To the Graduate Council:

I am submitting herewith a thesis written by Steve M. Wilson entitled "Geology of the Fall Branch, Tennessee Area." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

Don W. Byerly

Don W. Byerly, Major Professor

We have read this thesis and recommend its acceptance:

Alfred B. Keller

Accepted for the Council:

L. Evans Roth

Vice Chancellor
Graduate Studies and Research

GEOLOGY OF THE FALL BRANCH, TENNESSEE AREA

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Steve M. Wilson

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ABSTRACT

This investigation seeks to interpret the stratigraphic and structural relationships of a 43 square kilometer (27 square mile) area at Fall Branch, in northeastern Tennessee. Approximately 2362 meters (7750 feet) of sedimentary rocks ranging from Middle Cambrian to Middle Ordovician in age are exposed in the study area.

Exposures of the Nolichucky Formation consist of three distinct members: a lower shale member; a middle intraclastic and oolitic limestone member; and an upper silty shale member. Detailed examination of the middle limestone member reveals an offshore depositional environment which became progressively more shallow with time.

The study area is roughly bisected by the northeast-southwest trending trace of the Pulaski thrust fault. Post-Pulaski stress has resulted in the bending of the Pulaski glide plane and subsequent exposure of a window of Sevier Shale near Sulphur Springs.

An exposure of overturned Jonesboro Limestone beds in the northeastern portion of the study area, along Mill Creek, is interpreted to be the result of movement along the Mill Creek thrust fault, which developed in a drag fold along the Pulaski fault.

The southeastern half of the study area is characterized by numerous anticlines and synclines. Many of these

folds exhibit bent axial planes indicating that more than one episode of compression was involved in the shaping of these folds.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER I

INTRODUCTION

Purpose and Method of Investigation

The objective of this study is to describe and interpret stratigraphic and structural relationships of the rocks present in the Fall Branch, Tennessee area. Since no drilling nor geophysical data were available, this was accomplished by detailed areal mapping.

Numerous traverses were made across the regional strike to determine the gross structural picture and all stratigraphic and fault contacts were walked out where field conditions permitted. Attitudes of bedrock outcrops were measured with the use of a Brunton compass and plotted on topographic maps of the Tennessee Valley Authority (scale: one inch equals 2000 feet). Because of lithologic similarities and the scarcity of outcrops of the formations in some areas, criteria such as chert, soils, cryptozoans, shale chips, and sandstone float were often used in determining the areal extent of the formations. Formational thicknesses were measured directly in the field with a tape measure where possible, otherwise they were determined by calculations utilizing angle of slope, dip of the rock, and the apparent width of outcrop.

Much of the information concerning the stratigraphy of the units was obtained from the literature and then confirmed or modified by field observations. The writer also studied the well-exposed section at Jockey Creek (Oder, 1934) before beginning field mapping to aid in the identification of the formations.

The field studies were begun in July of 1978 and concluded in August of 1979.

Location and Size of Area

The area studied in this report is in the general vicinity of the community of Fall Branch in northeastern Tennessee, some 14.5 kilometers (9 miles) south of the Tennessee-Virginia border (Figure 1). The nearest metropolitan area is the city of Kingsport, which is approximately 12.8 kilometers (8 miles) to the northeast. A major transportation artery, Interstate 81, roughly bisects the area along strike.

The mapped area includes parts of Sullivan, Washington, and Greene Counties, and encompasses an area of 43 square kilometers (27 square miles). Equal portions of the area can be found on the Lovelace and Sullivan Gardens quadrangles (Tennessee Valley Authority 7.5 minute quadrangles 189-NW and 189-NE, respectively).

