragments	25	0
1. Limestone, light to medium-gray, medium-grained, medium bedded; recrystallized; anastomosing silty layers weathering to a buff color; detrital chert and dolomite clasts up to pebble size.	46	6

Erosional contact with the Upper Knox dolomite.

This section is similar lithologically to the limestone measured by Hergenroder (1957, Geologic Section 2) at the mouth of the Little River in the Radford, Virginia, area. Hergenroder's thickness of 327 feet compares favorably with the 355 feet of the above section and it is part of the same outcrop belt.

Liberty Hall Formation

Name and Age

The Middle Ordovician Liberty Hall Formation was named by Campbell (1905) for exposures near Lexington, Rockbridge County, Virginia. Cooper and Cooper (1946) applied the name Liberty Hall facies to the black limestone and shales of the Edinburg Formation.

Distribution and Thickness

In the area, limited exposures of the Liberty Hall Formation occur on the Catawba fault block in the extreme northeast corner of the map area. Eubank (1967) estimates the thickness of this belt of Liberty Hall south of Ellett, Virginia at about 1200 feet.

The black shaly facies of the Liberty Hall as described by Cooper and Cooper (1946) is apparently absent on the Saltville block. However, graptolite-bearing, black shale, which was probably derived from the Saltville block, was found on the Pulaski fault block adjacent to the north edge of the Christiansburg window by Dr. B.N. Cooper (oral communication, July,1969). This small patch of shale is located about 1000 feet north of the Christiansburg window on the north side of the Norfolk and Western Railway and a farm road, 0.4 mile west of the entrance to the

Christiansburg sewage disposal plant. This is the only Liberty Hall shale found near the Christiansburg window.

As previously noted banded limestone occurs locally above the Middle Ordovician limestones of the Saltville block along the north edge of the Christiansburg window (Plate 3B). This limestone may be equivalent to the shaly facies of the Liberty Hall and can be seen at the three locations described in the preceding section. The exposed thickness of this banded limestone is about 47 feet (Geologic Section 1).

Description

The Liberty Hall Formation on the Catawba fault block consists of dark gray calcareous shales which weather to olive-to light-tan chips. The small patch of Liberty Hall near the Christiansburg window is of a similar lithology. Eubank (1967) collected trilobite, gastropod, graptolite and calyptotomitid fragments from the shales on the Catawba block to the northeast.

Rocks which may be equivalent to the Liberty Hall above the Middle Ordovician limestones in the Christiansburg window consist of light-to medium-gray, fine-to medium-grained, medium-bedded limestone interbedded with a darker, silty limestone which weathers to a dark tan color. The weathered rock has a banded appearance. Nodules and stringers of dark gray chert weather to light tan and stand out in relief on the bedding surfaces. Veins of white calcite, up to 1/2 inch in thickness, are also present.

Martinsburg Formation

Name and Age

The Middle and Late Ordovician Martinsburg Shale was named by Geiger and Keith (1891) for exposures near Martinsburg, Berkeley County, West Virginia. In the Draper Mountain area, to the west, Cooper (1939) notes that the Martinsburg includes beds of the Trenton, Eden and Maysville groups.

Distribution and Thickness

The Martinsburg Formation in the Christiansburg area is exposed along the western boundary of the map in the eastern end of the Ingles-Barringer Mountain window and a smaller unnamed window to the south. The Martinsburg in both these windows covers Middle Ordovician limestones and together they form the southeast flanks of smaller anticlines on the crestal portion of the larger Christiansburg anticlinorium (Plate 1). The best exposures of the Martinsburg are in the eastern end of the Ingles-Barringer Mountain window along Montgomery County Road 720. Cooper (1961) states that the thickness of the Martinsburg in these windows is not over 800 feet which compares favorably with the thickness shown in structure section A-A' (Plate 1).

Description

The Martinsburg Formation in the Christiansburg area is confined to the Saltville fault block. The Bays Formation, which lies conformably below the Martinsburg on the Catawba flock to the northeast, is apparently absent on the Saltville block in this area. Exposures of Martinsburg in the Christiansburg area consist of olive and yellowish-brown weathering shale and siltstone with interbeds of medium- to dark-gray, fine- to medium-gray, thinly bedded and slabby limestone. The shales and limestones of the Martinsburg are quite fossiliferous in places. Prasopora occurs in slabby limestone float on a hill north of Montgomery County Road 661, about 1000 feet west of Cemetery Ford.

The shales exposed in the east end of the Ingles-Barringer Mountain window along Montgomery County Road 720 contain abundant finely ribbed brachiopods and bryozoans on their weathered surfaces. The bedding in these shales has been partially obliterated by fracture cleavage. In pastures northeast of this locality small, doubly terminated quartz crystals are found in the soil derived from the Martinsburg (H. D. Christman, oral communication, August, 1969).

Younger Paleozoic Formations

The Christiansburg area is a part of a larger window complex in the vicinity of Radford, Christiansburg and Blacksburg, Virginia, which exposes rocks of the Saltville fault block ranging in age from Cambrian to Mississippian. The oldest rocks are the Cambrian pre-Copper Ridge dolomite in the Christiansburg window. In the westward extension of the Ingles-Barringer Mountain window, Hergenroder (1957) mapped Silurian sandstones and Devonian shales and siltstones. To the north, Cooper (1961) and Ritter (1969) report Mississippian sandstones and shales in the large Price Mountain window.

Northeast of the Christiansburg area, the Salem synclinorium (Tillman and Lowry, 1968) also contains strata ranging in age from Cambrian to Mississippian. The Liberty Hall is the youngest formation in this sequence that is exposed within the map area. Younger units in the Salem synclinorium include Silurian sandstones and Devonian and Mississippian sandstones and shales.

Quaternary System

Surficial Deposits

Local deposits of alluvium, colluvium and small amounts of calcareous tufa are present locally in the Christiansburg area, but were not mapped. The alluvium consists of well-rounded, pebble to large cobble-size quartzite and vein quartz of the type common to the Blue Ridge Province. These cobbles are abundant along the leading edge of the Max Meadows fault block, where farmers have collected them from the fields. Smaller cobbles of the same type are found west of the WJJJ Radio Station tower along the Norfolk and Western Railway spur leading to Merrimac, Virginia. Chemically precipated calcareous tufa is present locally in and along the stream in the eastern part of the area, but thickness rarely exceeds a few feet.

STRUCTURAL GEOLOGY

General Statement

The Christiansburg area is within a section of the Appalachian Valley and Ridge Province that, though less than 30 miles wide, contains the trace of seven major reverse faults. From the Blue Ridge northwest to the Appalachian Plateau the faults are the Blue Ridge, Max Meadows, Salem, Pulaski, Saltville, Narrows and St. Clair thrusts (Figure 5). The local area contains evidence concerning the nature of the low-angle thrust faults in the Appalachian Valley in Southwest Virginia.

The Christiansburg area can be divided into five major fault blocks, (Figure 6), which are probably genetically related to a single thrust mass (Tillman and Lowry, 1968). The Saltville fault block is structurally the lowest block exposed in the area. The Catawba syncline, northeast of Christiansburg, is considered by Cooper (1961) and Ritter (1969) to be a parautochthonous part of the Saltville block. Others including Campbell (1925), Butts (1933), and Hazlett (1968) believe it to be a part of the Pulaski fault block which has been thrust northwest over the Saltville block. Locally, the Pulaski fault block has been eroded through to form windows which expose the overridden strata. Within the area mapped (Plate 1), from southeast to northwest, these windows are the Christiansburg window, a smaller unnamed window and the eastern end of the Ingles-Barringer Mountain window. The Salem fault block is essentially a part of the Pulaski block as the Salem fault was developed within the Pulaski block. The Salem fault block contains beds which are repeated by further faulting of the block. The Max Meadows fault block, which forms the south edge of the map area, is structurally the highest block and contains the oldest exposed beds in the Christiansburg area.

The following points were established during the detailed mapping of the Christiansburg area.

1. A major anticlinorium of the Saltville block is responsible for the numerous windows of the Pulaski thrust sheet in the Christiansburg-Radford area. The anticlinorium and window complex, which trends generally east, extends from Christiansburg Mountain to Claytor Lake, about 17 miles. The complex measures about 3 miles in a north-south direction (Figure 5).

2. From south to north, successively younger Saltville block rocks are exposed in the windows of the Pulaski thrust sheet.

3. The south side of the Christiansburg window is bounded by the Pulaski fault which is in turn terminated by the Max Meadows fault (Figure 6).

4. The north side of the Christiansburg window is bounded by a relatively high-angle reverse fault which cuts the Saltville and Pulaski-Salem fault blocks (Figure 6).

5. The extremely brecciated and fractured rocks of the Pulaski fault block between the north side of the Christiansburg window and Virginia Route 114 to the north suggest that the Pulaski fault is not far below the surface.

