University of Tennessee, Knoxville

6-1959

Geology of Newman Ridge and Brushy-Indian Ridge Between Sneedville, Hancock County, Tennessee, and Blackwater, Lee County, Virginia

Adrian Vance Greene
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Adrian Vance Greene entitled "Geology of Newman Ridge and Brushy-Indian Ridge Between Sneedville, Hancock County, Tennessee, and Blackwater, Lee County, Virginia." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

<div align="right">Harry J. Klepser, Major Professor</div>

We have read this thesis and recommend its acceptance:

George D. Swingle, R. E. McLaughlin, Paris B. Stockdale

<div align="right">Accepted for the Council:
Carolyn R. Hodges</div>

<div align="right">Vice Provost and Dean of the Graduate School</div>

(Original signatures are on file with official student records.)

May 25, 1959

To the Graduate Council:

I am submitting herewith a thesis written by Adrian Vance Greene entitled "Geology of Newman Ridge and Brushy-Indian Ridge Between Sneedville, Hancock County, Tennessee, and Blackwater, Lee County, Virginia." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

Harry J. Klepser
Major Professor

We have read this thesis
and recommend its acceptance:

George D. Swingle

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Paris B. Stockdale

Accepted for the Council:

Dale Harrtling
Dean of the Graduate School

GEOLOGY OF NEWMAN RIDGE AND BRUSHY-INDIAN RIDGE

BETWEEN SNEEDVILLE, HANCOCK COUNTY, TENNESSEE,

AND BLACKWATER, LEE COUNTY, VIRGINIA

————————

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

————————

by

Adrian Vance Greene

June 1959

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ACKNOWLEDGMENTS

The writer is greatly indebted to Dr. H. J. Klepser of the Department of Geology and Geography, The University of Tennessee, who acted as faculty advisor. Much assistance was also received from Dr. G. D. Swingle, Dr. R. E. McLaughlin, and Dr. Paris B. Stockdale, all of the Department of Geology and Geography, The University of Tennessee. For their assistance, the writer offers sincere thanks.

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CHAPTER I

INTRODUCTION

Location and Size of the Area

The area described in this thesis comprises portions of northeastern Hancock County, Tennessee, and southeastern Lee County, Virginia (Figure 1). It includes parts of the Sneedville and Kyles Ford quadrangles (Tennessee Valley Authority and United States Geological Survey topographic maps 170-SW and 170-SE respectively).

The mapped area, bounded on the southeast by the Hunter Valley fault and on the northwest by Blackwater Valley, is approximately fifty miles west of Bristol, Tennessee-Virginia, and fifty-five miles northeast of Knoxville, Tennessee. It is about eleven miles long and three miles wide and encloses approximately thirty-three square miles.

Physiography

General

The mapped area is situated in the western portion of the Ridge and Valley province, a region described by Fenneman (1938, p. 196) as "a lowland (an assemblage of valley floors) surmounted by long, narrow, even-topped mountain ridges."
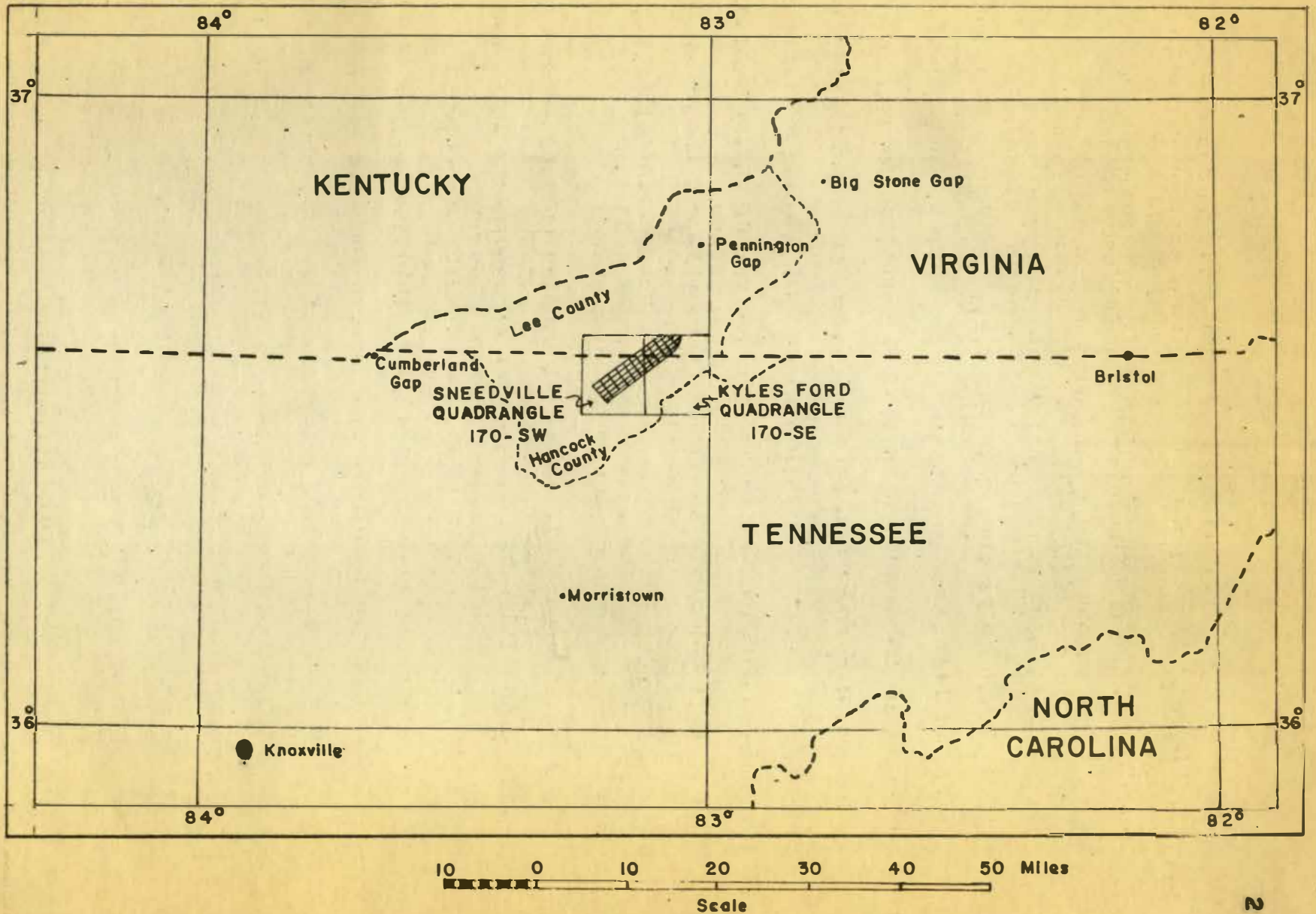
The major topographic features in the mapped area include Newman Ridge, Brushy-Indian Ridge, Panther Fork Valley, and Blackwater Valley.

Newman Ridge is a northeastwardly-trending hogback approximately thirty miles long and averaging one mile wide. The northern slope is steep and the southern slope is more gentle. Southeast of Newman Ridge, a similar, but lower and shorter ridge is divided by Panther Creek into two segments. West of the creek it is called Brushy Ridge; the eastern segment is called Indian Ridge. Newman Ridge and Brushy-Indian Ridge are separated by Panther Fork Valley. Newman Ridge is adjoined to the northwest by Blackwater Valley.

The highest elevation in the area, approximately 2,560 feet, is on Jabez Knob, about one and one-half miles northwest of Sneedville. The lowest elevation in the area, 1,120 feet, is along the Clinch River. Maximum relief is therefore 1,440 feet.

Drainage

The drainage pattern is of the trellis type with the exception of a limited area of dendritic drainage on the southern side of Brushy-Indian Ridge. The master stream in the area, the Clinch River, is essentially a strike stream, the gradient of which is slightly less than two feet per mile. Blackwater Creek and Panther Creek are also strike streams

through most of their courses. The latter two streams occupy valleys underlain by black shale.

Blackwater Creek flows northeastward from its point of origin for approximately fifteen miles before cutting through the northeastern end of Newman Ridge (outside of mapped area). It then turns south through the structurally-complex area at the northern end of Indian Ridge and joins the Clinch River.

Culture

Paved roads include Tennessee State Highway 33 in the southwestern portion of the area, Tennessee-Virginia State Highway 70 ("The Trail of the Lonesome Pine") at the extreme northeastern boundary, and a county road which extends north-westward from Sneedville to Mulberry Gap. All other roads are gravel or dirt surfaced.

Farming, the main occupation in the area, is concentrated along the Panther Fork Valley, an unusually productive black shale valley.

CHAPTER II

STRATIGRAPHY

Introduction

Strata in the mapped area range in age from Early
Cambrian to Late Mississippian, but because of faulting, the
stratigraphic sequence from Middle Cambrian to Lower Silurian
is absent (Figure 2). Exposed strata are mainly of Mississip-
pian or of Devonian-Mississippian (?) age. Cambrian rocks
are present only along the southeastern boundary of the area,
and rocks of Silurian age are confined to small sections in
the eastern and western portions. Excluding the rocks of
Devonian-Mississippian (?) age, approximately 1,200 feet of
definite Mississippian strata are present.