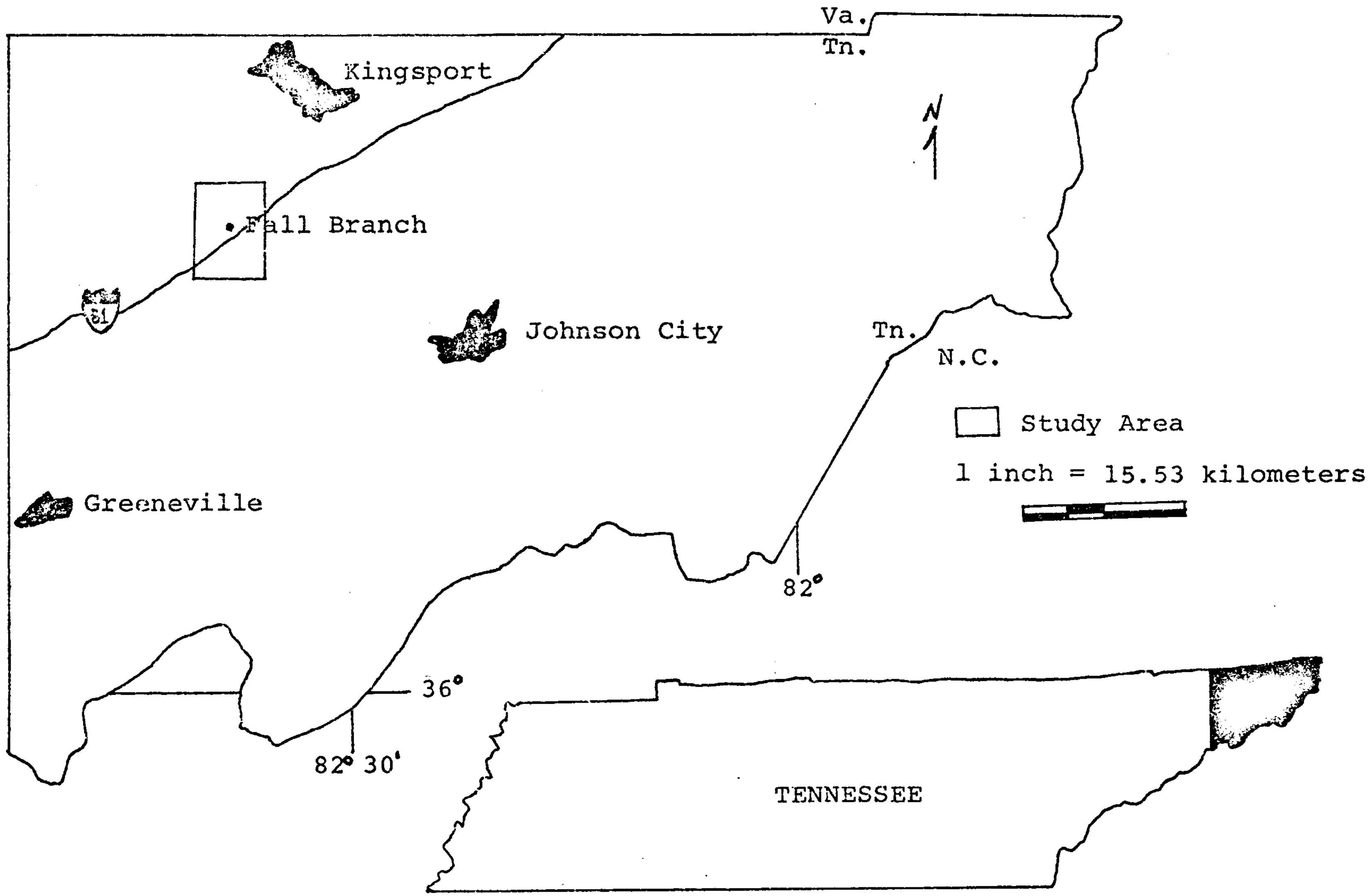

Figure 1. Location of study area.

Geologic Setting

The Valley and Ridge Physiographic Province, in which the Fall Branch area lies, is characterized by folded and faulted Paleozoic rocks. These rocks are predominately carbonates and shales that range in age from early Cambrian to late Ordovician.

In northeastern Tennessee, the rocks of the Valley and Ridge province are broken by a series of low angle thrust faults, some of which have surface expressions that may be traced for over 560 kilometers (350 miles). These fault traces are roughly parallel, striking predominately northeast-southwest, and dipping to the southeast. As a result, the rocks are broken into long, linear belts that tend to repeat the stratigraphic succession of the adjacent belt (Bridge, 1956). Horizontal displacement can be as much as 60 kilometers (37 miles) (Roeder and Witherspoon, 1978). In general, the axes of anticlines and synclines are roughly parallel to the strike of the associated thrust faults.

Within the Valley and Ridge province, one of the longest fault traces is formed by the Pulaski fault. This fault is present in the Fall Branch area and may be considered to be a "structural front," as it separates the lengthy open folds (tens of miles in extent) and longer fault traces of the northwestern footwall block from the more tightly folded strata of the southeastern hanging wall block. Within the study area, the fault trace strikes in a general northeast-southwest direction and has a calculated minimum stratigraphic displacement of approximately 1753 meters (5750 feet). The Pulaski fault also serves as a "stratigraphic front," separating cherty dolomites and limestones in the footwall block from the less cherty limestones and dolomites of the hanging wall block.

Previous Investigations

The geology of the Fall Branch area was first investigated as part of a larger scale regional study by Safford in 1869. Subsequent regional geologic studies include Keith (1905) and Rodgers (1953). For his doctoral dissertation, Cummings (ms.,1962) mapped and studied the stratigraphy of the Bays Mountain synclinorium, a portion of which lies immediately northwest of the Fall Branch area. The economic geology of the barite deposits occurring around Fall Branch was investigated by Stuart Maher in 1970.

Near by areal geologic studies include the Baileyton quadrangle (Byerly, 1969), located southwest of Fall Branch, an area around Quaker Knobs (Little, ms., 1969) which is just southeast of the present investigation, and the "Geologic Map of Tennessee" (Hardeman _et al._, 1966). Roper (ms., 1977) investigated mesoscopic fabric elements and the chronology of faulting and folding southwest of the study area.

CHAPTER II

STRATIGRAPHY

General

Approximately 2362 meters (7750 feet) of sedimentary rocks, ranging from Middle Cambrian to Middle Ordovician in age, are exposed in the Fall Branch area. Their general ages and relative thicknesses are shown in Figure 2. Because of their deeply weathered condition, rock outcrops are scarce in some areas; therefore, it was often necessary to map the bedrock by studying the residuum.

As previously noted, the Pulaski fault serves as a stratigraphic as well as structural front. In the Fall Branch area, the upper block of this fault contains the Honaker Formation, Nolichucky Formation, Maynardville Limestone, and the southeastern phase of the Knox Group (Conococheague Limestone and Jonesboro Limestone); the lower block contains the Sevier Shale and the Mascot Dolomite of the northwestern phase of the Knox Group (see Table 1). The Honaker is the oldest Middle Cambrian unit exposed in the area. A basal argillaceous section of this formation, exposed only at Tennessee Rectangular Coordinates (760,500N, 2,998,200E) in the Fall Branch area, probably served as the glide plane for the Pulaski fault. The upper Cambrian members of the Conasauga Group, the