6. The writer believes the Pulaski fault block has overridden the southwest margin of the Catawba syncline (Figure 6).

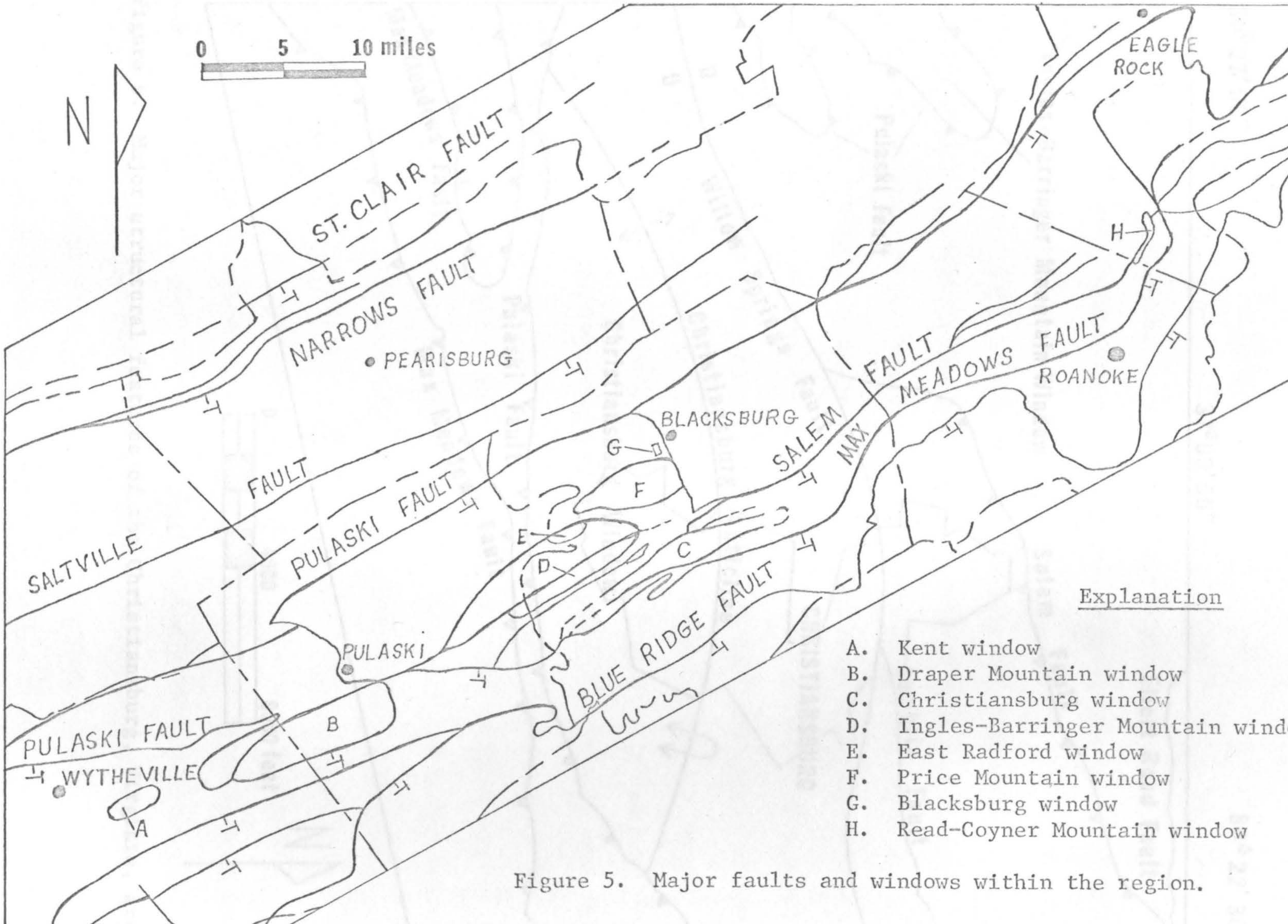
7. The Salem fault block contains Cambrian to Lower Ordovician strata and dies out west of Christiansburg, Virginia (Figure 6).

8. The rocks on the Salem fault block in the Christiansburg area are steeply dipping to overturned and are repeated by a high-angle reverse fault within the block (Structure section B-B', Plate 1).

9. The high-angle reverse faults bounding the windows in the

Christiansburg-Radford area are not directly connected with the Salem fault (Figure 6).

10. The writer believes that the fault block that has been thrust over the Saltville block west of Christiansburg is not the same fault block containing the Catawba syncline.



<u>Explanation</u>

A. Kent window
B. Draper Mountain window
C. Christiansburg window
D. Ingles-Barringer Mountain window
E. East Radford window
F. Price Mountain window
G. Blacksburg window
H. Read-Coyner Mountain window

Figure 5. Major faults and windows within the region.

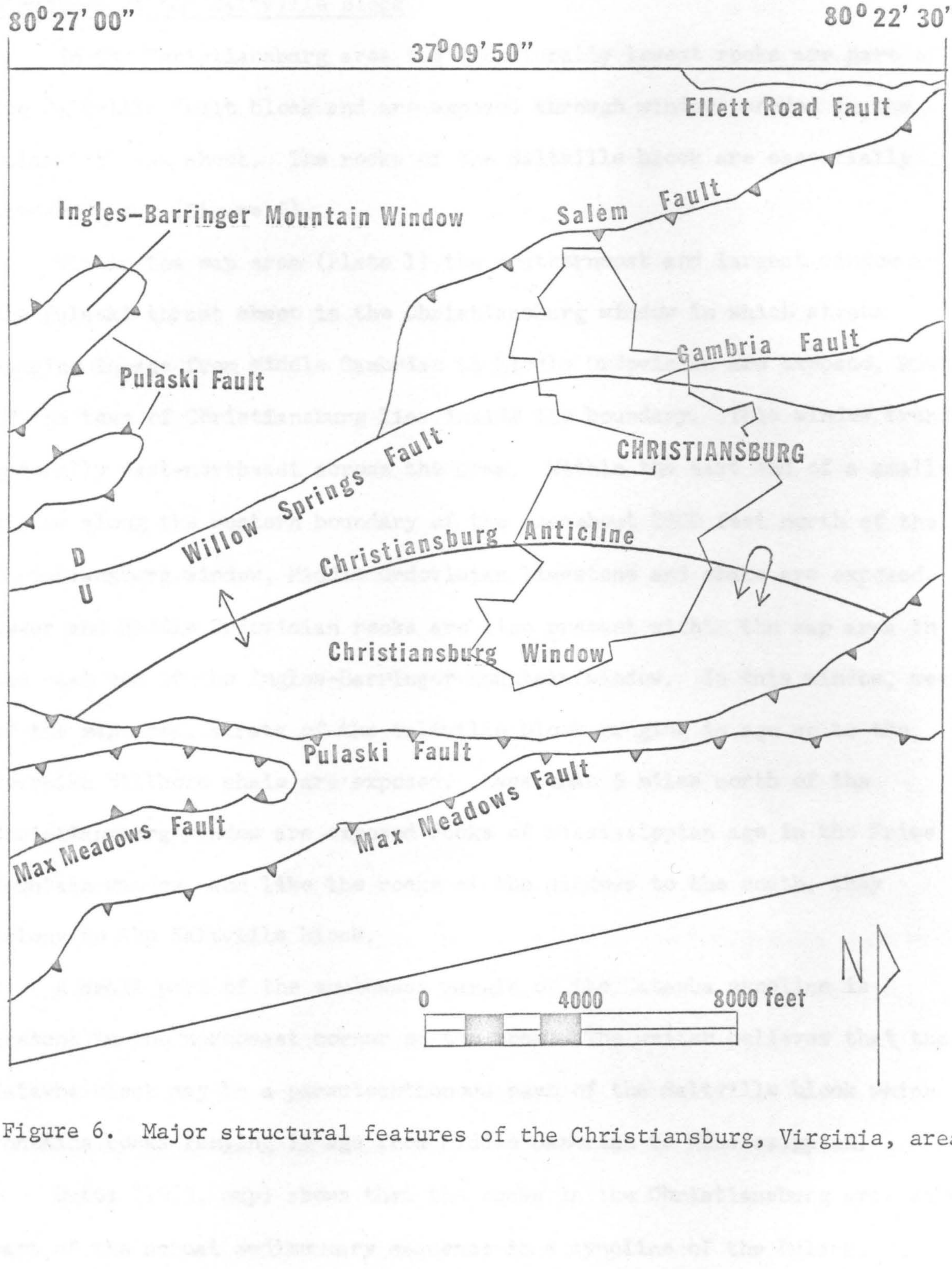


Figure 6. Major structural features of the Christiansburg, Virginia, area.

The Saltville Fault Block

Structure of the Saltville Block

In the Christiansburg area the structurally lowest rocks are part of the Saltville fault block and are exposed through windows eroded in the Pulaski thrust sheet. The rocks of the Saltville block are essentially autochthonous (Figure 5).

Within the map area (Plate 1) the southernmost and largest window in the Pulaski thrust sheet is the Christiansburg window in which strata ranging in age from Middle Cambrian to Middle Ordovician are exposed. Most of the town of Christiansburg lies inside its boundary. This window trends generally east-northeast across the area. Within the east end of a smaller window along the western boundary of the area about 2000 feet north of the Christiansburg window, Middle Ordovician limestone and shale are exposed. Lower and Middle Ordovician rocks are also present within the map area in the east end of the Ingles-Barringer Mountain window. In this window, west of the map area, strata of the Saltville block ranging in age up to the Devonian Millboro shale are exposed. Less than 5 miles north of the Christiansburg window are exposed rocks of Mississippian age in the Price Mountain window, and like the rocks of the windows to the south, they belong to the Saltville block.

A small part of the southwest margin of the Catawba syncline is present in the northeast corner of the area. The writer believes that the Catawba block may be a parautochthonous part of the Saltville block which contains rocks ranging in age from Middle Cambrian to Mississippian.

Butts (1933, map) shows that the rocks in the Christiansburg area as a part of the normal sedimentary sequence in a syncline of the Pulaski thrust sheet. He shows the southeast limb of this syncline overridden by the Blue Ridge fault and the northwest limb broken by a high-angle fault which he mapped as the Salem fault. Dietrich (1954) recognized the contact between the Cambrian Rome and Elbrook formations immediately south of Christiansburg as a thrust fault rather than a normal sedimentary contact in a syncline. In his report he called this fault the Christiansburg thrust. Hergenroder (1957) was able to show that the Christiansburg thrust is the Max Meadows fault mapped by Cooper (1939) in the Draper Mountain area. Cooper (1964, Fig. 19) shows some of the rocks in the Christiansburg area to be a part of the Saltville block, but complicated to the northwest by several high-angle reverse faults which he thought were western branches of the Salem fault. He considered the Middle Ordovician limestones a part of the Pulaski thrust sheet rather than a part of the Saltville block. He shows the Max Meadows fault block as directly overlying the Cambrian Elbrook Formation which was included as a part of the Saltville block. He also shows the Pulaski fault, which is ordinarily beneath the Max Meadows fault, as merging with the Max Meadows fault somewhere above the present land surface.