Since a portion of the area is in Virginia, the writer
has attempted to correlate the Mississippian formations of
the Sneedville area with equivalent formations in Virginia.
Butts' classical "Geology of the Appalachian Valley in Vir-
ginia" (1940) is the chief source of information on Virginia
stratigraphy.

Rome formation

The Rome formation, of Early Cambrian age, was named
by Hayes (1891) for Rome, Georgia. Smith (1890) applied the
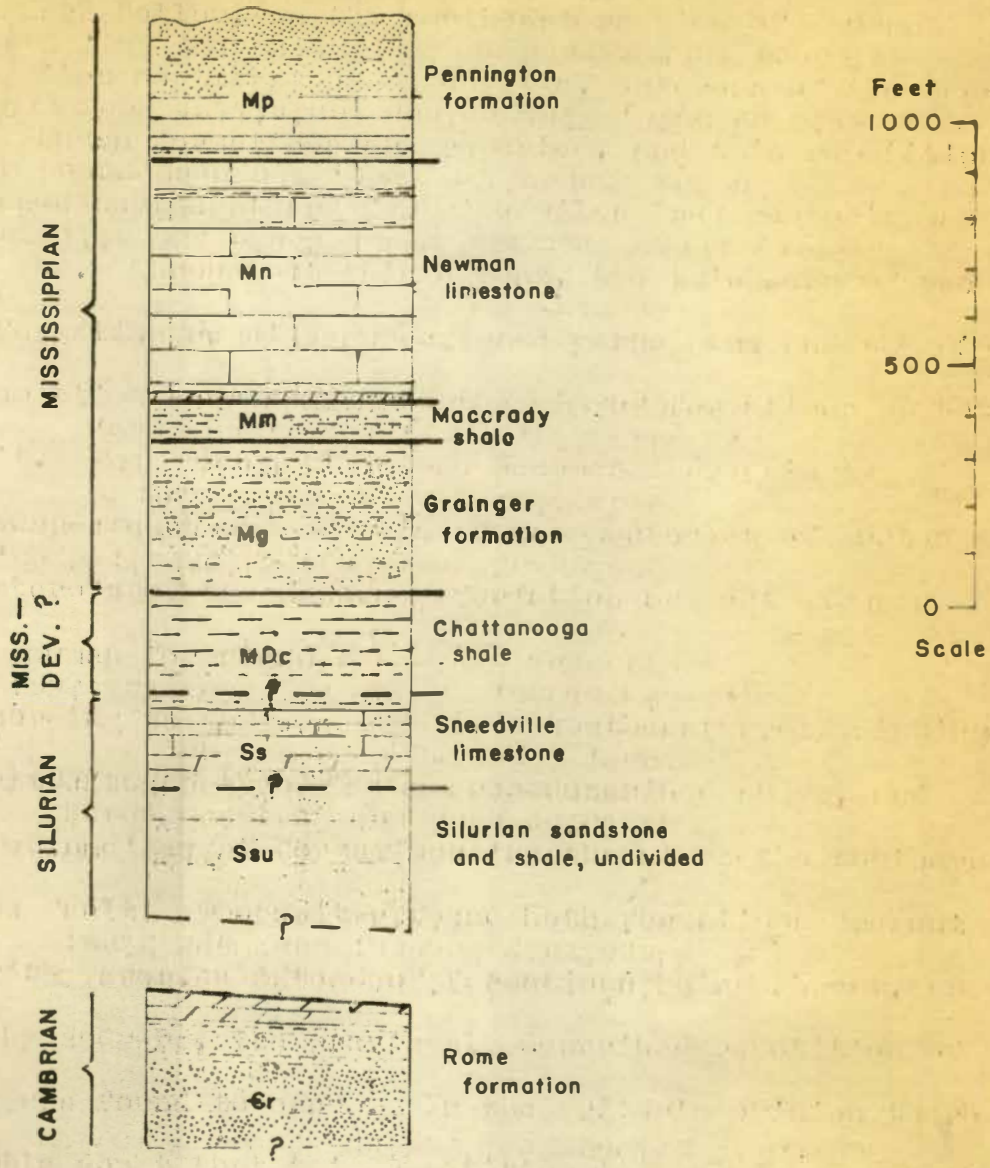
Figure 2. Columnar section of formations in mapped area.

term Montevallo to the same formation about one month prior
to the publication of Hayes' work, but despite the priority
of the term, it is rarely used. In Virginia, the terms
Russell and Buena Vista have been used for the same formation.
Stose (1906) applied the name Waynesboro to rocks now known
to be equivalent to the Rome formation, and this name is still
used north of Roanoke, Virginia.

Keith (1903) used the name Watauga to describe the red
shale and dolomite overlying the Shady dolomite in north-
eastern Tennessee. The Watauga shale is now considered to be
the northeastern phase of the Rome formation.

The Rome formation, dominantly composed of clastics in
the northwestern part of the Ridge and Valley province, con-
sists chiefly of sandstones, shales, and siltstones, with
minor amounts of dolomite and limestone. The shales are green,
maroon, buff, and brown in color, are thin-bedded, and often
have a glossy appearance on bedding planes due to the high
mica content. The maroon shale, one of the most striking
lithologies of the Rome formation, weathers to a red soil
that forms a vivid contrast to the soils adjoining it.

The sandstones and siltstones vary from thin- to
medium-bedded and are commonly ferruginous and glauconitic.
Primary features such as ripple marks and raindrop impres-
sions are common in the Rome sandstone (Figure 4).

The carbonates, usually gray in color, vary from fine-grained to coarsely crystalline, and from thin- to massively-bedded. At least fifty feet of carbonates are exposed in the Sneedville area, and consist of impure dolomite with minor amounts of limestone.

The Rome shales and sandstones are commonly deformed (Figures 3, 5), making accurate estimates of thickness difficult to obtain. In northeastern Tennessee, the Rome formation is estimated to be 1,200 feet thick. Elsewhere, the thickness is not known, but Rodgers (1953) believes that it is more than 700 feet in many places.

Strata of Silurian Age

Rodgers (1953) mapped two Silurian rock units in the Sneedville area, namely, an undivided unit of sandstone and shale (probably the Rockwood formation and Clinch sandstone equivalent), and the Hancock (Sneedville) limestone.

The Sneedville limestone was named by Safford (1856) for Sneedville, Hancock County, Tennessee. Referring to Campbell (1894) and Keith (1896), Rodgers (1953, p. 101) stated "Precisely the same rocks in the same area were later named the Hancock limestone." Although the name Sneedville has priority over Hancock, the latter term is the one used by the United States Geological Survey. In this thesis, the term Sneedville, however, is used in preference to Hancock.

Figure 3. Folds in Rome shale. Northeastern
end of Indian Ridge

Figure 4. Ripple marks on Rome sandstone.
Southern slope of Indian Ridge.

Figure 5. Folds in Rome sandstone. Northeastern end
of Indian Ridge.

Rodgers (1953) stated that rocks of both Silurian and Devonian age are present in the Hancock formation, but strata of known Devonian age are apparently limited to outcrops near the igneous bodies in Union County as described by Hall and Amick (1944). Butts (1940, p. 287), in his description of Devonian strata in the Big Stone Gap area of Lee and Wise counties, Virginia, made the statement that "The Helderberg in this area is the upper part of the Hancock limestone." Except for a reference to Keith (1896), he gave no basis for this correlation. In the Sneedville area, no fossils of Devonian age have been found in the Sneedville limestone. In this thesis the formation is mapped as being wholly of Silurian age.

In the mapped area, with the exception of a small exposure of limestone immediately north of Sneedville, Silurian outcrops occur only at the northeastern end of Indian Ridge. A fine-grained, highly-ferruginous sandstone occurs in the lower portion of this section. Above this is a thick-bedded, silty limestone of undetermined thickness with some interbeds of fine-grained, gray dolomite. The limestone, which contains ostracods and Favosites, emits a strongly asphaltic odor when crushed. Overlying the limestone is a medium-bedded, fine-grained, well-cemented sandstone with interbedded layers of siltstone. The sandstone is usually green, but dark-red, highly-ferruginous beds are also present. The

siltstone is brown and contains numerous fossils, mainly brachiopods and _Tentaculites._

The limestone present in the section described above is the Sneedville limestone, and the underlying sandstone is the unit mapped by Rodgers (1953) as Silurian sandstone and shale, undivided. As the base of the section is not exposed and outcrops are limited, the thickness of this sequence could not be determined.

Rodgers (1953) stated that a major disconformity over-lies the Sneedville limestone. The top of this formation is not exposed, and the disconformity was not observed in the mapped area.

Chattanooga shale

The Chattanooga shale was named by Hayes (1891) for exposures at Chattanooga, Hamilton County, Tennessee.