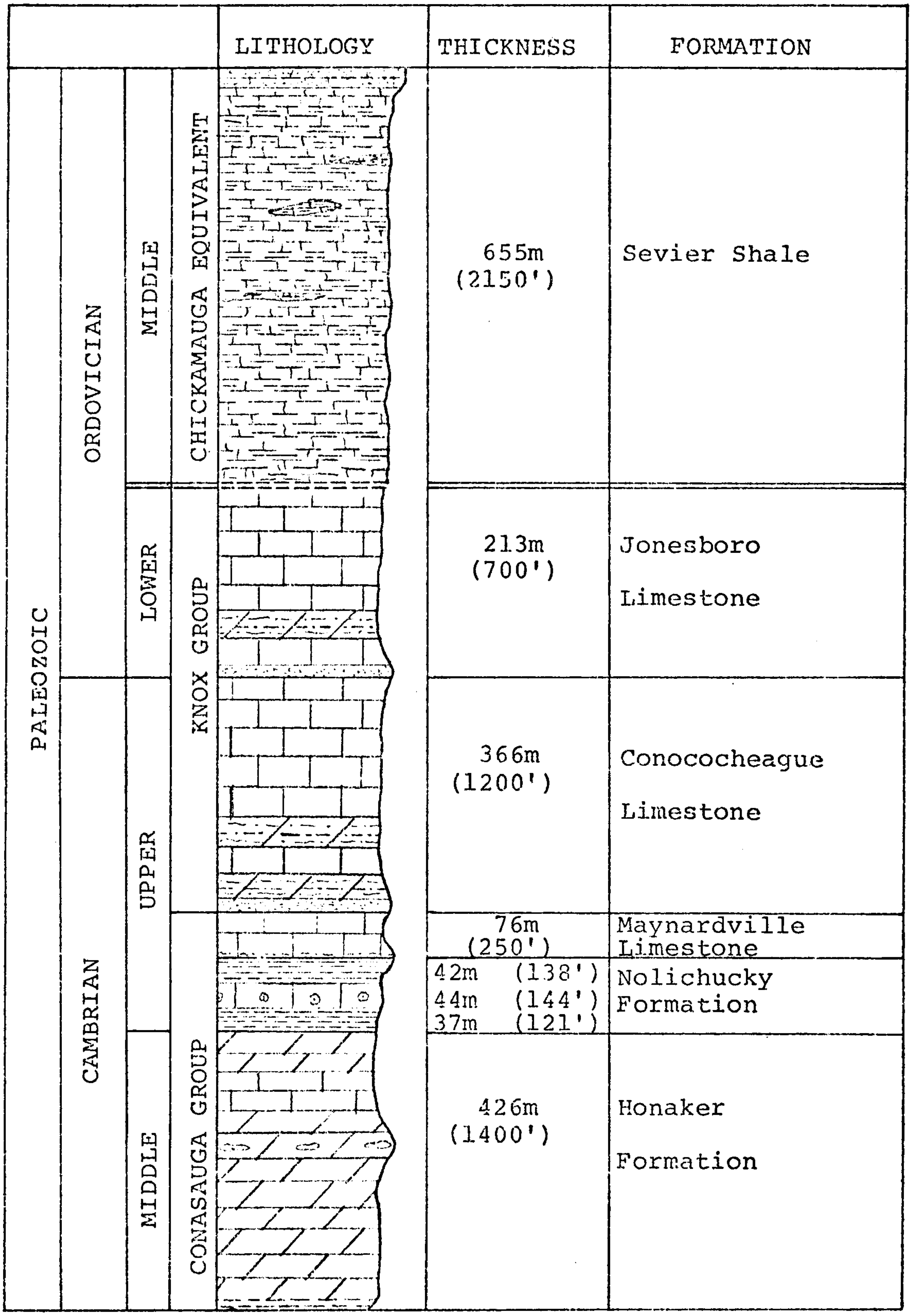

Figure 2. Generalized stratigraphic column of the Fall Branch, Tennessee area.

TABLE 1

SUBDIVISIONS OF THE KNOX GROUP

(after Rodgers, 1953)

Northwestern Phase		Southeastern Phase	
Mascot Dolomite	137m* (450')	Jonesboro Limestone	305m* (1000')
Kingsport Formation	**		
Longview Dolomite	**		
Chepultepec Dolomite	**		
Copper Ridge Dolomite	**	Conococheague Limestone	366m* (1200')

*Numbers indicate unit's average thickness in Fall Branch area.

**Not present in the Fall Branch area.

Nolichucky Formation and Maynardville Limestone, are easily distinguished from each other by their different lithologies. The overlying Knox Group (late Cambrian to early Ordovician) is separated from the Maynardville Limestone on the basis of occurrence of a persistent sandstone at the base of the Conococheague Limestone. Knox carbonates are unconformably overlain by the middle Ordovician Sevier Shale (Milici, 1973).

Description of Rock Units

Conasauga Group

The Conasauga Group was named by Hayes in 1891 for exposures along the Conasauga River in Whitfield and Murray Counties, Georgia (Table 2). Rodgers described three distinct phases in East Tennessee; a predominately shale phase to the northwest, a transitional central phase, and a predominately carbonate phase to the southeast. In the study area, the Conasauga consists of the middle Cambrian Honaker Dolomite and the upper Cambrian Nolichucky Shale and Maynardville Limestone. The best exposure of these units in the Fall Branch area can be found where Irvin Hollow cuts across Howard Ridge at Tennessee Coordinates (747,800N, 2,998,000E). A measured stratigraphic column of this exposure may be found in the Appendix.

TABLE 2

ORIGIN OF STRATIGRAPHIC NAMES

Stratigraphic Unit	Named by	Type Locality
Sevier Shale	Keith, 1895	Sevier Co., Tenn.
Lenoir Limestone	Safford & Killebrew, 1876	Lenoir City, Loudon Co., Tenn.
Knox Group	Safford, 1869	Knoxville, Knox Co., Tenn.
Jonesboro Limestone	Ulrich, 1911	Jonesboro, Washington Co., Tenn.
Conococheague Limestone	Stose, 1908	Conococheague Creek, Franklin Co., Penn.
Mascot Dolomite	Oder & Miller, 1945	Mascot, Knox Co., Tenn.
Conasauga Group	Hayes, 1891	Conasauga River, Whitfield and Murray Counties, Ga.
Maynardville Limestone	Oder, 1934	Maynardville, Union Co., Tenn.
Nolichucky Shale	Campbell, 1894 Keith, 1905	Nolichucky River, Greene Co., Tenn.
Honaker Dolomite	Campbell, 1897	Honaker, Russell Co., Virginia

Topographic expression of the Conasauga is quite pronounced, the lower Honaker forming a high southwest-northeast striking line of knobs, the middle and upper Honaker forming broad valleys, the lower Maynardville-upper Nolichucky forming high ridges, and the lower Nolichucky underlying a low bench adjacent to these ridges. Macroscopic fossils are rare, consisting mostly of algal structures in the lower Honaker and occasional trilobites in the Nolichucky. Thin sections of the Nolichucky reveal trilobite, brachiopod, and pelmatozoan fragments.