Mapping of the Christiansburg area by the writer shows that the extremely narrow belt of Cambrian Elbrook south of Christiansburg belongs to the Pulaski thrust sheet and that it in turn has been overridden by the Max Meadows fault block (Structure Section B-B', Plate 1). The Elbrook is not in normal sedimentary contact with the younger Knox carbonates.

The rocks of the Saltville block in the Christiansburg area are part of a large asymmetric anticlinorium which will be referred to as the Christiansburg anticlinorium in this report. As already noted, the

Christiansburg anticlinorium is responsible for the several windows in the Christiansburg-Radford area. These windows are the Christiansburg, Ingles-Barringer Mountain and East Radford windows. The Christiansburg anticlinorium trends east-northeast and is complicated by minor folding along its crest. The largest of these folds, herein called the Christiansburg anticline, is exposed in the Christiansburg window.

The Christiansburg anticlinorium is flanked on the northwest by the large Blacksburg synclinorium (Cooper, 1961) whose long northwest limb extends northwest to the Saltville fault. Saltville block rocks of the trough portion of the Blacksburg synclinorium are concealed by the Pulaski thrust sheet except where they appear in the Price Mountain window (Figure 7). Saltville block rocks farther up the northwest limb reappear at the foot of Brush Mountain.

Gravity data collected by Dr. C.E. Sears (oral communication, November, 1969) suggest that a large syncline exists southeast of the Christiansburg anticlinorium and is hidden beneath the Max Meadows and Blue Ridge fault blocks. He refers to this syncline as the Riner-Claytor Lake syncline and states that it is separated from the Blacksburg syncline by a medial anticline he refers to as the Christiansburg anticline. His Christiansburg anticline is the Christiansburg anticlinorium mapped by the writer, and may tie in with the Draper Mountain anticline mapped by Cooper (1939) near Pulaski, Virginia. Dr. Sears (oral communication, November, 1969) refers to the Blacksburg and Riner-Claytor Lake synclines and the intervening Christiansburg anticline as the Montgomery synclinorium.

The Christiansburg Anticline

The Christiansburg anticline is an asymmetrical to overturned

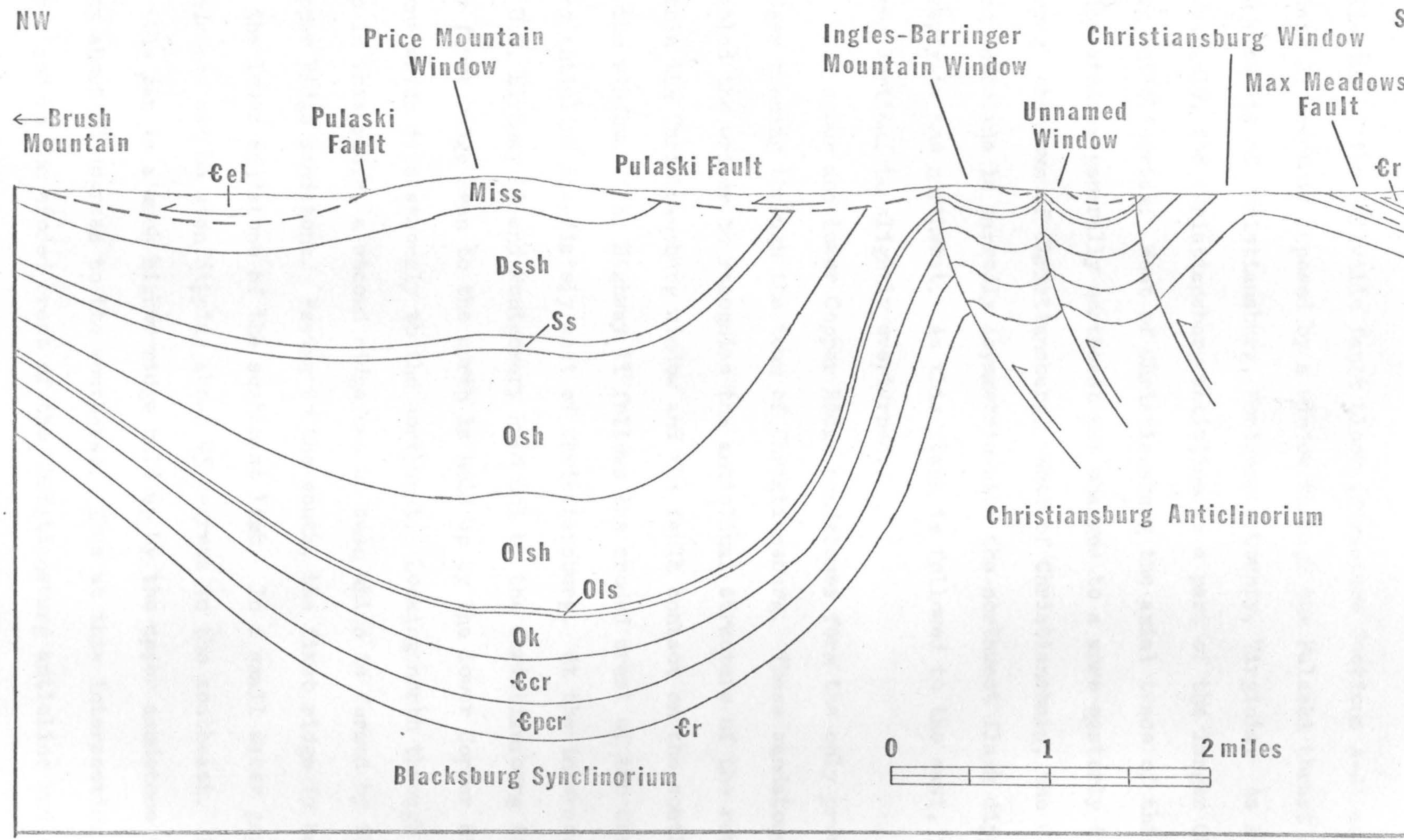


Figure 7. Diagrammatic structure section across the Christiansburg anticlinorium and the Blacksburg synclinorium. Land surface is about 2200 feet. Depth to the Cambrian Rome Formation, about 19,000 feet. Sh.- shale; s.- sandstone; ssh.- sandstone-shale; ls.- limestone; Ok- Knox; Ꞓcr- Copper Ridge; Ꞓpcr- pre-Copper Ridge carbonates; Ꞓr- Rome.

anticline of the Saltville fault block (Structure Sections A-A' and B-B', (Plate 1) which is exposed by a window through the Pulaski thrust sheet in the vicinity of Christiansburg, Montgomery County, Virginia. As stated previously, the Christiansburg anticline is a part of the larger Christiansburg anticlinorium. West of Christiansburg the axial trace of this anticline strikes generally northeast but changes to a more easterly trend through the town of Christiansburg. West of Christiansburg, the Christiansburg anticline is markedly asymmetric with the northwest flank dipping steeply to the northwest. As this flank is followed to the east, it becomes vertical to slightly overturned.

The upper and lower Copper Ridge sandstones form the only prominent ridges running through the town of Christiansburg. These sandstone ledges enabled the writer to recognize the anticlinal structure of the rocks within the Christiansburg window and the fault contact on the south side of the window. U.S. Highway 11 follows the eroded crest of the Christiansburg anticline immediately west of Christiansburg. At the intersection of U.S. Highway 11 and Montgomery Road 661 by the Christiansburg fairgrounds, the first ridge seen to the north is held up by the lower Copper Ridge sandstone which dips strongly to the northwest. Looking north through a water gap in this ridge, a second ridge can be seen which is formed by the upper Copper Ridge sandstone. Facing to the south, the first ridge is held up by the lower sandstone of the southeast limb. In a small water gap this sandstone can be seen dipping about 45 degrees to the southeast. South of this gap is a much higher ridge held up by the upper sandstone which dips about 23 degrees to the southeast. Thus at this intersection one can stand in the eroded crest of the Christiansburg anticline and see both the northwest and southeast flanks of the anticline.

The eroded crest of the Christiansburg anticline exposes pre-Copper Ridge dolomite which is probably equivalent in age to the Cambrian Elbrook and the "Dolomites of Uncertain Age" discussed by Ritter (1969) in the Blacksburg area. Although exposures of this dolomite are poor, enough was seen to distinguish the difference in lithology from the overlying Copper Ridge Formation. The contact was placed at the base of the sandstone considered to be the base of the Copper Ridge formation (Aronson, 1966).

As previously noted, the northwest limb of the Christiansburg anticline is steeply dipping to the northwest in the western part of the area and becomes vertical to overturned farther to the east. The exposed portion of the northwest limb contains a stratigraphic section extending from Middle to Late Cambrian carbonates up into the Middle Ordovician limestones. The Pulaski fault block covers this limb on the northwest, but the actual surface contact is a high-angle reverse fault which cuts both the Saltville and Pulaski blocks. The fault is called the Willow Springs fault in this report and is discussed later.