Rodgers (1953) divided the shale sequence above the Silurian unconformity into two units: the Chattanooga shale, a term applicable only to a dominantly grayish-black shale unit, and an unnamed, thicker unit in which the black shale is divided by a wedge of gray, silty shale, siltstone, and sometimes sandstone. This latter unit is found in the belts between the Saltville and Wallen Valley faults. Stose (1923) at Big Stone Gap, Virginia, named a similar unit the Big

Stone Gap shale. Swartz (1929) divided Stose's Big Stone Gap shale into the Cumberland Gap shale, a basal black shale, the Olinger shale, a silty gray or green shale, and the Big Stone Gap shale (restricted), an upper unit of black shale. This group has been correlated with the Chattanooga shale of Tennessee.

The Brallier shale of Butts (1940) can probably be correlated, at least in part, with the Chattanooga-Big Stone Gap group. Butts (1940, p. 321) gave the following inter-pretation.

> In the section at South Clinchfield, Russell County, Virginia, the Brallier is typically de-veloped, is 1000 feet thick, and contains no black shale. . . . At Big Stone Gap the section is not fully exposed, but the upper 350 feet, called the Big Stone Gap shale, is much like the Brallier but is dark-colored to black. In Hunter Valley the equivalent of the Brallier contains beds of black shale. . . . It is thought that this transition of the Brallier to black shale continues southwest directly along the strike to Cumberland Gap, where almost all of the interval between the Price sand-stone (Mississippian) and the Clinton (lower Silurian) is occupied by black shale. . . . It is surmised that the black shale at Cumberland Gap is in the main a facies of the Brallier or some part of it.

According to Rodgers (1953), the Chattanooga shale be-comes progressively thicker eastward and northeastward. It is about 12 feet thick at Chattanooga, 30 to 50 feet thick in Blount County, Tennessee, 50 to 80 feet thick near Clinton, and about 400 feet thick at Cumberland Gap. The threefold

unit is about 400 feet thick at the southwestern end of Clinch Mountain and thickens to 900 feet at the Virginia line.

The age of the Chattanooga shale has been variously placed as Devonian, Mississippian, and Devonian-Mississippian. Current opinion favors the latter, although Hass (1956), after a study of conodonts found within the formation, believes that all of the Chattanooga shale is of Devonian age.

In the Sneedville area, the Chattanooga shale consists mainly of grayish-black, bituminous shale. When weathered, it is fissile; on freshly exposed surfaces it is often blocky and difficult to split. In the lower part of the formation on the northern side of Newman Ridge, green argillaceous shale, containing elongated concretions, occurs interbedded with the grayish-black shale. In one locality, about three-quarters of a mile northeast of Sneedville, a few thin beds of sandstone, resembling the Grainger sandstone, are present.

Pyrite, common throughout the formation, occurs as small oval nodules, or more rarely as thin laminae. Fossils are few and consist almost wholly of linguloid brachiopods. Conodonts, reported to be a common fossil in certain portions of the Chattanooga shale, were not observed in the mapped area.

The Chattanooga shale weathers to an iron-stained, brown color and forms a thin, silty soil. Erosion of this

formation commonly produces deep strike valleys (Blackwater
Valley, Panther Fork Valley) bordered by low, rounded knolls
(Figure 7).

Due to deformation, no section of Chattanooga shale in
this area can be measured accurately, but it is at least 150
feet thick. The top of the formation is placed below the
thin beds of sandstone that underlie the Grainger formation
(Figure 6). The base is not exposed in the area.

Grainger formation

The Grainger shale was named by Keith (1895) for ex-
posures southeast of Clinch Mountain in Grainger County,
Tennessee. Rodgers (1953) suggested that this might better
be called the Grainger "formation" because the rocks include
considerable sandstone. In Virginia, the correlative forma-
tion essentially is called either the Price or Pocono.

The Grainger formation is composed wholly of clastics
in the southeastern part of Tennessee and grades southwest-
wardly into the cherty limestone of the Ft. Payne chert.
Rodgers (1953) recognized the Grainger formation in the belts
southeast of the Whiteoak and Wallen Valley faults.

Rodgers' description of this formation (1953, p. 106-
107) is as follows:

The Grainger formation consists of bluish, green-
ish, and brownish argillaceous shale, sandy shale,
sandy siltstone, and generally silty and thin-bedded

Figure 6. Contact of Grainger formation (light-colored beds) and Chattanooga shale. A small reverse fault is shown at left.

Figure 7. Small hill formed in Chattanooga shale on southern slope of Newman Ridge. Valley in foreground is also in Chattanooga shale.

sandstone. Thin coaly beds and highly glauconitic
sandstone layers occur in the upper half of the
formation and locally, especially near the top,
there are layers of coarse sandstone or even fine
conglomerate.

Rodgers stated that the thickness of the Grainger
formation in Tennessee is approximately 1,100 feet in Blount
and Monroe Counties, about 900 feet southeast of Clinch
Mountain, about 500 feet in Hancock and eastern Claiborne
Counties, and a little less than 350 feet at Cumberland Gap.

Butts' (1940, p. 337) description of the Price-Pocono
formation is generally similar to that given for the Grainger
formation by Rodgers.

The Price-Pocono is generally a clastic forma-
tion composed of shale and sandstone but in some
places has two or more beds of coal. . . .   It con-
tains no limestone. The Price facies of the forma-
tion southwest of New River has at the bottom
locally a quartz conglomerate, the Cloyd (. . .),
containing quartz pebbles as much as 1½ inches in
diameter. Elsewhere, (. . .), the basal part is
composed of thick- to moderately thick-bedded, fine-
grained, purplish sandstone. Near the top the
Price is commonly marked by one or more beds of
sandstone. . . .   Besides the sandstone strata
mentioned above, the main constituents of the Price
are thin-bedded sandstone, greenish clay, and sandy
shale containing relatively thin layers of green-
ish, micaceous sandstone. A little red shale occurs
in the bottom of the Price at Cumberland Gap. . . .

The thickness of the Price formation is reported by
Butts (1940) to be about 300 feet at Cumberland Gap, Tennes-
see, and at Little Stone Gap, Wise County, Virginia; 1,000
feet on Pine Mountain in Virginia; 360 feet at Bluefield, Vir-
ginia; and 1,700 feet in Montgomery County, Virginia.

Sanders (1952b) described in detail the Grainger formation in the Greendale syncline in Tennessee. A published abstract (1952a, p. 1295) of his work in that area follows:

> The Grainger formation (early Mississippian) has been traced and mapped in detail in the Greendale syncline northeastward from the type locality in Grainger County, Tennessee, across Hawkins County, Tennessee, to the Tennessee-Virginia line. Four sub-divisions are recognized: in ascending order, basal, lower sandstone, middle, and upper sandstone members.
>
> The basal member, 200 to 300 feet thick, changes laterally from fissile gray shale in Grainger County to fossiliferous green siltstone in Doubling Mountain, Hawkins County, and to yellowish silty shale near the Tennessee-Virginia line.
>
> The lower sandstone member is composed of 75 to 200 feet of very fine-grained, medium-bedded sandstone that locally includes pebbly layers and fossiliferous beds.
>
> The middle member consists predominantly of structureless green, fossiliferous siltstone and also includes a few beds of fine-grained sandstone, shale, and fossiliferous glauconitic material.
>
> The upper sandstone member, 100 to 150 feet thick, consists of gray, coarse-grained, cross-bedded, feldspathic sandstone and conglomerate.
>
> Fossils from the Grainger formation have not yet been studied in detail but seem to indicate the formation spans at least part of the Kinderhook and probably most of the Osage intervals of the Mississippian standard section.
>
> The Grainger formation of the present writer agrees with the "Grainger shale" of Campbell (1894) and requires that the "Grainger shale" of Keith (1896) be redefined in its type area to exclude the Devonian beds Keith included in the lower part of the "Grainger shale."

In the Sneedville area, the Grainger formation consists of alternating beds of sandstones and shales (Figures 6, 8, 9). The shales form thick beds at the top of the formation, but in the lower and middle portions they occur in relatively

Figure 8. Gently dipping beds of Grainger formation in northwestern limb of Newman Ridge syncline. Northern slope of Newman Ridge.

Figure 9. Vertical beds of Grainger formation in southeastern limb of Newman Ridge syncline at Blackwater, Virginia.

thin beds. They are predominantly green in color, although some gray, brown, and red beds are also present. The red beds occur locally in the lower portions of the formation. The shales, silty and containing much mica, are commonly fissile, but they occasionally occur as compact beds.

The sandstones are light-green or grayish-green in color, and weather to purple, brown, red, or darker green. The weathered color often extends inward for an inch or more, and on breaking a piece of this weathered sandstone, a striking contrast of colors is seen. The sandstone is very fine-grained, often almost a siltstone, and thickness of bedding varies from one inch to four feet. Primary flow structure is often found at the bottom of beds. Spheroidal weathering is characteristic of the Grainger sandstone in the mapped area, and is probably due to the numerous small joints present throughout the formation. Solutions along joints probably result also in the small, boxwork-like structures composed of iron oxide that often occur in weathered areas of the Grainger formation. Pyrite is fairly common throughout the sandstone, and minute cubes of galena are occasionally present.