Honaker Dolomite

The Honaker Dolomite, of middle Cambrian age, is the oldest formation that crops out in the Fall Branch area. The name Honaker Limestone was first used by Campbell (1897), who interpreted this unit as equivalent to the Rutledge Limestone, Rogersville Shale, and Maryville Limestone. Other writers (Rodgers, 1953) have used the name Honaker Formation because of the unit's lithologic variation. A portion of the basal Honaker is not present in the study area, so a thickness of no less than 426 meters (1400 feet) can be assigned to this unit. Where exposed, the lower Honaker is composed of a dark gray (N3)* dolomitic shale that grades upward into the lighter

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*Geological Society of America Rock-Color Chart, Goddard, 1963.

colored Honaker dolomites. The middle and upper parts of the Honaker consist of medium- to massively-bedded, dark to medium dark (N3 to N4), fine- to medium-grained dolomite alternating with medium gray to medium dark gray (N5 to N4) fine-grained limestone. The dolomite tends to weather to a medium light gray (N6) color with a "blocky" appearance. Silty layers in the middle portion of the formation serve to give the rock a "ribboned" appearance. Near the Pulaski fault in the southwestern portion of the study area, the middle part of the Honaker weathers to produce boulder-sized (20 to 30 centimeters in diameter) "algal head" chert (Figure 3). These form by silica replacement of thinly to thickly laminated limestone and dolomite (Little, ms., 1969). The middle part of the Honaker that contains this chert forms prominent rounded knobs and ridges (Figure 4), in contrast to the lower and upper parts of the Honaker, that tend to form broad open valleys. The darker layers of dolomite, particularly in the upper portions of the formation, are characterized by a fetid odor when freshly broken, which serves as a helpful aid in the identification of the Honaker. The contact with the overlying Nolichucky Formation is sharp where exposed in the study area.

Figure 3. Typical "algal head" chert of the lower Honaker.

Figure 4. Lower Honaker ridge upheld by "algal head" chert. The view is from Kyle Hill, looking northeastward.

Nolichucky Formation

The name Nolichucky was first used in 1894 by Campbell in the U.S.G.S. Estillville folio. He described the formation as 500 to 730 feet of calcareous shale containing lentils of blue limestone. Milici (1973), Helton (ms., 1967), Haney (ms., 1966), and Pugh (ms., 1966) also mentioned these carbonate units and described them as oolitic and intraclastic limestones within the shale (Figure 5). Other writers (Bridge, 1956, Byerly, ms., 1966, and French, ms., 1966) regarded the middle limestone and upper shale as part of the overlying Maynardville Limestone. This writer believes the limestone constitutes a separate member of the Nolichucky at least in the Fall Branch area, and agrees with Haney (ms., 1966) that the term Nolichucky Formation be used in place of Nolichucky Shale as a formational name.

In the Fall Branch area, exposures of the Nolichucky Formation consist of an upper and a lower calcareous, silty shale separated by a middle limestone member (Table 3). Field measurements of the Nolichucky indicate an average total thickness of 122 meters (400 feet). The shales are thin- to very thin-bedded and vary in color from grayish orange (10 YR 7/4) to yellowish gray (5 Y 8/2) and dark yellowish orange (10 YR 6/6). The carbonate member of the Nolichucky Formation consists of a medium gray (N5) to medium dark gray (N4) limestone that weathers to

Figure 5. Carbonate member in the Nolichucky Formation exposed at Irvin Hollow.

TABLE 3

FIELD MEASUREMENTS OF THE NOLICHUCKY FORMATION

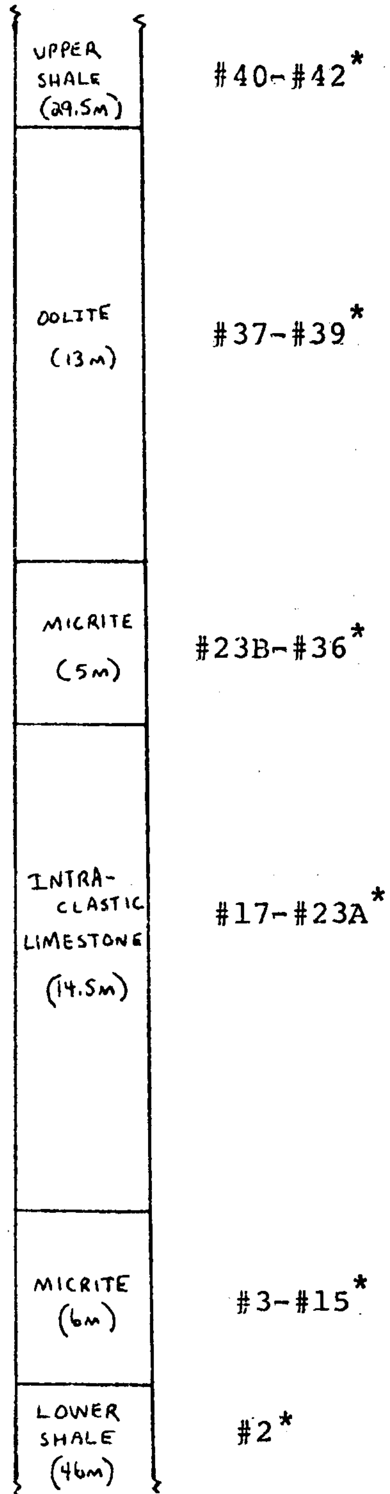
Member	Measured at Tennessee Coordinates			
	(745,200N, 2,994,550E)	(746,600N, 2,996,550E)	(747,800N, 2,998,000E)	(752,700N, 3,002,900E)
Upper Shale	50m	43m	30m	46m
Middle Limestone	44m	43m	41m	50m
Lower Shale	36m	37m	46m	30m
Total	130m (427')	123m (404')	117m (384')	126m (413')

a light to medium light gray color (N7 to N6). The middle limestone member of the Nolichucky (Figure 6) varies in thickness from 41 to 50 meters (135 to 165 feet) but shows no directional trend in thickness variation.