The southeast limb is composed of the Upper Cambrian Copper Ridge and Lower Ordovician Knox formations which dip 20 to 40 degrees beneath the Elbrook carbonates of the Pulaski fault block. As previously noted, the Elbrook Formation which Cooper (1964, Fig. 19) thought to be in normal contact with the Copper Ridge in a syncline of the Saltville block is a part of the Pulaski fault block. The Pulaski fault dips beneath and probably merges with the Max Meadows fault whose trace is only about 700 feet farther south at their closest points. The southeast limb is broken by an apparently right-lateral fault which offsets the Copper Ridge and Upper Knox formations immediately south of the town limits of Christiansburg. Movement along this fault dies out to the northeast; the rocks on the north flank of the anticline do not seem to be affected by it.

The plunge of the Christiansburg anticline within the map area could not be accurately determined as the main body of the structure is covered by the Pulaski fault block. The change in strike of the beds west of Christiansburg may indicate a plunge to the west. However, to the east, the Christiansburg anticlinorium appears to plunge rather strongly to the east. West of Radford it plunges southwest before reversing its plunge to reappear in the Draper Mountain area. This agrees with the gravity data collected by Dr. C. E. Sears (oral communication, November, 1969) which indicates that the Christiansburg anticlinorium is doubly plunging.

Several large blocks of interbedded quartzite and sandstone, in part characterized by a brecciated structure, were found between the upper and lower Copper Ridge sandstones in the eroded crestal portion of the Christiansburg anticline. These blocks are in a pasture on the southeast flank of the anticline, about 1000 feet south of the water gap in the lower sandstone behind the Christiansburg fairgrounds. The blocks are randomly oriented and are believed to represent part of the main zone of upper Copper Ridge sandstone, which in this area appears to have been cut off by the Pulaski fault a short distance to the south. They probably are remnants of the rocks that once overlay the crest of the Christiansburg anticline and which have been let down to their present position as the underlying carbonates were dissolved. These blocks could have been clipped off by the advancing Pulaski thrust sheet and dragged along to their approximate present position. This would indicate that the Pulaski thrust decapitated the crestal and upper portion of the southeast limb of the Christiansburg anticline at about the horizon of the upper Copper Ridge sandstone.

The Pulaski Fault Block

The Pulaski Fault

The Pulaski fault was named by Campbell and Holden (Campbell and others, 1925) for the town of Pulaski, Pulaski County, Virginia through which the fault passes. They traced the fault from Timberidge, Greene County, Tennessee, northeast to the vicinity of Eagle Rock in Botetourt County, Virginia. Butts (1933) extended the Pulaski fault northeast to Greenville, Augusta County, Virginia. Cooper (1946) stated that the Pulaski fault could be traced northeast from Greenville to Staunton, Virginia, the type locality of the Staunton fault, and concluded that the Staunton fault is the northeast extension of the Pulaski fault. Cooper (1960) stated that the Pulaski fault and its associated breccia can be recognized southwest of Marion, Virginia, and traced to the vicinity of Newport, Tennessee, where it passes beneath the Blue Ridge fault.

Cooper (1961) pointed out that the main trace of the Pulaski fault does not extend along the northwest side of the Catawba syncline as mapped by Campbell and Holden (1925). He believed that this fault was a northeastward extension of the Tract Mountain fault; thus the Catawba syncline would be parautochthonous like the Saltville block. He stated that the Pulaski fault swings southeast, as marked by a breccia zone, passes through Blacksburg, and continues southeast to the Yellow Sulphur Springs where it is terminated by the Salem fault. Ritter (1969) called the trace of this fault the Yellow Sulphur Fault Line and interpreted it to be a high-angle reverse fault with little displacement. He found that the fault cuts the Pulaski fault block, a postulated fault (his Catawba fault), beneath the Catawba syncline, and the Mississippian rocks of the Saltville block exposed in the east end of Price Mountain window. Cooper (oral communication, October, 1969) later stated that he no longer believes that the fault along the northwest side of the Catawba syncline is the Tract Mountain fault, but neither does he think it is the Pulaski fault. He now believes that the Pulaski fault swings southeast through Blacksburg and Yellow Sulphur to form a major reentrant around the Catawba syncline.

South of Christiansburg the Pulaski fault trends generally east. The Pulaski thrust sheet overlies most of the south limb of the Christiansburg anticline. The thrust sheet not only bounds the south edge of the Christiansburg window, but also the windows to the north. The Pulaski thrust sheet is adjacent to the north side of all the windows in the Christiansburg area, but, in the Christiansburg and Ingles-Barringer Mountain windows, it is broken by high-angle reverse faults which cut both the Saltville and Pulaski blocks at the contact of overthrust and window rocks.

Along the southern boundary of the map area, the Pulaski block is overridden by the Max Meadows fault block. Immediately south of the town limits of Christiansburg, the leading edge of the Max Meadows block is less than 700 feet from the rocks of the Saltville block in the Christiansburg window. The belt of Pulaski block rocks between the Max Meadows fault and the Christiansburg window does, however, widen to both the east and west of this point, but nowhere is the block more than one mile wide. In the northeastern part of the area the Pulaski thrust sheet is overlapped by the Salem fault block, which is considered an imbrication of the Pulaski sheet. The leading edge of the Salem fault block enters the area in the northeast corner of the map area and the fault trends southwest to about the Christiansburg sewage disposal plant where it terminates. From this point east to the eastern boundary of the map area, it is rocks of the Salem fault block rather than the Pulaski thrust sheet that border the Saltville block rocks of the Christiansburg window. West of the termination of the Salem fault, essentially all the rocks between the window complex and the Price Mountain window to the north belong to the Pulaski thrust sheet proper.

The Pulaski fault block in the Christiansburg area is made up predominantly of the Upper Cambrian Elbrook Formation. Small patches of Cambrian Rome are present locally (Plate 1). Some of these Rome patches are probably remnants of the eroded Max Meadows block; however, others adjacent to or near known faults could be blocks which were clipped off the underlying Rome Formation and carried along by the advancing Pulaski fault block. The Rome on the crest of a hill north of Montgomery County Road 661, west of Cemetery Ford, may be an example of this later origin.

Butts (1940) gave an estimate of 20 miles for horizontal northwestward movement of the Pulaski thrust. Hergenroder (1957) gives a minimum of 8 miles and a maximum of 10 miles movement along the Pulaski fault in the Radford area, whereas Cooper (1939) states the Pulaski fault moved northwest at least 11 miles and probably more in the Draper Mountain area. In the Christiansburg area a movement of at least 9 miles is indicated. This is the distance from the leading edge of the Pulaski fault along the southeast foot of Brush Mountain to the south edge of the Christiansburg window.

Structure within the Pulaski Block

The Pulaski fault must be very close to the surface in the Blacksburg-Christiansburg-Radford area as evidenced by the numerous windows through the thrust sheet. Supporting this premise is the chaotic structure of the rocks of the Pulaski block surrounding the windows. In the western and central parts of the Christiansburg area, the Elbrook Formation of the Pulaski block between the north edge of the Christiansburg window and Virginia Route 114 is extremely fractured, with widespread zones of tectonic breccia. Most of the breccia is the crush conglomerate described by Cooper and Haff (1940) in their report on the breccias associated with the Pulaski fault. They describe this breccia as a matrix of finely ground phyllite, limestone and dolomite with angular and rounded pebbles and clasts of limestone and dolomite. The breccia ranges in size from small isolated patches to zones up to several hundred feet across. Also, as previously stated, patches of Cambrian Rome shale are present within or on top of the Pulaski fault block. As noted previously the shale and breccia may be interpreted two ways.

Cooper (1946) suggested that the breccias associated with Pulaski faulting may have intrusive relations with the rocks of the Pulaski fault block. Also, high-angle reverse faults locally cutting the Pulaski block may allow large amounts of crush conglomerate and breccia to be dragged upward with the upthrown block. The fractured and brecciated nature of the Pulaski block in the Christiansburg area make this interpretation a distinct possibility. If the Pulaski fault is not far below the surface, the breccia generated during its movement could be brought to the surface along fractures and faults in the lower part of the fault block. The Rome shales within the Pulaski block could have been plucked from the top of the underlying Rome formation at irregularities in the fault surface and carried along as the fault advanced.

The second interpretation of the blocks of Rome and breccias is that the Rome structurally overlies the Elbrook with the two formations separated by the Max Meadows fault. Hergenroder (1957) states that the Max Meadows fault extended at least to the south side of the Ingles-Barringer Mountain window before being eroded back to the present fault trace. Ritter (1969) considers the Rome present in the Blacksburg area, several miles to the north, to be erosional remnants of the Max Meadows fault block. This would mean that both the Pulaski and Max Meadows fault blocks moved a minimum distance of several miles (unless Max Meadows faulting pre-dates Pulaski faulting, which no one has advocated). If this interpretation be correct, then the Rome shales on the Pulaski block in the Christiansburg area could also be considered remnants of the Max Meadows block.

The chaotic nature of the Pulaski block could have been generated by the initial movement along the Pulaski fault with further fracturing as the Max Meadows fault block advanced. The Max Meadows block has certainly overridden the Elbrook of the Pulaski block south of Christiansburg. Therefore, much of the post-Cambrian section had to be removed somehow before or during Max Meadows thrusting unless that section was carried forward by the Pulaski sheet, leaving the Elbrook behind and bare.

The writer believes a study of the breccia and Rome shales within the Pulaski block would contribute much toward determining which of the above interpretations is better.

Windows in the Pulaski Block

The size of each window in the Pulaski thrust sheet is proportional to the size of the anticlinal fold which developed in the crestal portion of the larger Christiansburg anticlinorium beneath. The south side of each of the major windows is bounded by the Pulaski fault, whereas high-angle reverse faults cutting both the Pulaski thrust sheet and the underlying Saltville block form the north edge. The apparent parallelism of the Pulaski block and the underlying rocks, and the high-angle faults imply that much of the present structural relief was formed after the emplacement of the Pulaski thrust sheet. The rise of the anticlinorium after Pulaski thrusting promoted sufficient erosion to form the large window complex in the Christiansburg-Radford area.