The Grainger formation is not very fossiliferous in the Sneedville area, the fossils when present generally occurring as molds or impressions. Brachiopods, bryozoans, crinoid stems and <u>Taonurus caudi-galli</u> are the common fossils;

however, the latter is much more abundant in the overlying Maccrady shale. A few pyritized plant fossils are also present.

The Grainger formation forms steep slopes covered by thin, sandy soil that is rarely cultivated. A narrow bench is often formed on the shale at the top of the formation. Occasionally erosion has proceeded along the strike of this shale to form a small valley that divides the Grainger from overlying formations. More rarely, small, rounded hills are formed by erosion of the Grainger formation; for example, the almost perfectly rounded hill between Fox Branch Church and School at the northeastern end of Indian Ridge.

The Grainger formation is 325 feet thick in a section measured on the southern side of Newman Ridge.

Maccrady shale (restricted)

The Maccrady shale was named by Stose (1913) for the town of Maccrady, two miles northeast of Saltville, Virginia. Stose's original Maccrady shale consisted mainly of rocks of Warsaw age, and Butts (1927, p. 14) suggested that "the red beds, being of New Providence age, and the overlying limestone of Warsaw age should not be included together in the same formation, and that if the name Maccrady is to be retained its application should be restricted to the red beds at base."

According to Rodgers (1953), a unit corresponding to
the Maccrady shale is present in most of the Grainger forma-
tion belts in Tennessee, and Butts (1940) stated that the Mac-
crady shale occurs as far north as Alleghany Station, Alle-
ghany County, Virginia. The beds overlying the Maccrady shale
are either of Warsaw or of St. Louis age.

The most distinctive feature of the Maccrady shale is
its red color. Butts (1940) stated that this formation con-
sists mainly of coarse-grained, lumpy, red shale or sandy mud-
rock, although at one area in Washington County, Virginia,
limestone is present. Rodgers (1953) described this formation
as being composed of red shale and siltstone.

In the Sneedville area, the Maccrady shale consists of
red shale in the lower portion, and blocky, red and green
siltstone or mudstone with red and green shale in the upper
portion (Figure 10). The Maccrady shale, like the Grainger
formation, is much jointed, and solutions along this jointing
often result in a red and green mottled or veined appearance.

Layers of fine hematite, two or three inches thick,
are often found. Granular glauconite is found in thin layers
at the top of the formation, along with thin layers and
nodules of green chert.

With the exception of the cryptic Taonurus caudi-galli,
fossils are rare in the Maccrady shale and consist of molds of
crinoid stems, brachiopods, and bryozoans contained in

hematitic siltstone. In all observed localities, <u>Taonurus</u> is
present; in fact, abundance of this fossil is generally con-
sidered evidence of the Maccrady shale in the Sneedville area
(Figure 11). Butts (1927, p. 12) used this fossil to deter-
mine the age of the Price formation in Virginia.

> The <u>Taonurus</u> is especially significant, as it is the
> most abundant fossil along the western escarpment of
> the Cumberland Plateau just east of the Blue Grass
> region of central Kentucky, where the fossil is pres-
> ent in nearly every sandy layer of the New Providence
> throughout the full thickness of about 600 feet.
> Hence the Price formation is correlated with the New
> Providence. . . .

Although Butts believes the Maccrady shale to be
Osagian in age, B. N. Cooper (1944) believes that it could
well be of Warsaw age.

In the Sneedville area, the Maccrady shale is 75 feet
thick. The base of the formation is placed below the red
shale that overlies the Grainger formation, and the upper
limit is marked by the carbonates of the Newman limestone.

Newman limestone

The Newman limestone was named by Campbell (1893) for
Newman Ridge in Hancock County, Tennessee, and Lee County,
Virginia. The name Bangor limestone has been applied to the
Newman equivalent in Alabama, but the term Bangor is now re-
stricted to the upper part of the Newman sequence. The term
Floyd shale is also used in Georgia and Alabama to describe

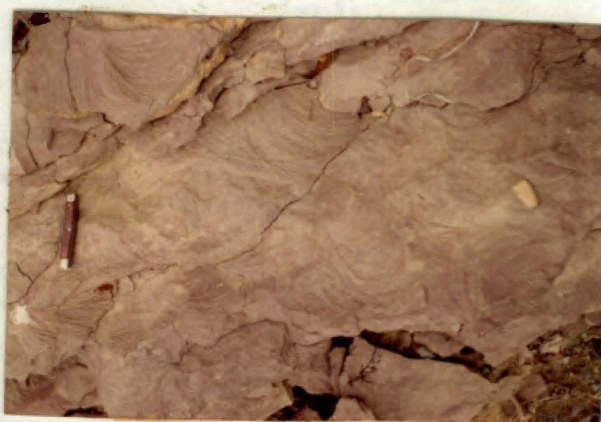Figure 10. Blocky siltstone of Maccrady shale on Newman Ridge.

Figure 11. _Taonurus caudi-galli_ in Maccrady shale, Newman Ridge.

the lower, shaly equivalent of the Newman limestone. The Greenbrier limestone in West Virginia and part of Virginia is essentially equivalent to the Newman limestone.

According to Rodgers (1953), the Newman limestone varies considerably in Tennessee. The belts near the Cumberland Plateau consist mainly of pure, gray, massive limestone with some shaly limestone, and the thickness varies from 600 to 850 feet. In Blount County, Tennessee, the Newman formation consists of about 1,200 feet of shaly limestone and calcareous shale. Along Whiteoak Mountain, the formation is 1,200 to 1,500 feet thick and is lithologically similar to that in Blount County except that purer limestone occurs in the middle of the formation.

In the Sneedville area, the Newman limestone is composed of massively-bedded limestone with some dolomite, and calcareous shale. The shale, green in color, occurs as thin partings in the lower portion of the formation, but as thick beds toward the top (see geologic section, p. 29).

The dominant color of the carbonate beds is gray, although blue, reddish, and green beds occur irregularly. Dolomite is present in the lower portion of the formation. Oolitic limestone occurs as intermittent beds throughout the formation. The limestone and dolomite at the base are compact, whereas higher the limestone is mainly crystalline, although a few compact beds are present. The basal beds are

sandy, but sand is rare in the upper portion of the formation.

Green or dark-gray chert is common in the basal portion of the Newman limestone. Crystals of fluorite about one-half inch in width are found in the lower part, and an unidentified, amorphous, green mineral is common in the lower and middle parts.

Slightly weathered sections of the Newman limestone are characterized by massive bedding and by marked cross-bedding. In more weathered sections, these features are often absent due to weathering of thin shaly beds.

The top of the Newman limestone is placed below the characteristic unit of shale and thin-bedded sandstone that is present at the base of the Pennington formation.

Measurement of the formation on Indian Ridge indicates a thickness of approximately 500 feet. No complete section is exposed in the area, and measurement was made by tracing beds along strike. This resulted in an unavoidable amount of error in measurement, an error believed to be less than 50 feet.

The Newman limestone in Virginia has been divided into six lithologic units by Butts (1940). Some of these lithologies can be recognized in the Sneedville area.

The Warsaw lithology of Butts is not recognized in the mapped area, rocks similar to the St. Louis limestone being present immediately above the Maccrady shale. These consist

of compact and crystalline limestone with some dolomite. The basal beds are very silty. Bedded chert is usually abundant but in some localities it is virtually absent. Litho-strotionella canadensis and Syringopora cf. S. virginica are commonly present. Below is a measured section of basal Newman limestone from Indian Ridge.

		Thickness	
		Ft.	In.
6.	Limestone, light-gray, crystalline, massively bedded; weathers blue; slightly oolitic at top	8	0
5.	Limestone, similar to Unit 4, but contains abundant greenish chert that occurs as lenses, nodules, and long, pencil-shaped bodies	10	6
4.	Limestone, light-gray, crystalline; abundant Syringopora	4	6
3.	Dolomite, bluish-gray, compact, nodules of green chert (rare); fine, thread-like streaks of calcite; dark-green mineral occurs as streaks	4	6
2.	Dolomite, gray, silty, compact, massively-bedded	3	0
1.	Covered, believed to be mainly Maccrady shale	15	0

Maccrady shale (red and green shale and siltstone)

In the Sneedville area, the occurrence of the diag-nostic crinoid, Platycrinus penicillus Meek and Worthen, is evidence that strata equivalent to the Ste. Genevieve as described by Butts is present. This fossil occurs through at least 70 feet of vertical section. At the base of this section

is a bed of gray, massively bedded, crystalline limestone
with interbedded layers of oolitic limestone. On weathering,
this bed has a characteristic, blocky appearance. It is over-
lain by a bed of compact limestone, three feet thick, which
is stained by the previously described green mineral. Over-
lying this, a gray, crystalline, sparsely oolitic limestone
represents the highest level at which Platycrinus was found.
At Caney Sinks, two miles east of Sneedville, brachiopods,
tentatively identified as Leptaena sp., were found in this
section. To the writer's knowledge no occurrence of this
genus has been reported elsewhere above the Burlington lime-
stone of Middle Osage age.