Thin section analysis of a measured section of the Nolichucky Formation (Appendixes A and B) reveals an orderly progression of lithologies that can be used to infer the depositional environments of these rocks. The general lithologic subdivisions, shown in Figure 7, progress from a lower micritic shale unit of 46 meters (151 feet) in thickness through 6 meters (19.7 feet) of micrite, 14.5 meters (47.6 feet) of intraclastic limestone, 5 meters (16.4 feet) of micrite, 13 meters (42.6 feet) of oolite, to an upper 19.5 meter (97 foot) unit of micritic shale.

The lower micrite is a mudstone (Dunham, 1962) with occasional shale laminae. Numerous burrows, occasional laminae rich in trilobites, and some sparse inarticulate brachiopods are the only fossils present. Fossil fragments throughout the middle Nolichucky are uncrushed, indicating early cementation which led to little or no compaction (Pettijohn, 1975, p. 369) of these units. The stratigraphically higher micrite, like the lower, is a mudstone with shale laminae, however, the upper micrite contains less fossil material, with only some trilobites and burrows.

Figure 6. Typical Nolichucky Oolite (Acid treated to enhance ooids).



Scale: 1 inch = 5.9 meters.

Figure 7. Generalized stratigraphic column of the middle Nolichucky.

*Corresponds to unit numbers in Appendix A.

The intraclastic limestone units are the most fossiliferous of the middle Nolichucky, containing abundant trilobites, pelmatozoans, burrows, and pellets. Intraclasts are generally round to subround, show a wide range in size, and occasionally have a thin layer of calcite precipitated on their rims. This calcite precipitation gives the appearance of the early stages of ooid formation around the clasts. These features suggest that the clasts were either transported some distance to the depositional site after being set into motion or reworked in place.

The oolite units are composed predominately of large (1-2 mm) ooids and pellets which are often replaced by calcite. Fossils present include abundant trilobites and pelmatozoans. Because the only known present day occurrences of ooids are in shallow waters, these units are assumed to have been deposited in a similar environment.

The sequence of the lower shale to the oolite indicates a general shallowing trend in the environment of deposition. Whether this is due to an infilling of the depositional basin or a rise in sea level cannot be determined for certain. Fossils found in the middle Nolichucky (trilobites, pelmatozoans, inarticulate brachiopods) and the total lack of quartz and grains, dessication features, and near shore organisms, indicate these sediments were deposited in an offshore environment. The contact between the oolite and the upper shale was not exposed in the study area but is believed to be an unconformity because of the different depositional environments of oolites and calcic shales.

The Nolichucky shales are the most fossiliferous Cambrian rocks in the Fall Branch area, containing macroscopic specimens of trilobites, brachiopods, and pelmatozoans. The fauna of this unit helps to distinguish it from another shale formation found in the area, the Sevier Shale. Topographically, the upper Nolichucky underlies ridges and knobs due to the increased siltiness of the shale near the contact with the overlying Maynardville Limestone. This contact is gradational over 1 to 2 meters as the shale becomes more calcareous upward, eventually giving way to the ribboned limestones of the Maynardville.

Maynardville Limestone

The Maynardville Limestone was originally described by Oder (1934), who placed the formation within the basal Knox Group. Subsequent workers have placed the Maynardville Limestone within the Nolichucky Formation (Bridge, 1956), while others regard the unit as a separate formation at the top of the Conasauga Group. Although the contact with the underlying Nolichucky is gradational, the Maynardville can easily be mapped as a distinct lithologic unit in the Fall Branch area. Its thickness in this area averages 76 meters (250 feet).

The lower part of the Maynardville consists of a medium- to thick-bedded, medium gray (N5), fine-grained limestone that is ribboned with a silty dolomitic limestone. Upon weathering, the limestone turns a light bluish gray (5 B 7/1) color. The dolomitic limestone weathers to yellowish brown (10 YR 6/1) and tends to stand out in relief. The upper portion of the formation is composed of fine-grained, medium- to thick-bedded, medium gray (N5) limestone that weathers to a light gray (N7) color. Dolomite also occurs as discrete beds interbedded with the limestone. Toward the top of the formation, silty limestones and dolomites become more abundant and, in addition to the overlying basal sandstone in the Conococheague, tend to form topographic highs. The upper boundary of the Maynardville Limestone is drawn at the base of the lowermost thick-bedded sandstone occurring in the Conococheague Limestone.

Knox Group

In the Valley and Ridge Province of East Tennessee, the Knox Group consists of two distinct phases. A predominately dolomite phase (relatively to the northwest) that produces much chert upon weathering is separated by the Pulaski fault from a predominately limestone phase (relatively to the southeast) which produces little chert. The lower formation of each phase of the Knox is considered to be late Cambrian in age while the remaining Knox units are early Ordovician (Rodgers, 1953). Well exposed sections of the Knox are rare due to the high degree of weathering. Knox residuum consists of an orange-red, clayey, sometimes very deep soil that underlies a rolling topography.

The southeastern phase of the Knox is divided into the Conococheague Limestone and the overlying Jonesboro Limestone. These two units are similar in appearance, but can be distinguished from each other on the basis of sandstones that occur within the basal Jonesboro. The northwestern phase of the Knox is divided into several formations (see Table I, page 8) of which only the uppermost Mascot Dolomite is present in the study area.

Conococheague Limestone

The Conococheague Limestone was named by Stose (1908) for exposures at Conococheague Creek at Scotland, Franklin County, Pennsylvania. The Conococheague is late Cambrian in age (Rodgers, 1953) and underlies a gently rolling topography. Its thickness in the Fall Branch area is approximately 366 meters (1200 feet).