The southernmost and largest of the windows in the map area, the Christiansburg window, exposes the eroded crest of the Christiansburg anticline. It is bounded on the south by the Pulaski fault and on the north by a high-angle reverse fault called the Willow Springs fault in this report.

Only the extreme eastern end of the large Ingles-Barringer Mountain window is exposed along the west boundary of the map area. The south side of this window is bounded by the Pulaski fault and the north side by a high-angle reverse fault. Hergenroder (1957) and Cooper (1964) considered this fault to be a western extension of the Salem fault cutting both the Pulaski and Saltville blocks, but that no longer seems reasonable as the Salem fault block ends west of Christiansburg. This north border fault probably extends to the east for some distance, but it is difficult to trace the fault through the chaotic structure of the Pulaski fault block. In and adjacent to the map area, the main body of the Ingles-Barringer Mountain window consists of the Ordovician Martinsburg Formation. Farther to the west, Silurian and Devonian rocks, which lie well down the northwest flank of the Christiansburg anticlinorium, are present within the window.

Along the western edge of the map area, the east end of a small window of Ordovician limestone and shale is located about 2000 feet north of the Christiansburg window. Hazlett (1968, Plate 7) refers to this window as the "Christiansburg fenster" which may lead to some confusion as to the nomenclature of this window and the larger one to the south. The writer prefers to leave this smaller window unnamed and use the name Christiansburg window to designate the window in the vicinity of Christiansburg. Hergenroder (1957) mapped the west end of this window and also left it unnamed. He states that it is actually not a window, but a high-angle fault block bounded on the north and south sides by the Shrouds Creek and Claytor Dam faults respectively. Although these two faults are present in the Radford area, they appear to die out before reaching the Christiansburg area, leaving this smaller window surrounded only by the Pulaski fault.

The Willow Springs Fault

The name Willow Springs fault is given to a high-angle reverse fault which trends northeast across the central part of the map area. It limits the north side of the Christiansburg window. The fault runs through the vicinity of Willow Springs, which were formerly the source of water for the town of Christiansburg. The Willow Springs fault cuts the Saltville fault block and depending on the location, either the Pulaski or Salem fault blocks. In the western part of the area, the Middle Ordovician limestones in the Christiansburg window are in contact with the Pulaski fault block along the Willow Springs fault. In the eastern part of the area, these limestones are adjacent to the Cambrian Elbrook and Copper Ridge formations of the Salem fault block. The north side of the limestone inside the window marks the trace of the Willow Springs fault. The fault can nowhere be seen in cross-section; it is assumed that it dips steeply to the southeast.

The basis for the existence of the Willow Springs fault is the way in which the contact between the overthrust and window rocks parallels the Ordovician limestones, the lack of parallelism of the bedding, and the apparent elimination of the Middle Ordovician black shales along the north side of the Christiansburg window. The Middle Ordovician limestones differ very little in thickness as they are traced east to west and are in contact with the overthrust rocks across the entire area of the window. If this contact were erosional, it should be much more uneven than it actually is, as the Pulaski fault is presumed to be dipping at a relatively low angle in the Christiansburg area.

In the western part of the map area where the window rocks are in contact with the Pulaski block, there is a zone of randomly oriented blocks adjacent to the limestones of the Saltville block. These blocks, which represent the Elbrook, Copper Ridge, Upper Knox and Middle Ordovician limestone formations, were originally probably a part of the Saltville block and were detached and rotated in various ways by the overriding Pulaski thrust sheet. It is from within this zone of jumbled blocks that part of the Willow Springs originate. Where the Salem fault block is in contact with the window rocks, this chaotic structure along the Willow Springs fault is not seen.

Other High-angle Faults in the Pulaski Block

Northwest of the map area another fault branches from the north side of the Ingles-Barringer Mountain window, trends northwest through Vicker, Virginia, and bounds the north side of the East Radford window. In the map accompanying his text, Cooper (1964) shows the Salem thrust splitting into three high-angle branches west of Christiansburg to form the northern boundaries of the Christiansburg, Ingles-Barringer Mountain and East Radford windows. These faults were found by the writer to have no direct connection to the Salem fault which is terminated immediately west of Christiansburg, Virginia. The faults undoubtedly extend to the east of the windows, but are extremely difficult to trace through the chaotic structure of the Pulaski fault block.

Cooper (1968) attributes the origin of these faults to continued downwarping of the Blacksburg synclinorium after emplacement of the Pulaski thrust sheet. Continued subsidence of the basin folded and faulted both the overthrust and underlying rocks. These faults and the Willow Springs fault were probably formed at about the same time.

The Salem Fault Block

The Salem Fault

The Salem fault was first recognized by W. B. Rogers (1884) and later named by Campbell and Holden (Campbell and others, 1925) for the city of Salem, Roanoke County, Virginia. Campbell and Holden traced the fault southeast from Salem, Virginia, along the southeast edge of the Catawba syncline to the vicinity of the Ingles-Barringer Mountain window. The Salem fault is known to extend northeast of Salem to the vicinity of Read Mountain, northeast of Roanoke, Virginia (Woodward, 1932) and possibly even farther northeast (Hazlett, 1968). As stated previously, Cooper (1964, Fig. 17) shows the Salem fault splitting into three branches west of Christiansburg, Virginia, forming high-angle reverse faults partially bounding the windows of the Christiansburg-Radford area. West of Radford, Virginia, he shows two of the branches merging to become a single fault which extends into the Draper Mountain area.

Edwards (1959), Eubank (1967), Amato (1968), Hazlett (1968) and Ritter (1969) have mapped the Salem fault from Roanoke southwest to Christiansburg, Virginia, as a low-angle thrust fault. They all agree that it originated from within the Pulaski block and was thrust over the southeast limb of the Catawba syncline. The writer believes that at least in the Christiansburg area, the fault along the extreme southwest part of the Catawba syncline is not the Salem fault. The leading edge of the Salem fault block, as interpreted by the writer, occurs southeast of this fault and runs southwest across U.S. Route 460 Bypass and is terminated in the vicinity of the Christiansburg sewage disposal plant (Plate 4A). The rocks between the southeast edge of the Catawba syncline and the Salem fault as mapped by the writer appear to belong to the Pulaski fault block which is present west of Christiansburg.

Structure of the Salem Block

The Salem fault block in the Christiansburg area structurally overlies the Pulaski block and extends from the eastern edge of the map, west to about the Christiansburg sewage disposal plant where it terminates. The south edge of the block is adjacent to the Saltville rocks in the Christiansburg window along the Willow Springs fault. The Salem block contains the stratigraphic section from the Cambrian Elbrook to the Ordovician Longview formation which is overturned and repeated by faulting within the block (Plate 1, Structure section, B-B').

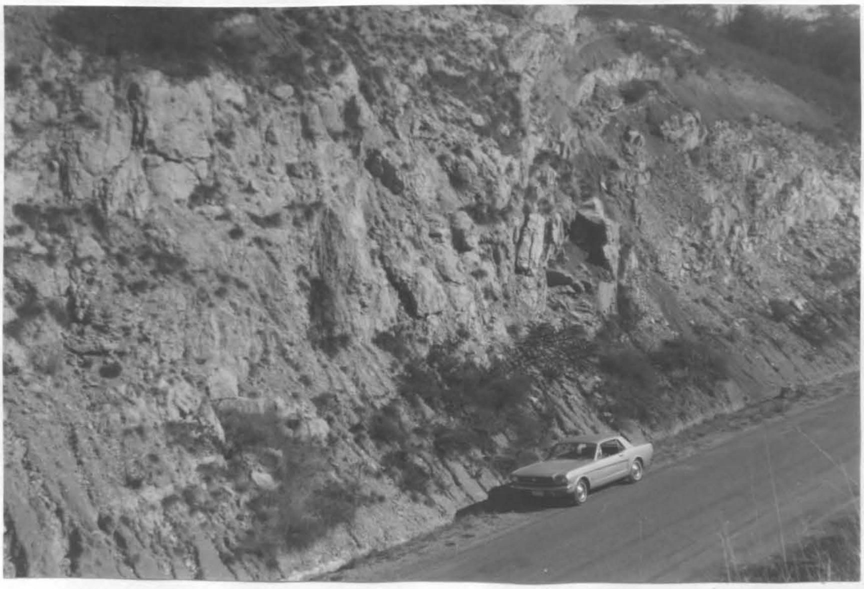
The Salem fault block is complicated by a reverse fault, herein named the Cambria fault, which places the overturned Copper Ridge and Elbrook formations in contact with Elbrook. The trace of this fault can be followed by the enormous amount of tectonic breccia and crush conglomerate outcropping along the Norfolk and Western right-of-way east of Cambria, Virginia. This breccia locally contains blocks of limestone and dolomite up to 50 feet across (Plate 4B). The Cambria fault ends in the vicinity of the Christiansburg Railway Station where it abuts the edge of the Christiansburg window. Just east of the map area, the fault places the slightly overturned Ordovician Chepultepec Formation in contact with the also slightly overturned Cambrian Elbrook across the fault to the north. As the Cambria fault continues southwest into the map area, it cuts obliquely across the section eliminating the carbonates of the Knox Group. The Cambrian Elbrook forms both the hanging and footwall blocks.

The rocks between the Cambria fault and the trace of the Salem

Plate 4.

A. Folded and brecciated strata along the trace of the Salem fault. This road cut is along Montgomery County Road 643 (the Yellow Sulphur Road) where it parallels U.S. Highway 460 Bypass.