Butts described three formations of Chester age in
Virginia: the Gasper limestone, the Fido sandstone, and the
Glen Dean limestone (Bluefield shale, Cove Creek limestone).
With the exception of the Fido sandstone, which occurs only
in the Greendale syncline, the units of Chester age are
divided by Butts mainly on fossil evidence. The Gasper lime-
stone is recognized by the presence of Talarocrinus. This
fossil is found in the Sneedville area, but it is rare.
Other fossils, however, are abundant, and detailed study of
these could result in a satisfactory division of the upper
units of the Newman limestone.

A list of fossils identified from the upper portion of the Newman limestone follows.

Zaphrentis sp.

Campophyllum (?)

Lithostrotionella prolifera (?)

Fenestrellina, several species

Lyropora cf. L. ranosculum Ulrich

Archimedes, several species

Pentremites, several species

Agassizocrinus sp.

Talarocrinus sp.

Composita subquadrata

Dictyoclostus sp.

Cliothyridina

Tooth of Cladodus

Generalized Geologic Section of Newman limestone
along Indian Ridge

	Thickness	
	Ft.	In.
Newman limestone		
Limestone, drab-gray, mottled with red, thick-bedded; numerous crinoid stems throughout; oolitic in part	24	0
Limestone, gray with reddish tinge, oolitic	4	0
Covered	7	0

	Thickness	
	Ft.	In.
Limestone, porphyritic appearance caused by large white calcite crystals in reddish, compact limestone; grades upward into drab-gray limestone	6	0
Shale, green, fissile, calcareous; weathers to coarse fragments	37±	0
Limestone, light-gray, compact, thick-bedded; greenish at base, very fossiliferous at top; Archimedes abundant, also contains Pentremites and Agassizocrinus	11	0
Limestone, shaly, light-blue, thin-bedded; weathers to shale, largely covered	27±	0
Limestone, light-gray, small oolites, thick-bedded	11	0
Limestone, gray, weathers green, contains small, gray calcite crystals	3	0
Limestone, shaly, green	8	0
Limestone, light-gray, thick-bedded; crinoidal	25	6
Covered	5	0
Limestone, light-blue with green mottling; blue compact, green crystalline; Archimedes abundant	9	0
Limestone, light-gray, alternates with greenish limestone and thin, green shale beds; weathers blocky	17	6
Limestone, shaly, light-blue, fossiliferous	11	6
Limestone, greenish-gray, crystalline, thick-bedded; sparse chert nodules	10	6
Limestone, shaly, light-green; Fenestrellina abundant	3	0
Limestone, gray, crystalline, fossiliferous, thick-bedded; weathers blue	12	0

	Thickness	
	Ft.	In.
Covered	4	0
Limestone, light-green, crystalline	6	6
Limestone, blue, compact, cross-bedded; weathers to white color	10	6
Limestone, light-green, silty, thin-bedded	3	0
Limestone, light-gray, crystalline	5	6
Shale, limy, blue, fissile	2	6
Limestone, dark-gray, oolitic	3	6
Limestone, grayish-green, thick-bedded; contains white calcite crystals, Fenestrellina, Pentremites	13	0
Limestone, light-gray, thick-bedded	10	6
Limestone, light-gray, crystalline; sparsely oolitic	2	0
Limestone, light-green, compact, thin-bedded	3	0
Limestone, light-gray, crystalline; contains Pentremites	5	0
Limestone, grayish-green, compact; shelly	3	6
Covered, probably limestone	3	0
Limestone, greenish-gray; contains black crystals of calcite	2	6
Limestone, light-green, fine-grained; contains crystals of fluorite	3	0
Covered, probably limestone	15	0
Limestone, reddish-gray, silty, thick-bedded	8	0
Limestone, greenish-gray, crystalline, thick-bedded	13	6

	Thickness	
	Ft.	In.
Limestone, gray, fine-grained, brittle, thick-bedded; small bryozoans cause dotted effect	24	0
Covered	3	0
Limestone, dark-gray, compact and crystalline interbeds; numerous streaks of calcite	9	0
Limestone, light-gray, compact, brittle; a few black chert nodules; streaks of green mineral	5	0
Limestone, reddish-gray, compact; weathers to light-red color	3	6
Limestone, light-gray, coarsely crystalline, sparsely oolitic; contains Platycrinus	8	0
Limestone, light-gray, crystalline	4	6
Limestone, light-green, compact, silty	3	6
Limestone, light-gray, coarsely crystalline, oolitic; contains Platycrinus	8	6
Dolomite, light-blue, compact; weathers white; conchoidal fracture; fluorite crystals; sparse lenses of chert that weathers sandy	5	6
Limestone, gray, coarsely crystalline; sparse chert nodules; fossiliferous	1	6
Limestone, dark-gray, finely crystalline; weathers to bluish color; many small, white crystals of calcite	6	6
Covered	14	0
Limestone, gray, coarsely crystalline, oolitic in part, thick-bedded	10	0
Dolomite, blue with greenish tint, very compact, silty	3	0
Limestone, gray, coarsely crystalline, thick-bedded, oolitic in part	12	0

	Thickness	
	Ft.	In.
Limestone, gray, compact to coarsely crystalline, thick-bedded, oolitic at top	14	6
Limestone, bluish-gray, finely crystalline	3	0
Dolomite, gray, tinted light-green in part; weathers to dark-brown; sparse nodules of gray chert	12	0
Total	503 feet	

Maccrady shale

Pennington formation

The Pennington formation, of Late Chester age, was named by Campbell (1893) for Pennington Gap, Lee County, Virginia.

Butts (1940, p. 333) described the Pennington formation as follows:

> The Pennington formation is almost wholly composed of shale and sandstone and contains but a few thin beds of impure limestone. . . .   The sandstone is mainly in thin layers, fine grained, greenish and red. A few beds are conglomeratic. . . .   The shale is largely coarse-grained, crumbly or lumpy mudrock, commonly red, but some beds are yellowish or greenish, or nearly black and calcareous. The red color is the most distinctive characteristic of the formation in its northeastern areas.

Rodgers (1953, p. 111) described the Pennington formation as being "heterogenous and varicolored, including red, purple, and green clay shale, pink, red, green, and brown (normally calcareous) sandstone, and yellow shaly or silty fossiliferous limestone."

The Pennington formation in the mapped area differs somewhat from these descriptions (see geologic section, p. 36). The lower portion of the formation contains several beds of blue and gray, crystalline limestone. Green or gray shale, usually argillaceous, is interbedded with the limestone. This shale generally weathers to a characteristic, coarse, sawdust-like appearance. Thin beds of gray, medium-grained sandstone are also present in the lower portion of the Pennington formation (Figure 12).

Figure 12. Shale and thin-bedded sandstone in Pennington formation, Newman Ridge.

Higher in the formation, sandstone is dominant and limestone is absent. The sandstone is thin- to medium-bedded, medium-grained, and mainly green in color, although some pink beds are present. On weathering, this sandstone becomes friable, and abundant flakes of mica are visible.

Fossils are abundant in the lower portion of the formation and consist mainly of Archimedes and other bryozoans, brachiopods, Agassizocrinus, and crinoid stems. In the sandstone higher in the formation, plant fossils are common.

This formation, which caps both Newman Ridge and Brushy-Indian Ridge, is at least 300 feet thick.

Generalized Geologic Section of Pennington
formation along Indian Ridge

Hunter Valley fault

	Thickness	
	Ft.	In.

Pennington formation

Base covered, probably shale and sandstone, upper part is medium-bedded, gray and green sandstone with thin beds of green shale, estimated — 200±

Limestone, blue, coarsely crystalline, silty; scattered crinoid stems and large, tan-colored brachiopods — 2 — 6

Shale, green, fissile — 3 — 6

Limestone, bluish-gray, with a few thin beds of black shale; many productid-like brachiopods — 12 — 6

	Thickness	
	Ft.	In.
Covered	3	0
Limestone, blue-gray, crystalline, thick-bedded	7	0
Limestone, shaly, blue, very fossiliferous	1	6
Shale, green; a few thin layers of fossiliferous limestone	7	0
Limestone, blue, compact, fossiliferous	3	6
Limestone, blue, silty	4	0
Limestone, blue, finely crystalline, thick-bedded, crinoidal	11	0
Limestone, blue, crystalline, thick-bedded	5	6
Limestone, brownish-gray, oolitic, thick-bedded	8	6
Limestone, light-blue, very silty, fossiliferous; weathers to white color mottled with red	3	0
Shale, green and crumbly, with interbeds of green calcareous sandstone; many crinoid stems	9	0
Shale, blue, and green shaly sandstone	8	0
Covered, believed to be mainly gray shale with some gray, crystalline limestone and thin beds of gray sandstone, estimated	75	

Newman limestone

CHAPTER III

STRUCTURE

Introduction

As previously stated, the mapped area is located in the western portion of the folded and faulted Ridge and Valley province. Approximately ten miles southeast of the area is the Greendale syncline, a major structure that contains an enormous thickness of Mississippian strata. To the northwest is the great Cumberland overthrust block, comprising a surface area of 3,000 square miles. This immense block is believed to have moved from two to ten miles in a northwestwardly direction (Butts, 1940). The southern limit of this block is sometimes placed at the Hunter Valley fault extending through Hancock County just south of Sneedville, but Butts (1940) believes that the boundary should be the Wallen Ridge fault, approximately six miles northwest of the Hunter Valley fault.