The Conococheague consists of medium- to thick-bedded limestone interbedded with dolomite. The lower boundary of the unit is defined at the base of the lowest sandstone within a 9 meter (30 foot) thick zone of alternating sandstones and sandy limestone (Figure 8). These quartzose sandstones are cross-bedded and ripple-marked, and upon weathering, leave blocks of friable sandstone in the residuum. Consequently, the basal Conococheague tends to form ridges capped by a sandy soil. In a study of the basal sands in the Knox, Collins (1956) concluded that these sands were deposited in a stable shelf environment with a sediment source from the northeast. The limestone is fine- to medium-grained, medium dark gray (N4), medium- to thick-bedded, and in the lower part the formation is generally ribboned with thin layers of silty dolomite. The dolomite is medium to light gray (N6 to N7), fine-grained, medium-bedded, and tends to be less abundant in the upper portion of the Conococheague. Weathered colors, where exposed, are medium bluish-gray (5 B 7/1) for the limestones, slightly darker (5 B 5/1) in the upper portion of the formation, and light gray (N7) for the dolomites. Except for silicified cryptozoans, fossils and chert are rare. The upper contact with the overlying Jonesboro Limestone is placed at the base of the next stratigraphically higher sandy zone.

Jonesboro Limestone

The name Jonesboro was first used by Ulrich (1911) for exposures near Jonesboro, Tennessee. In his original

Figure 8. Basal Conococheague sand exposed along Highway 93 at Howard Ridge.

description, Ulrich placed the base of the Jonesboro Limestone at the top of the Nolichucky Shale and included the Maynardville within the Jonesboro. In this report, the Jonesboro Limestone extends from the base of the lowermost sandy zone above the sandy zone in the basal Conococheague to the unconformable contact with the overlying Sevier Shale. In the Fall Branch area, the Jonesboro is 213 meters (700 feet) in thickness and is not found in stratigraphic contact with the Sevier. Previous geologic studies near the study area, which include exposures of the entire Jonesboro (Byerly, ms., 1966 and Little, ms., 1969), indicate its total thickness to be approximately 610 meters (2000 feet).

The Jonesboro consists mostly of fine- to medium-grained, dark gray (N3), thick- to massively-bedded limestone that weathers to a medium blue-gray (5 B 5/1) or gray (N5) color. Lower portion of the formation contain laminae of silty dolomite which give the rock a "ribboned" appearance (Figure 9). Thin sandstone beds averaging about 0.3 meters (one foot) in thickness occur in the basal 60-90 meters (200-300 feet) of the Jonesboro. These sands probably correspond to the basal sandy member of the Chepultepec Dolomite of the northwestern phase of the Knox. Although not as easily traceable as the basal Conococheague sands, the Jonesboro sands can be found in the residuum where they tend to form low, broad, ill-defined ridges. Chert can be found in the residuum of the lower and upper portion of the formation, but is very sparse throughout the entire unit. The contact with the overlying Chickamauga Group is not present in the Fall Branch area, but is reported to be a disconformity (Little, ms., 1969).

Figure 9. "Ribboned" Jonesboro Limestone exposed near Haws Crossroads.

Mascot Dolomite

The Mascot Dolomite is the only formation of the northwestern phase of the Knox present in the Fall Branch area. The name Mascot first appeared on a geologic map of the Copper Ridge district by Rodgers in 1943 but wasn't published until Oder and Miller did so in 1945. The thickness of the Mascot is probably between 122-152 meters (400-500 feet) in the Fall Branch area. Its greater apparent thickness on the areal map (Plate I) is due to folding and faulting.

The Mascot Dolomite consists largely of thick- to medium-bedded, medium gray (N5), fine-grained dolomite interbedded with blue-gray (5 B 5/1), fine-grained limestone. Beds are commonly 0.3 to 0.6 meters (1 to 2 feet) in thickness. One or two chert-cement or quartzitic sandstone beds occur near the base of the formation. Although the writer found none in the study area, "cannonballs" of chert are characteristic of the weathered Mascot (Rodgers, 1953). The Mascot does not form a distinctive topography in this area, although occasional sinkholes can be found in the upper portions of the formation.

The contact with the overlying Chickamauga Group, as in the case of the Mascot's southeastern equivalent of the Knox, the Jonesboro, is considered to be a disconformity. Although not observed in the Fall Branch area, "fossil" sinkholes of up to 90 meters (300 feet) in depth have been reported in the Mascot (Laurence, 1944).

Lenoir Limestone

The Lenoir Limestone, found throughout East Tennessee between the upper Knox and the overlying Mid-Ordovician shales, is conspicuously absent in the study area. The writer lacks sufficient data to explain its absence. It might be noted however, that this unit has also been reported absent in other localities (Bearce, ms., 1966).

Sevier Shale

The Sevier Shale was named by Keith in 1895 for a thick series of calcareous yellow shale "immediately northwest of Chilhowee Mountain," which is located in Sevier County, Tennessee. The middle Ordovician Sevier Shale lies disconformably on the Knox as a result of an episode of erosion before mid-Ordovician time. Extensive cleavage development and numerous folds are characteristic of this unit.

In the Fall Branch area, the Sevier is highly weathered and appears as a moderate yellowish brown (10 YR 5/4) to light brown (5 YR 5/6), silty to sandy, calcareous, fissile shale. Where bedding can be distinguished from a well developed cleavage, numerous graptolites can often be found in addition to brachiopods and bryozoans. When freshly exposed, the shale appears dark gray (N3) to grayish black (N2) in color.

Near the middle of the Sevier, in the northwestern corner of the study area, there is a series of alternating shale and sandstone (Figure 10) which is shown on Plate I as Osvs. The sandstone is a medium- to massively-bedded, calcareous, fine-grained, medium gray (N5) quartz sandstone. These sediments weather light to moderate brown (5 YR 5/6 to 5 YR 4/4) in color, occasionally show a fining upward in grain size, and tend to form a pronounced topographic high, which has been traced for over 4½ kilometers (3 miles). The writer believes these persistent sands allow a subdivision of the Sevier into a lower shale member, a middle alternating shale and sandstone, and an upper shale member. However, no attempt has been made to assign stratigraphic thicknesses to the shales based on this subdivision, because of the intense folding, faulting, and cleavage development in the incompetent shale. The middle sandstone member is also extensively folded so that its thickness can only be said to be in excess of 30 meters (100 feet). The thickness of the Sevier in the Fall Branch area is 655 meters (2150 feet) and its total thickness in this vicinity is probably greater than 850 meters (2790 feet).