B. Tectonic breccia along the Cambria fault exposed in cuts along the Norfolk and Western Railway east of U.S. Highway 460 Bypass. This breccia contains blocks of limestone and dolomite up to 50 feet across.



fault, as herein interpreted, are also overturned to the northwest and from southeast to northwest consist of the Cambrian Elbrook and Copper Ridge formations and the Ordovician Chepultepec and Longview formations. The Ordovician Longview forms the majority of the leading edge of the Salem fault in the Christiansburg area and has been thrust over the Cambrian Elbrook of the Pulaski fault block. Nowhere outside the Christiansburg area have formations as young as Ordovician been reported to form the leading edge of the Salem fault block.

The sandstones in the Copper Ridge Formation were especially useful in determining the structure of the Salem fault block. Along the eastern edge of the map area, the lower Copper Ridge sandstone is overturned and dips steeply to the southeast. This sandstone can be traced southwest to the intersection of Main Street and Montgomery Avenue in Cambria, which is less than 1000 feet from outcrops of Middle Ordovician limestones inside the Christiansburg window. The upper sandstone is also overturned in the eastern part of the area and can be traced southwest across U.S. Route 460 Bypass and U.S. Route 460 north of Christiansburg. It continues west, outcropping on the crest of a ridge immediately north of Friends School on U.S. Route 460. However, the sandstone abruptly terminates about 2000 feet west of the school. To the north, chert and dolomite beds of Longview-type were traced westward from the Ellett Road (Montgomery County Road 723) into the vicinity of Friends School where they also terminate. It is the abrupt termination of these beds of the Salem fault block that led the writer to believe that the Salem fault does not continue to the west, but dies out or perhaps merges with the Pulaski block immediately northwest of Christiansburg.

If the Salem fault block is adjacent to the Christiansburg window along its northern boundary, it should also be present on the southern edge of the window. If the dashed contact on Plate 1 that marks the termination of the Salem block west of Christiansburg is projected southward across the Christiansburg window, it very nearly intersects a breccia zone on the Pulaski fault block. This zone of breccia is located at the intersection of Virginia Route 8 and the Frontage Road paralleling the south side of Interstate 81. Breccia also crops out in a small drain about 900 feet west of this intersection and may represent the western end of the Salem fault block. However, as the writer considers the Salem and Pulaski fault blocks to be essentially the same in this area, all the rocks outside the south edge of the Christiansburg window are shown as part of the Pulaski block.

The Max Meadows Fault Block

The Max Meadows Fault

The name Max Meadows fault was applied by Cooper (1939) to a major Appalachian fault along which the Cambrian Rome formation has been thrust northwest over the Elbrook formation of the Pulaski fault block. The fault was named for the town of Max Meadows, Wythe County, Virginia. Dietrich (1954) recognized the Rome-Elbrook contact south of Christiansburg as a fault which he referred to as the Christiansburg thrust. As noted previously, Hergenroder (1957), mapping in the Radford, Virginia area was able to demonstrate the equivalence of the Max Meadows and Christiansburg faults. Mapping by Andrews (1952), Edwards (1960), Amato (1968) and Hazlett (1968) have extended the Max Meadows fault from

Christiansburg northeast into the Roanoke, Virginia area.

The Max Meadows fault, which crosses the Christiansburg area in an east-northeast direction, is roughly parallel to and south of Interstate 81 and the Appalachian Power Company high tension line. Dietrich (1954) showed an isolated patch of Rome shale along the western edge of the area lying on top of the Elbrook north of the main trace of the Max Meadows fault. This patch lies just east of a tongue of Rome attached to the main body of the fault block in the Radford area (Hergenroder, 1957). Dietrich (oral communication, May, 1969) stated that the two bodies may be attached, but the relations in the field were too obscure to be certain.

As noted previously, the Cambrian Rome strata on the south of the Max Meadows fault is thrust over the Cambrian Elbrook of the Pulaski block. As the Elbrook normally directly overlies the Rome, the stratigraphic displacement along the Max Meadows fault is relatively small. In the Draper Mountain area Cooper and Haff (1949) indicate that laternal movement of the Max Meadows block was at least eight miles. Ritter (1969) considers the Rome present in the Blacksburg area to the north to be a part of the Max Meadows block and implies a movement of about 10 miles.

Structure of the Max Meadows Block

The Rome shales of the Max Meadows fault block have been much folded and faulted making the structure within the block somewhat complex (Dietrich, 1954). Within the map area several folds in the shales can be followed along strike for several hundred feet. The fold axes are essentially parallel to the strike of the main fault trace. Very little breccia associated with the Max Meadows fault was found in the Christiansburg area. The breccia zones of the Pulaski block to the north are wider and more

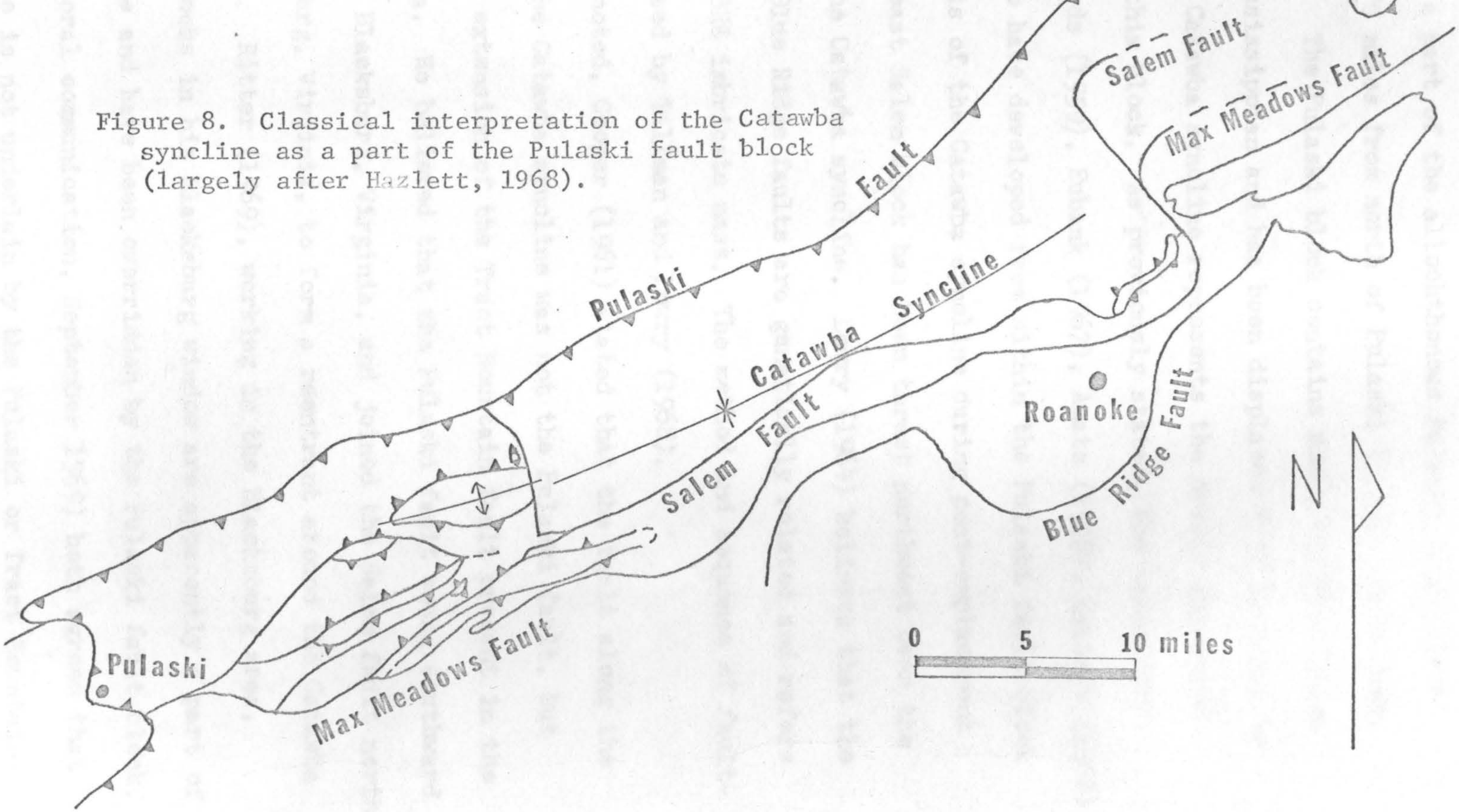


Figure 8. Classical interpretation of the Catawba syncline as a part of the Pulaski fault block (largely after Hazlett, 1968).

Hazlett (1968) summarizes the generally accepted view that the Catawba syncline is a part of the allochthonous Pulaski fault block which extends some 70 miles from north of Pulaski to near Eagle Rock, Virginia (Figure 8). The Pulaski block contains rocks ranging in age from Cambrian to Mississippian and has been displaced 8 to 12 miles to the northwest. The Catawba syncline represents the deeply depressed central segment of this block. As previously stated, the Salem fault is believed by Edwards (1959), Eubank (1967), Amato (1968), Hazlett (1968), and Ritter (1969) to have developed from within the Pulaski fault block southeast of the axis of the Catawba syncline during post-emplacement folding. The southeast Salem block has been thrust northwest over the southeast limb of the Catawba syncline. Lowry (1964) believes that the Pulaski, Salem and Blue Ridge faults are genetically related and refers to them as the PUSABRE imbricate mass. The method and sequence of faulting is well summarized by Tillman and Lowry (1968).