According to Rodgers (1953), four thrust faults are present in Hancock County, Tennessee. The Wallen Valley fault extends through the northwestern part of the county between Powell Mountain and Wallen Ridge. The Copper Creek fault is in the southeastern part of Hancock County and parallels the northern base of War Ridge. The Hunter Valley

and Clinchport faults extend through the central portion of
the county and merge east of Sneedville. The resulting fault
continues as the Hunter Valley fault southwestward to near
Clinton, Tennessee. Northeastward, the Hunter Valley and
Clinchport faults apparently merge again about thirty miles
east-northeast of the Tennessee-Virginia state line. In Vir-
ginia this fault is called the St. Paul.

Of the faults mentioned above, only the Hunter Valley
is present in the mapped area. Other faults in the area in-
clude a northwestwardly dipping fault (the Sneedville fault),[1]
and two smaller faults, one at either end of Brushy-Indian
Ridge. (Plate II)

Hunter Valley fault

Campbell (1893, p. 20) described this fault at Big
Stone Gap, Virginia, as follows:

A profound break--the Hunter Valley fault--
stretches from near Rome, Georgia, to the New River,
Virginia, and forms the southeastern limit of all
known Coal-measures. This is one of the most ex-
tensive faults in the Appalachian Province, having
a length of 370 miles and a stratigraphic throw of
11,000 feet.

The Hunter Valley fault is exposed on State Highway 33
one-quarter of a mile south of Sneedville, where the Rome

---

[1]This fault, northeast of Sneedville, Hancock County,
Tennessee, mapped as a southeastwardly dipping fault by Rodgers
(1953), is herein named the Sneedville fault by the writer.

formation has been thrust from the southeast over the Chatta-
nooga shale (Figures 13, 14). Butts (1940) described an ex-
posure of the St. Paul fault (considered to be an extension
of the Hunter Valley fault) near St. Paul, Virginia, where
it dips 12° to the southeast. The Hunter Valley fault at
Sneedville dips 30° to the southeast. Possibly this exposure
represents a local steepening of the fault. (Plate II)

Except for the squeezing of thin layers of Chattanooga
shale along the bedding planes of the Rome formation, there
is very little deformation along the fault. Drag is slight,
and the southeastwardly dips of the formations on both sides
of the fault are approximately the same.

From the exposure south of Sneedville, the Hunter
Valley fault extends northeastward along the southern side of
Brushy-Indian Ridge with an approximate strike of N65E. Along
most of this distance, the Rome formation is in fault contact
with the Pennington formation, the youngest rock unit present,
but at the northern end of Indian Ridge, the Rome formation
has been thrust over Silurian strata. Thus, within a distance
of approximately nine miles, the Rome formation is in fault
contact with a stratigraphic section ranging from Silurian to
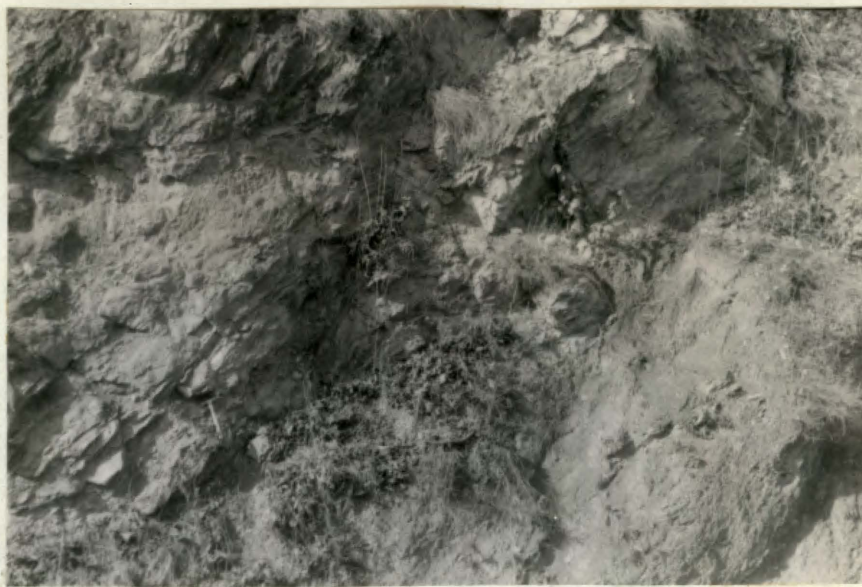upper Mississippian. (Plate II)

Figure 13.   Hunter Valley fault south of Sneedville.
At the left (southeast) is the Rome formation. At right is
the Chattanooga shale.

Figure 14.   Closer view of fault shown in Figure 13.

Sneedville fault

In Dark Hollow, on the southeastern side of Newman
Ridge two miles northeast of Sneedville, outcrops of the Mac-
crady and Newman formations are repeated, and this repetition
can be traced northeastward for nine miles (see geologic maps
Plate Ia, Ib). Throughout this extent, the thickness of the
Maccrady formation remains approximately the same and the dip
of this formation corresponds to the dip of formations on both
sides of it. The Newman limestone becomes increasingly
thinner towards each end of this area. Southwest of Horton
Hollow, outcrops of the Maccrady formation are not exposed
above the Newman formation.

According to Rodgers (1953), a southeastwardly dipping
thrust fault extends through the area described above, and
the Grainger and Newman formations are absent on the southern
side of the fault. The writer found both formations present
throughout the area. Instead of formations being absent, as
indicated by Rodgers, the previously described repetition of
formations was found to occur. In the writer's opinion there
can be little doubt that this repetition is caused by a north-
westwardly dipping thrust fault, herein called the Sneedville
fault. The exposed fault southwest of the bridge on State
Highway 70 at Blackwater, Virginia (at the northeastern edge
of Plate Ib), is believed to be the northeastern extension of
this fault (Figures 15, 16, 17, 18).

Figure 15. Fault at Blackwater, Virginia. At left (southeast) is Newman limestone. At right is Grainger formation.

Figure 16. Closer view of fault shown in Figure 15.
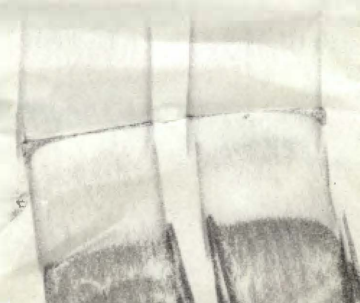
Figure 17. Fault at Blackwater, Virginia. At left (southeast) is Newman limestone. At right is Grainger formation.


Figure 18. Closer view of fault shown in Figure 17.

Northwestwardly dipping thrust faults are not common in the Ridge and Valley province. The writer offers two explanations to account for the northwestwardly dip of the Sneedville fault. The first, based on regional tectonic activity, assumes a pressure from the southeast. The main thrust faults would be expected to dip southeastwardly, but (theoretically, at least) minor, northwestwardly dipping thrust faults should also be present (McKinstry, 1948, 1955). Therefore, the Sneedville fault could be the result of strains resulting from northwestwardly directed forces.