Topographically, the shales of the Sevier tend to form roughly northeast-southwest rows of "haystack"-like knobs of roughly 30 to 60 meters (100 to 200 feet) in relief. Figure 11 shows typical "haystack" weathering.

Figure 10. Sevier sandstones exposed at Tennessee Coordinates (766,050N, 2,981,600E).

Figure 11. Typical "haystack" weathering of the Sevier Shale. Exposure located at Tennessee Coordinates (762,800N, 2,986,300E).

CHAPTER III

STRUCTURE

General

The structure of the Fall Branch area is dominated by low angle thrust faults and their associated folds. In general, the rocks strike N 45-50° E and dip steeply to the southeast. The area is roughly bisected by the trace of the northeast-southwest striking Pulaski fault, one of the major thrust faults of the Appalachians. An 11.5 kilometer (7 mile) segment of the Pulaski fault was mapped in the study area. One to 1½ kilometers (0.6-0.9 miles) northwest of the Pulaski fault lies the trace of another low angle thrust, the Cliffs fault. Throughout its 45 kilometer (28 mile) length, the Cliffs fault is roughly parallel to the Pulaski and both curve eastward at the northernmost extent of the Cliffs fault near the Tennessee-Virginia border. The Mill Creek thrust fault in the northeastern part of the study area brings Jonesboro Limestone into fault contact with Honaker Dolomite. To the south, another small thrust fault, located 1.6 kilometers (one mile) west of Haws Crossroads, places the Honaker in contact with the Maynardville and the Conococheague. This fault, herein called the Fall Branch fault, is typical of numerous minor (i.e., small displacement) thrust faults which lie between the Pulaski and Dunahm Ridge faults in northeast Tennessee (Rodgers, 1953, p. 137). Other important structural features in the Fall Branch area include a window of Sevier Shale in the Honaker (herein called the Sulphur Springs window), the Jackson Ridge anticline, and the Bald Hill syncline. All of these features have some additional degree of minor folding associated with them.

Structural Features of the Pulaski Footwall Block

Cliffs Fault

The Cliffs fault trace strikes consistently N 50° E and extends entirely across the Fall Branch area, separating Sevier Shale (footwall) and Mascot Dolomite (hanging wall). Differential weathering of the underlying Sevier has led to a distinct topographic expression of this structural feature, giving rise to its appropriate name. Field calculations (three point method) show that the Cliffs fault dips 25-30° at the surface. Stratigraphic displacement along the Cliffs fault is approximately 152 meters (500'). Figure 12 is an exposure of the Cliffs fault.

Pulaski Fault

As previously mentioned, the Pulaski fault separates lengthy open folds of the footwall block from the tighter, more numerous folds of the hanging wall block. Throughout the study area, the oldest rock unit exposed in the hanging

Figure 12. Cliffs fault with Mascot Dolomite overlying Sevier Shale. Exposure located along Mill Creek Road 2.8 kilometers north of the study area at Tennessee Coordinates (773,500N, 3,000,100E).

wall is the Honaker Formation. Where the Honaker is thrust over the lower Sevier Shale, the stratigraphic displacement is some 1753 (5750 feet). The basal shaley portion of the Honaker probably served as the initial glide plane for the Pulaski fault before it stepped upward into the Sevier Shale. The only exposure of this shaley zone in the Honaker in the study area occurs north of Sulphur Springs, at the Pulaski fault and is characterized by small tight folds.

Northeast of Fall Branch, the trace of the Pulaski curves northward a short distance before once again following a general N 50° E bearing. This sinuous trace is probably due to the low dip of the fault plane, which was estimated by field calculations (three point method) near Sulphur Springs to be approximately 20°. A warping of the fault plane just south of this area (Plate I - section C-C') has led to the exposure of a window of Sevier Shale within the Honaker and suggests that continued deformation occurred some time after displacement along the Pulaski fault had ceased.

Extensive cleavage development along the Pulaski was found at two locations. At one outcrop, 1524 meters (5000 feet) north of Mill Creek Chapel, cleavage in the lower Honaker strikes a relatively uniform N 25° E and dips 75-85° to the southeast. Similar data from an outcrop 305 meters (1000 feet) northwest of Sulphur Springs suggests that the compressive stresses responsible for the cleavage development were directed from the east-southeast and west-northwest.

Structural Features of the Pulaski Hanging Wall Block

Mill Creek Fault

In the northeast corner of the study area, 0.8 kilometers (0.5 miles) north of the Sulphur Springs window, a block of Jonesboro Limestone lies in contact with Sevier Shale to the northwest (Figure 13) and Honaker Dolomite to the southeast. The boundary between the Jonesboro and the Honaker is a thrust fault, herein named the Mill Creek fault.

Figure 13. Pulaski fault, with Jonesboro overriding Sevier. Exposure located along Mill Creek Road at Tennessee Coordinates 772,400N, 3,002,850E).