As previously noted, Cooper (1961) stated that the fault along the northwest side of the Catawba syncline was not the Pulaski fault, but instead a northeast extension of the Tract Mountain fault present in the Draper Mountain area. He believed that the Pulaski fault swung southward through the town of Blacksburg, Virginia, and joined the Salem fault northeast of Christiansburg, Virginia, to form a reentrant around the Catawba syncline (Figure 9). Ritter (1969), working in the Blacksburg area, believes that the rocks in his Blacksburg window are apparently a part of the Catawba syncline and have been overridden by the Pulaski fault block. Cooper and Ritter (oral communication, September 1969) both agreed that the Catawba syncline is not underlain by the Pulaski or Tract Mountain

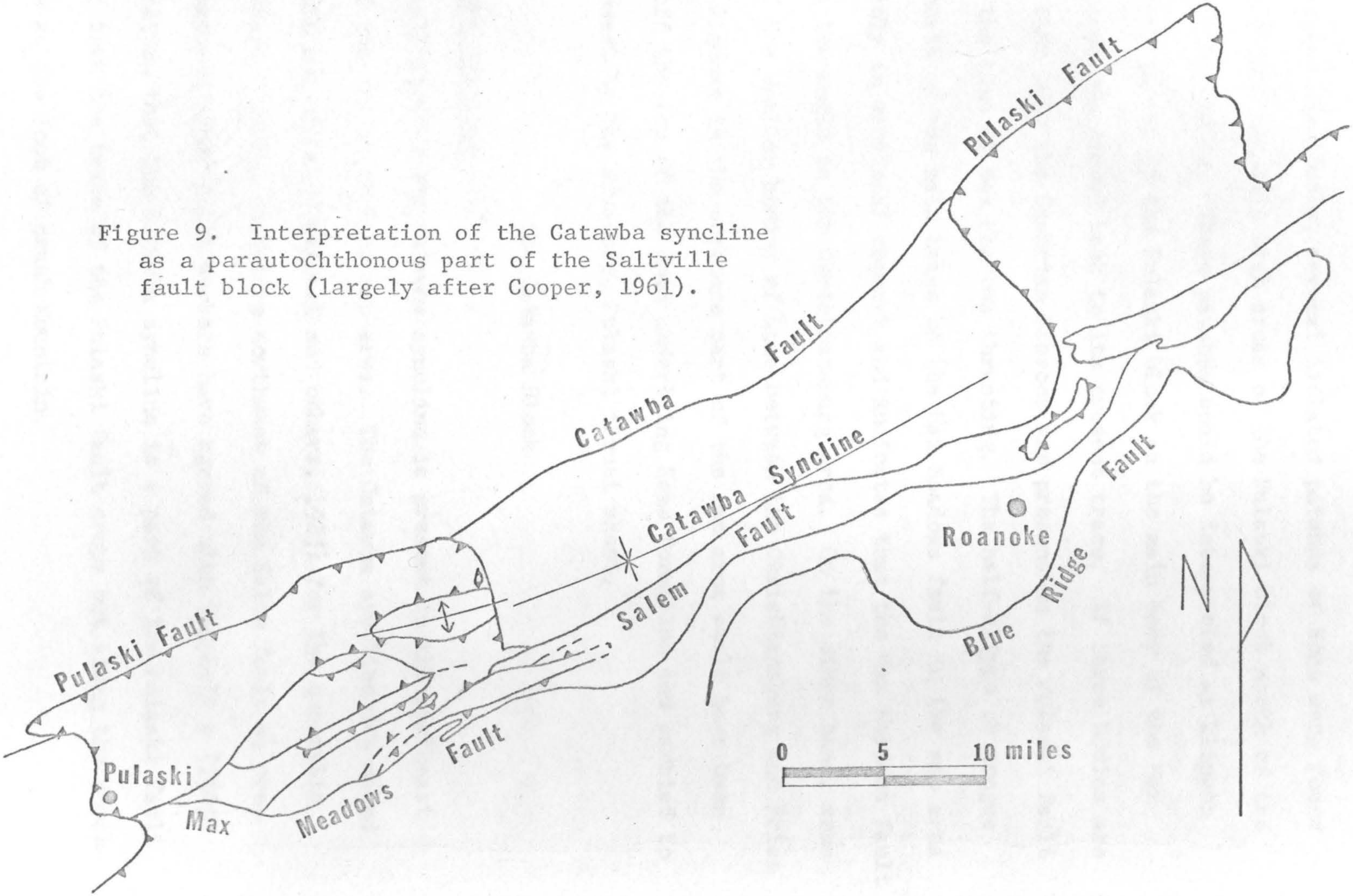


Figure 9. Interpretation of the Catawba syncline as a parautochthonous part of the Saltville fault block (largely after Cooper, 1961).

numerous.

As stated previously, several isolated patches of Rome were found occupying topographically high areas of the Pulaski block north of the Christiansburg window. These patches could be interpreted as klippen of Rome left on top of the Pulaski block as the main body of the Max Meadows block was eroded back to its present trace. If these bodies are klippen, then only the Cambrian Elbrook was present on the Pulaski fault block at the time of Max Meadows thrusting. The half-klippe or tongue of Rome north of the main trace of the Max Meadows fault in the map area is certainly an erosional remnant and indicates that the Max Meadows fault dips at a low angle in the Christiansburg area. On the other hand, some or all of the smaller bodies of Rome between the Christiansburg and Price Mountain windows in the northern part of the map area could have been clipped off the top of the once underlying Rome formation and carried to the northwest by the advancing Pulaski thrust sheet.

The Catawba Block

The Catawba Syncline

A small part of the Catawba syncline is present in the northeast corner of the Christiansburg map area. The Catawba syncline was named by Campbell and Holden (Campbell and others, 1925) for the generally northeastward trending structure northwest of the Salem fault as previously mapped. Nearly all workers have agreed with Campbell's (1925) interpretation that the Catawba syncline is a part of the Pulaski fault block and that the trace of the Pulaski fault crops out along the northwest side at the foot of Brush Mountain.

faults, but instead is a parautochthnous part of the Saltville block. They believe that sometime before Pulaski thrusting the Blacksburg and Catawba synclines were continuous. The Catawba syncline moved to the southwest along a reverse fault to override what is now the east end of Price Mountain. Ritter (1969, p. 29) calls this fault the Catawba fault and states that it may be exposed on the east end of Price Mountain window where rocks of the Catawba block are in contact with the Mississippian rocks of the Saltville block. Cooper (oral communication, December, 1969) believes the fault dips 30 to 45 degrees to the east or northeast making a movement of 3 to 4 miles along the fault plane necessary to place Cambrian in contact with Mississippian rocks at the east end of Price Mountain. Some of this displacement may be taken up by both folding and faulting. After movement along the Yellow Sulphur Fault Line moved the Catawba block upward, the part of the Pulaski sheet over the Catawba syncline east of the fault was lost to erosion. West of the fault line, enough of the Catawba block is left to show up in Ritter's (1969) Blacksburg window. In the Price Mountain window, both the Catawba and Pulaski blocks were removed exposing Saltville block rocks.

Either of these two interpretations are distinct possibilities, yet whichever one is accepted, several hard to answer questions are brought up. From the mapping done in the Christiansburg area, the writer was unable to solve some of the problems concerning the origin of the Catawba syncline; however the questions which arise from each of the two interpretations will be stated.

In the Christiansburg area, the chaotic and brecciated rocks that undoubtedly form the Pulaski fault block west of Christiansburg can be traced to the east, where they are found to overlie the southwest margin of the Catawba syncline. These rocks, which belong to the Cambrian Elbrook Formation, are highly fractured and contain tectonic breccia zones and bodies of Rome shale like the Pulaski block surrounding the windows west of Christiansburg. The fault along the leading edge of this fault block enters the area from the east and was mapped by Ritter (1969) and Eubank (1967) as the Salem fault. It continues west, overriding the rocks of the Catawba syncline, and joins the Yellow Sulphur Fault Line. In the Christiansburg map area, at least, the writer believes that the fault along the southeast margin of the Catawba syncline is not the Salem fault and is herein called the Ellett Road fault. He believes that the Salem fault lies southeast of the trace of the Ellett Road fault and that the Salem fault block dies out or merges with the Pulaski block to the southwest. The Salem block continues to the northeast, probably overlapping the Pulaski fault block and the southeastern part of the Catawba syncline a short distance east of the Christiansburg area.

If Cooper's (1961) interpretation that the Pulaski fault block is thrust over the southeast limb of the Catawba syncline is followed, then the Ellett Road fault is essentially the Pulaski fault. However, if the classical view that the Pulaski fault underlies the Catawba syncline is accepted, it is probably a branch of the Salem fault. Until the question of whether the Pulaski or Catawba fault underlies the Catawba syncline is resolved, the writer prefers to call the fault along the southeast edge of the Catawba syncline within the map area the Ellett Road fault (Plate 1).

If the Catawba syncline is considered to be a part of the Pulaski fault block extending from Pulaski to Eagle Rock, Virginia (Hazlett, 1968), then strata in the Catawba syncline which ranges in age from Cambrian to Mississippian is missing from the Pulaski block in the Christiansburg-Radford area. The Pulaski thrust sheet surrounding the windows in the Christiansburg-Radford area contains only highly fractured Cambrian rocks which indicate that the Pulaski fault is relatively close to the surface. To date, there have been no reports of any major occurrences of rocks younger than Cambrian on the Pulaski block in this area.

The missing post-Cambrian section is difficult to explain by either of the two alternative explanations. If the rocks in this area were continuous with the section of the Catawba syncline and a part of the Pulaski fault block, some 10,000 feet of stratigraphic section would have to be disposed of. Although this section would have been in the structurally highest portion of the synclinal trough and most subject to erosion, it seems reasonable to expect that some remnants of it would still be present in the Christiansburg-Radford area. If on the other hand the section were displaced by thrusting, no trace of it apparently remains today.