The second explanation is based on local deformation resulting from the movement of the Hunter Valley thrust block. As this block moved across the minor folds in the area, two forces were active along the fault plane: one produced by low-angle, northwestwardly movement, and the other by the tremendous vertical pressure supplied by the weight of the overlying thrust block. The component of these forces would tend to compress the limb of an anticline dipping toward the fault, while the limb dipping away from the fault plane would be subjected to tension. A tension crack could form on the flank of such an anticline, and further movement of the thrust block could cause the crack to develop into a fault with the southeast footwall thrust under the northwest hanging wall (Figure 19).
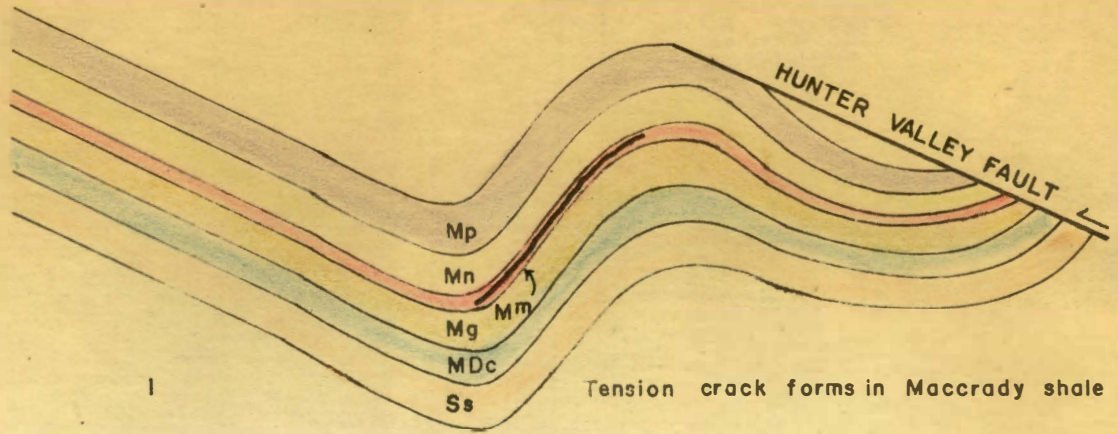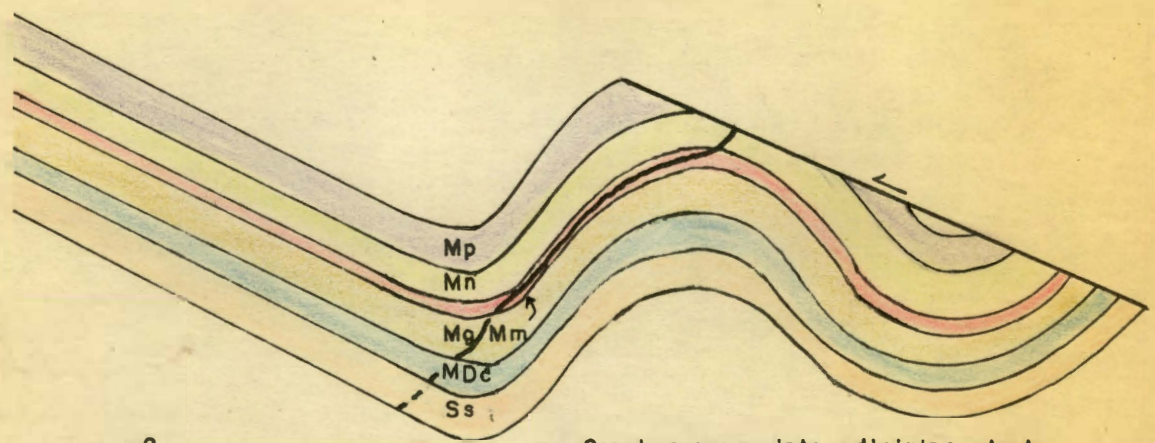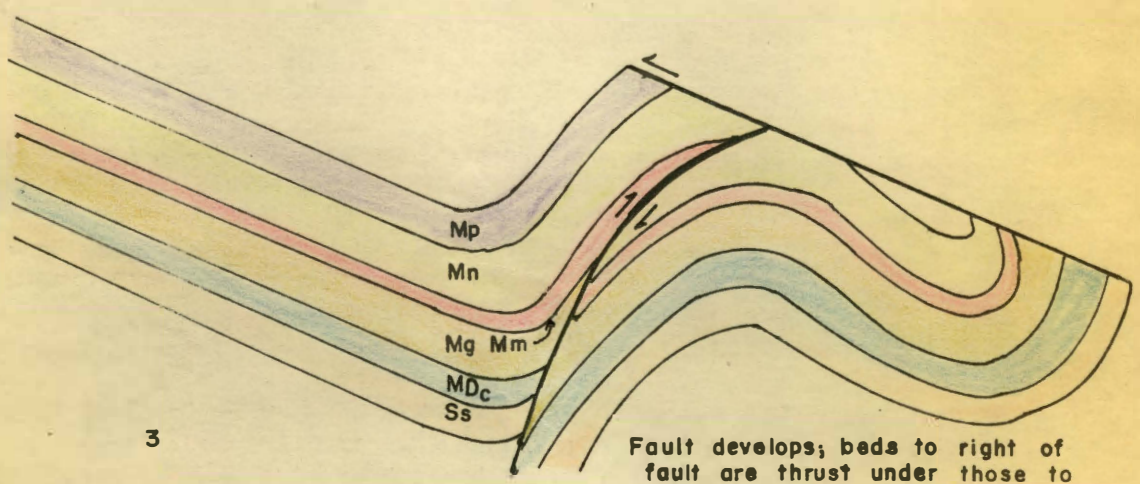
Figure 19. Possible sequence of events that formed Sneedville fault.

The effects of either sequence of tectonic activity suggested above would be similar to the other. The main difference would be that if regional forces produced this fault, the hanging wall has been thrust over the footwall. If movement of the Hunter Valley fault was responsible, the footwall has been thrust under the hanging wall. In either case, shaly beds of the Maccrady formation probably served as a lubricant to the action, and a great part of the fault movement was along the bedding plane of this formation. The Sneedville fault is a combination of a bedding plane fault and a thrust fault.

Minor faults

At the southwestern end of Brushy Ridge, faulting has brought the Chattanooga shale in contact with the Newman limestone. The resulting fault, the throw of which is at least 300 feet, cannot be traced beyond the end of Brushy Ridge, but it probably dies out northwardly. To the south, the fault probably continues in the formations underlying the Hunter Valley thrust; there is no indication that it extends into the thrust block.

The attitude of this fault cannot be determined from the surface evidence available. On cross-section C-C', it is interpreted as a westwardly dipping thrust fault, but it could be a gravity fault with eastwardly dip, or possibly a

strike-slip fault with northward movement of the eastern
block.

A similarly striking fault is present at the north-
eastern end of Indian Ridge. The attitude of this fault can-
not be ascertained, but apparently the eastern block has been
thrust over the western block. The throw of this fault could
not be determined.

Newman Ridge syncline

Newman Ridge is underlain by a syncline that extends
from Howard Quarter, Claiborne County, Tennessee, northeast-
wardly into Virginia. Butts (1940) stated that the over-
turned portion of the Newman Ridge syncline crops out along
the southeast base of Powell Mountain between Duffield, Scott
County, and St. Paul, Wise County, Virginia. Its length in
Tennessee is approximately 25 miles and in Virginia at least
45 miles, a total length of at least 70 miles.

In the Sneedville area, the northern limb of the syn-
cline has a constant, gentle, southeastwardly dip. The dip
of the southern limb varies from gentle to overturned. At
the southwestern end of the area, the southern limb is over-
turned, and small overturned folds occur. Northeastwardly,
the dip of the southern limb flattens and the small folds are
absent. Farther to the northeast, the dip of the southern
limb steepens, and small folds again occur. (Plate II)

Brushy-Indian Ridge syncline

Brushy-Indian Ridge, approximately nine miles long, is underlain by a syncline, the southern portion of which has been overridden by the Hunter Valley thrust block. Only the northwestern limb of the syncline is present throughout most of the length of Brushy Indian Ridge, but at the northeastern end, the axial portion of this structure is exposed.(Plate II)

As was pointed out to the writer by Dr. G. D. Swingle of the University of Tennessee (personal communication), if the interpretation of the northeastern end of this structure is correct, then this is one of the few instances in the Ridge and Valley province of Tennessee where beds in the overridden block of a thrust fault strike discordantly with respect to beds in the thrust block. This condition would indicate that folds existed prior to faulting.

Panther Fork anticline

This anticline is between the Newman Ridge and Brushy-Indian Ridge synclines. To the northeast, this structure probably dies out in a series of small folds. To the southwest, the anticline continues beyond the mapped area.

The axial portion of this anticline is nowhere exposed, but it presumably follows Panther Fork Valley. Horizontal beds, representing a local widening of this structure, are

present about three miles northeast of Sneedville. At Horton Hollow, two and one-half miles northeast of Sneedville, a change of strike occurs. This is interpreted by the writer to be a small nose in the anticlinal structure.

Rodgers (1953, p. 159) apparently referred to this structure as a "Faulted anticline in Devonian and Mississippian rocks." The only indications of faulting observed by the writer are the local changes of strike and dip mentioned above.

Summary of Conclusions

The major structural features of the mapped area are the Newman Ridge syncline and the Hunter Valley fault. The northwestern limb of the Newman Ridge syncline has a constant, gentle dip, whereas the dip of the southeastern limb varies from gentle to overturned. Along the Hunter Valley fault, the Cambrian Rome formation is thrust over the Mississippian Pennington formation, thus bringing in contact the oldest and youngest formations commonly present in the Ridge and Valley province of Tennessee.

Minor features include a northwestwardly dipping thrust fault (the Sneedville fault), two smaller faults, and a small anticline and syncline.

Rodgers' geologic map of East Tennessee (1953) is essentially correct in the Sneedville area, although his

interpretation of the fault northeast of Sneedville as a northeastwardly dipping thrust fault is apparently in error, and the fault that he maps in the anticline northeast of Sneedville is questionable. The two small faults recognized by the writer at each end of Brushy-Indian Ridge are not mapped by Rodgers.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

UNITED STATES
TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS BRANCH

TENNESSEE-VIRGINIA
SNEEDVILLE QUADRANGLE
170-SW

83°15'   36°37'30"   12'30"   (Hubbard Springs 170-NW)   10'   TENN. 2,840,000 FEET   83°07'30"   36°37'30"

WALLEN   RIDGE

Phoebe Butt

Fitts Gap

VIRGINIA
TENNESSEE

MOUNTAIN

HANCOCK CO.
HANCOCK CO.

Sally Gap

Bryson Gap

NEWMAN RIDGE

POWELL

Vardy Community Sch.

MANO RIDGE

Mulberry Gap

Dry Branch

FAULT

SNEEDVILLE

Jabez Knob

HUNTER VALLEY

FAULT

Rider Chapel

CLINCH   RIVER

KNOBS

CHESTNUT

RIDGE

CHESTNUT   RIDGE

RICHLAND   HOLLOW

WAR RIDGE

CLINCH   RIVER

36°30'   83°15'   (Lee Valley 171-NW)   10'   83°07'30"   36°30'

Scale 24000

Control by USC&GS, USGS, and TVA
Topography by USGS and TVA from aerial
photographs by stereophotogrammetric methods
Field examination by Tennessee Valley Authority, 1946

Maps distributed by the Geological Survey

APPROXIMATE MEAN
DECLINATION, 1947

Contour interval 20 feet
Datum is mean sea level

Polyconic projection. 1927 North American datum
10,000 foot grid based on Tennessee and
Virginia (South) rectangular coordinate systems

SNEEDVILLE, TENN.-VA.
170-SW
Edition of 1947

Plate Ia

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

UNITED STATES
TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS BRANCH
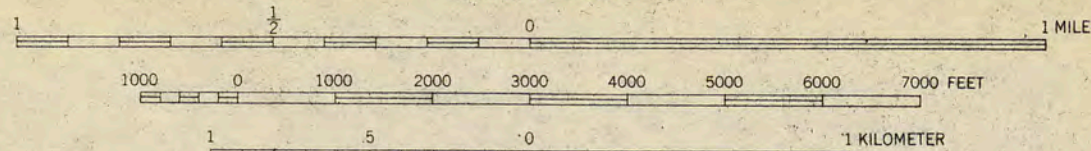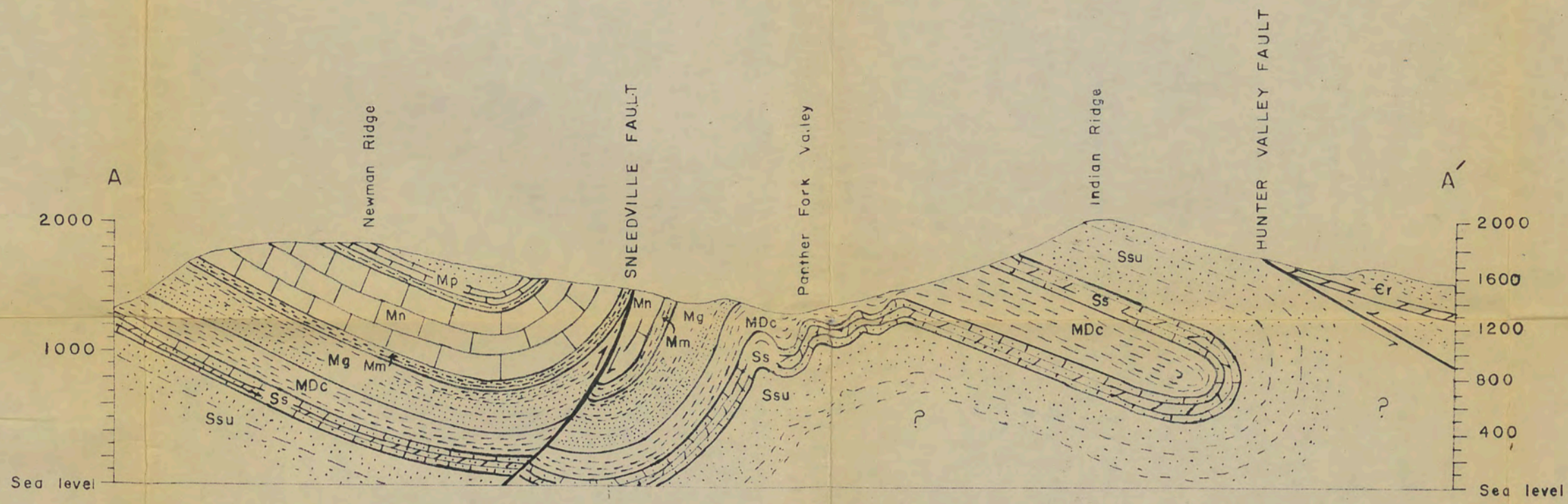
TENNESSEE-VIRGINIA
KYLES FORD QUADRANGLE
170-SE

GEOLOGIC MAP OF NEWMAN RIDGE AND BRUSHY-INDIAN RIDGE FROM SNEEDVILLE, HANCOCK COUNTY, TENNESSEE, TO BLACKWATER, LEE COUNTY, VIRGINIA

EXPLANATION

MISSISSIPPIAN

Mp — Pennington formation

Mn — Newman limestone

Mm — Maccrady shale

Mg — Grainger formation

DEVONIAN

MDc — Chattanooga shale

SILURIAN

Ss — Sneedville limestone

Ssu — Silurian sandstone and shale, undivided

CAMBRIAN

Єr — Rome formation

⤢20 — Strike and dip of beds

⤢30 — Strike and dip of overturned beds

⟋ — Strike of vertical beds

⊕ — Horizontal beds

— — — Contact, dashed where approximately located, dotted where inferred

⊤ ⊤ ⊤ — Thrust fault, showing direction of dip, dashed where approximately located, T on upper plate

— — — — Fault, direction of dip unknown

— ? — ? — Probable fault

—┼— Syncline, showing trace of axial plane, dashed where approximately located

Geology by Adrian V. Greene 1958-1959

SCALE 1:24000

1000   0   1000   2000   3000   4000   5000   6000   7000 FEET

1   0   1 MILE

1   0   1 KILOMETER

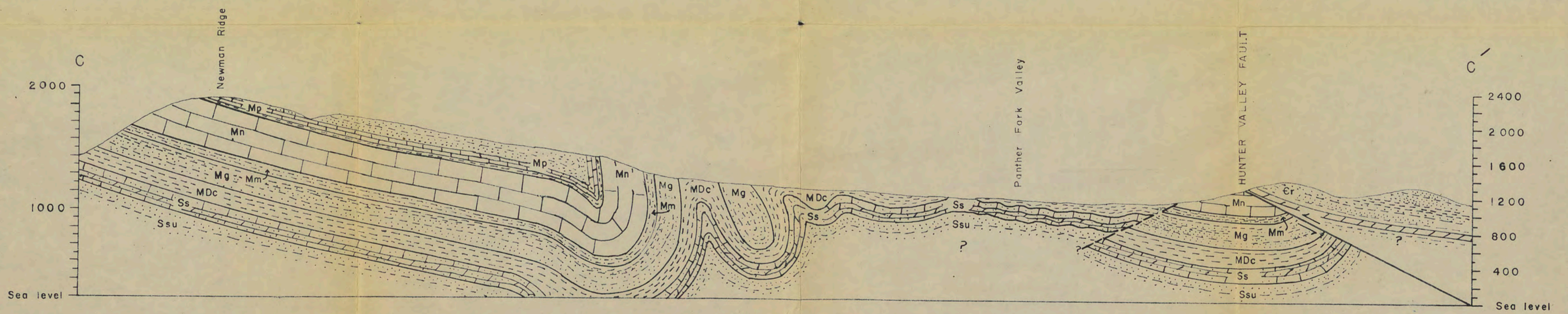Contour interval 20 feet
Datum is mean sea level

Plate 1b

GEOLOGIC CROSS SECTIONS

SECTION ALONG LINE A—A'
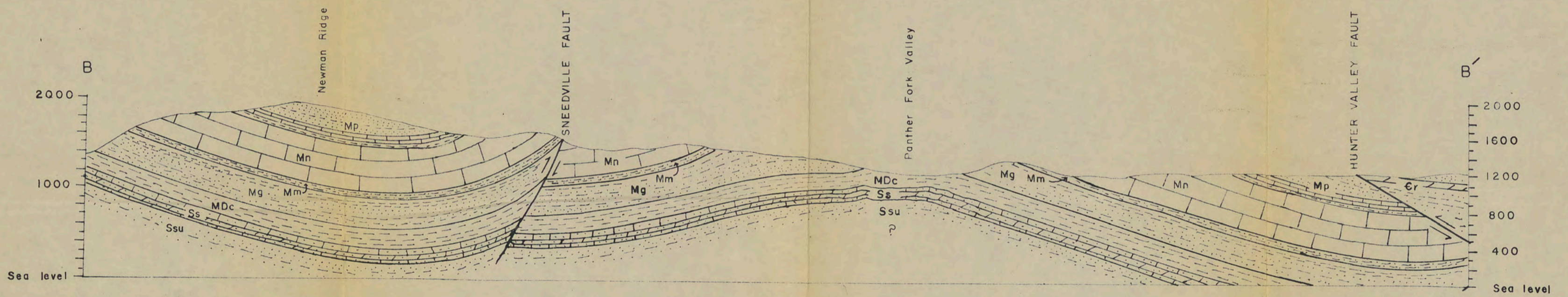
SECTION ALONG LINE B—B'

SECTION ALONG LINE C—C'

Plate II