As stated previously, Cooper (oral communication, September, 1969) believes that the Blacksburg and Catawba synclines were originally continuous parts of the Saltville fault block and that the Catawba syncline moved southwest to override the rocks which now form Price Mountain. The Pulaski block was later thrust northwest onto the margin of the block containing the Catawba syncline as well as other Saltville block rocks to the west. The present thinness of the Pulaski thrust sheet in the Christiansburg area may indicate that it did not contain any rocks much younger than the Lower Ordovician Longview Formation at the time of Pulaski thrusting. This formation is present on the Salem block, which is essentially a part of the Pulaski block, near the point where the two blocks merge west of Christiansburg.

If the bodies of Rome shale locally present in the Pulaski block are considered to be remnants of the Max Meadows thrust sheet, then post-Cambrian rocks of the Pulaski block had to be removed somehow before Max Meadows thrusting. At least the stratigraphic section from the Elbrook, which is in contact with the Rome remnants, up to and including the Longview, 2000 to 3000 feet of strata, had to be disposed of. If the block containing the Catawba syncline was a part of the Pulaski thrust sheet, then 8000 to 10,000 feet of section would have had to have been removed.

The removal of the post-Elbrook section, however thick, from the Pulaski thrust sheet in the Christiansburg-Radford area is a particularly significant problem. This section must have been present in the root zone of the Pulaski thrust sheet southeast of the Christiansburg window. The section probably included strata as young as the Devonian Millboro Shale, which occurs on the northwest limb of the Christiansburg anticlinorium, and may have included beds of Mississippian age which do occur both on Price Mountain to the north and Draper Mountain, the presumed southwest extension of the Christiansburg anticlinorium. Somehow this section was eliminated between the time of Pulaski and Max Meadows thrusting. If this was done by erosion, the writer believes that the post-Elbrook section must not have been thick, as there would have been a relatively short time interval between the two periods of thrusting.

If on the other hand the bodies of Rome shale locally present in the Pulaski fault block were detached and carried along by the Pulaski thrust sheet, it is possible that the Max Meadows thrust sheet may have extended only a short distance north of its present position. In such a case, the Pulaski thrust sheet north of the Christiansburg window could have possessed the missing post-Elbrook part of the section and it could have been removed by prolonged erosion extending from the time of Pulaski thrusting to the present. However, there would still remain the problem of eliminating all this post-Elbrook section from beneath the Max Meadows thrust sheet south of the Christiansburg window.

Hazlett (1968) faced the same problem on the southeast side of the Read-Coyner Mountain window in the Roanoke area where the Elbrook is also directly overlain by the Rome. He proposed detachment of the lower part of the Elbrook Formation from the base of the advancing Pulaski thrust sheet while the upper Elbrook to Mississippian strata continued to move forward. He pictured the Elbrook that remained behind to be directly overridden by the Rome of the Max Meadows thrust sheet. This mechanism might apply to the Christiansburg area, but there is a problem here that Hazlett did not encounter. Because there are substantial amounts of Rome along the leading edge of the Pulaski thrust sheet northwest of Blacksburg, the original detachment of the Pulaski sheet would have had to be below the Elbrook along what is now the leading edge in the Blacksburg area and somewhat higher in or at the base of the Elbrook in what is now the Christiansburg-Radford window complex.

Evidence outside the Christiansburg area which seems to support Cooper's hypothesis that the Catawba block is parautochthonous part of the Saltville block is that there is little or none of the tectonic breccia and crush conglomerate that is commonly associated with Pulaski faulting (Cooper, 1946) along the fault northwest of the Catawba syncline along the foot of Brush Mountain. Cooper (1961) points out that the breccia zone along the Pulaski fault swings southeast through Blacksburg and Yellow Sulphur to join what is herein called the Ellett Road fault to form a major reentrant around the Catawba syncline.

Ritter (1969) mapped Cambrian dolomites of the Catawba syncline overlying Mississippian rocks of the Saltville block along the east end of Price Mountain window. South of the window he mapped these dolomites in fault contact with the limestones of the Cambrian Elbrook formation of the Pulaski thrust sheet along his Yellow Sulphur Fault Line. The Elbrook and the dolomites belonging to the Catawba syncline are essentially age equivalent, but differ somewhat in lithology and do not appear to be a part of the same structural block (Ritter, 1969). Ritter also found Cambrian dolomites which he believes are apparently a part of the Catawba syncline overridden by the Pulaski thrust sheet. These are exposed in his Blacksburg window just north of Price Mountain window, but are apparently missing in the Price Mountain window a short distance to the south.

For the reasons stated above the writer is inclined to believe that the views of Cooper and Ritter that the Catawba syncline is not a part of the Pulaski fault block are correct. However, their hypothesis also brings up problems that are difficult to solve. In the Christiansburg area, the exposures of the Upper Knox formations of the Saltville block are not lithologically similar to those of the Catawba block. The Upper Knox of the Catawba block more closely resembles the Chepultepec and Longview formations of the Salem block. The Middle Ordovician limestones of the Catawba block are not the reefy type limestones of the Saltville block. Little evidence of the shaly facies of the Liberty Hall formation was found in the Saltville block of the Christiansburg window although it is at least 1200 feet thick in the Catawba block. Likewise, the Bays Formation, which directly overlies the Liberty Hall and which reaches a thickness of approximately 1000 feet near Ellett, east of Cambria (Hergenroder, 1966), is apparently missing in all the windows in the Christiansburg-Radford area.

As already noted, in the Blacksburg area to the north, the presumed Catawba block rocks exposed in the Blacksburg window are apparently absent in the Price Mountain window little more than 1000 feet to the south.

Gravity data (Dr. C. E. Sears, oral communication, November, 1969) show that it is 18,000 to 20,000 feet to basement rock under the Catawba syncline. As the Catawba syncline contains only about 10,000 feet of Paleozoic section it would appear that the syncline does overlie a thick block underneath.

The fault along the northwest edge of what Hazlett (1968) considers to be the Pulaski fault block places rocks of Cambrian age in contact with those of Mississippian along almost its entire length from Pulaski to Eagle Rock, Virginia. This is also true around the Price Mountain window if the Catawba block is considered to be a part of the Pulaski fault block.

The structural relationship of the Catawba syncline will continue to be a challenging problem for further study. At the present time the advantages of either interpretation are about as numerous as the disadvantages.

Dating and Sequence of Thrusting

It is presumed that movement along the thrust faults in the Christiansburg-Radford area was initiated shortly after the deposition of the youngest Mississippian beds exposed in the Price Mountain window. These rocks are the Middle to Upper Mississippian Stroubles Formation and are, so far as known, the youngest formation to be overridden by the Pulaski thrust sheet. It is possible that younger strata were at one time present above the Stroubles and were removed during thrusting or by pre-thrusting erosion. Thus, assuming that thrusting took place not long after deposition and no significant strata were removed during thrusting, the faults within the area began to be emplaced in Middle to Late Mississippian time.

The fault block that was emplaced first depends on which interpretation of the place of origin of the Catawba syncline is followed. If the views of Cooper (1961) and Ritter (1969) are correct that the Catawba block is parautochthonous and the Catawba fault (Ritter, 1969) is beneath the Catawba syncline, then this fault would pre-date Pulaski thrusting. However, if the classical interpretation of the Catawba syncline belonging to the Pulaski fault block is followed, then the initial thrusting took place along the Pulaski fault. Salem faulting is believed to have been an offspring of Pulaski thrusting. Although Max Meadows thrusting certainly is younger than Pulaski and Salem thrusting, it could represent reactivation of a proto-Pulaski fault (Hazlett, 1968).

As noted previously, the general parallelism of the thrust sheets and the overridden strata indicate that much of the present structure was due to folding which followed the emplacement of the thrust sheets. The major windows in the Christiansburg-Radford area were apparently formed as the rise of the Christiansburg anticlinorium promoted sufficient erosion to remove the overlying Pulaski thrust sheet. The high-angle faults which bound these windows cut both the thrust sheet and the overridden strata, indicating that they were also formed during post-emplacement deformation.

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STRUCTURAL GEOLOGY OF THE

CHRISTIANSBURG AREA

MONTGOMERY COUNTY,

VIRGINIA

by

FRANK R. GLASS, JR.

Abstract

The Christiansburg map area consists of about 19 square miles in Montgomery County, Virginia, and is underlain by sedimentary rocks ranging in age from Middle Cambrian to Middle Ordovician. Post-Ordovician strata have been eliminated by thrusting and erosion. From south to north the rocks belong to five fault blocks: the Max Meadows, Pulaski, Saltville, Salem, and Catawba blocks.

The Max Meadows block contains only the Middle Cambrian Rome Formation, the oldest rocks exposed within the area. The parautochthonous Saltville block includes rocks from Upper Cambrian to Middle Ordovician in age, which are exposed in windows of the Pulaski fault block. The Pulaski block contains highly fractured and brecciated Cambrian carbonates. The Salem block contains rocks ranging in age from Middle Cambrian to Lower Ordovician. The Salem fault terminates west of Christiansburg, Virginia. Rocks of the Catawba block range from Middle Cambrian to Mississippian in age, but only the section up to the Middle Ordovician is exposed in the map area.

The windows through the Pulaski thrust sheet expose the large Christiansburg anticlinorium of the Saltville fault block. The size of each window is proportional to the size of the anticlinal fold developed

on the crestal portion of the anticlinorium. The faulting may have occurred shortly after deposition of the Mississippian strata exposed in the Price Mountain window north of the area. The apparent parallelism of the thrust sheets and the overridden strata indicates that much of the present structural relief was formed after emplacement of the thrust sheets.