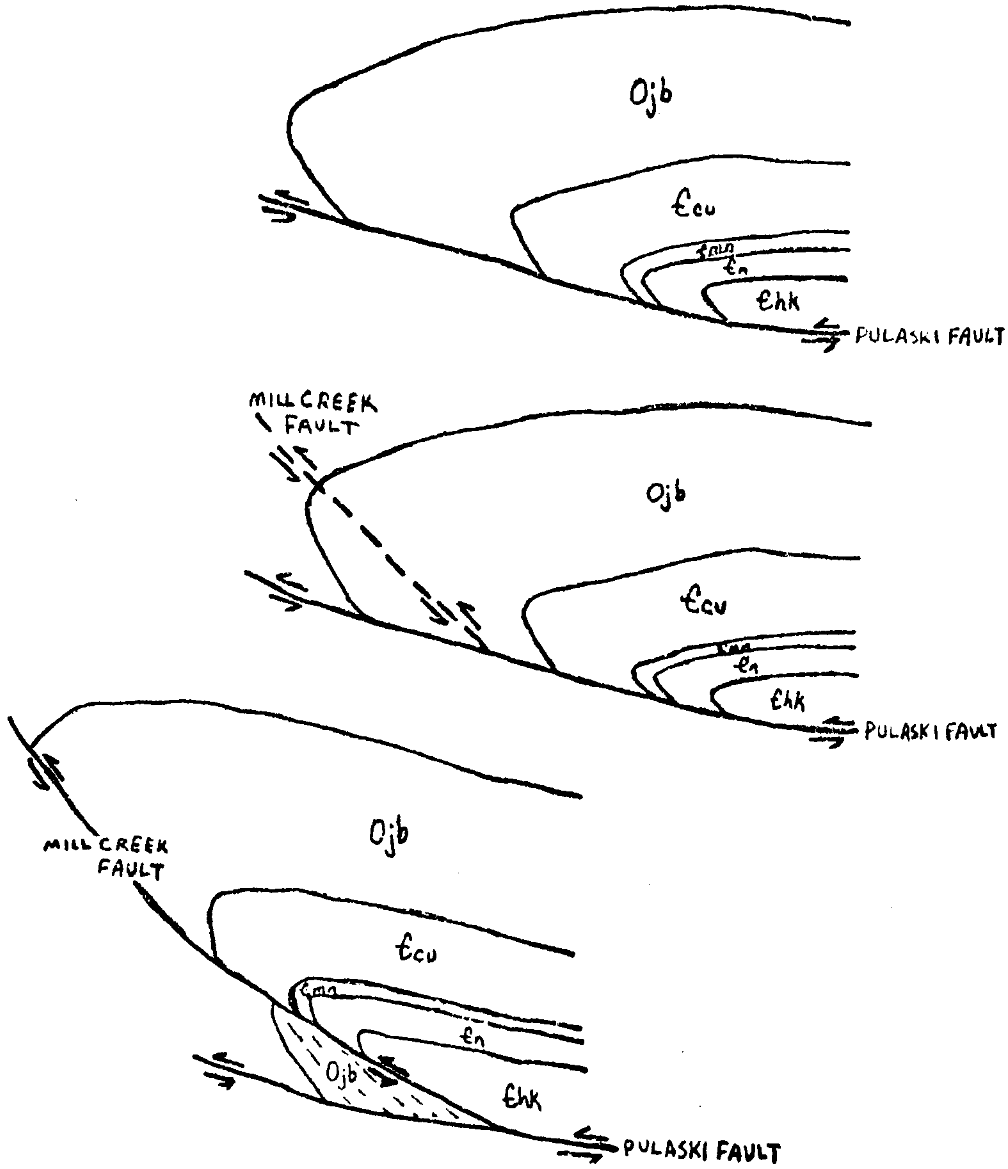
The Mill Creek fault appears to have developed during the latter stages of movement along the Pulaski fault. Development of a drag fold along the Pulaski and subsequent fault development within the Jonesboro led to Honaker Dolomite being thrust upon the younger rocks (See Figure 14). Horizontal displacement along the Mill Creek fault is calculated to be 1300 meters (4260 feet). A maximum of 366 meters (1200 feet) of Jonesboro Limestone are exposed by this fault. The overturned beds of the Jonesboro consistently strike N 50° E and dip 60° to the southeast.

Sulphur Springs Window

Northeast of Fulwiler Hill, a window is exposed in the hanging wall block of the Pulaski fault. The Honaker Dolomite surrounds a 1460 by 122 meter (4800 by 400 foot) area of middle Ordovician-aged Sevier Shale. As mentioned previously, this window suggests an anticlinal warping of the Pulaski fault plane in this area (Plate I - section C-C'). The calcareous shales of the Sevier are intensely deformed throughout the window, exhibiting extensive cleavage development and indications of widespread intraformational shearing.

Bald Hill Syncline

The Bald Hill syncline is the nearest major fold of the Pulaski thrust block to the Pulaski fault along its



A

B

C

Figure 14. Development of Mill Creek fault.

A. Drag fold develops along Pulaski fault.
B. Development of Mill Creek fault within Jonesboro.
C. Movement along Mill Creek fault.

trace in the southern half of the study area, and extends over 8 kilometers (5 miles) through the study area. The syncline plunges gently to the southwest and dies out just northeast of Kyle Hill in the south. The trough of this syncline contains shale of the lower Nolichucky throughout most of its length. Where weathering is more advanced, the shales have been completely eroded away, leaving only sparse exposures of Honaker Dolomite to mark the synclinal axis. The Bald Hill syncline is slightly asymetrical; the northwest limb has an average dip of 40° southeast, whereas the southeast limb averages 55° northwest. Both limbs strike roughly N 50° E. Topographically, this feature underlies a long narrow ridge of 20-70 meters (60-120 feet) relief where Nolichucky Shale is preserved in the trough, with topographic relief decreasing in the direction of plunge. Cross-sections of the Bald Hill syncline can be found on Plate I - sections A-A', B-B', and C-C'.

Folding Southeast of Bald Hill Syncline

Flanking the Bald Hill syncline to the southeast lies a complementary anticline. This anticline parallels the Bald Hill syncline throughout its length in the study area and also plunges gently to the southwest. The northwest limb of this anticline dips 55°, and the southeast limb dips approximately 60°.

Southeast of the Bald Hill syncline and its complementary anticline to the southeast, another pair of folds occur, herein called the Cemetery folds (Plate I - section A-A'). Plunging more steeply than the Bald Hill folds, the Cemetery folds surficially involve rocks ranging from Conococheague Limestone in the southwest to Honaker Dolomite in the northeast. These folds are exposed along the middle and southern portions of the study area, but are not traceable in the Honaker Dolomite at their northeastern extent.

During the folding in this area, a kink was formed in the rocks 1500 meters (4920 feet) east-northeast of Kyle Hill which resulted in a bending of the axial plane of the Cemetery syncline. South of the bend in the Cemetery syncline's axial plane, another syncline is parallel to the Cemetery anticline to the southern extent of the study area. Where they parallel each other, the strike of the Cemetery folds' axial planes range from N 60° E in the northeast to N 50° E in the southwest. The northwest limb of the Cemetery syncline dips 55°, the common limb of the Cemetery folds dips 60° (northwest), and the southeast limb of the Cemetery anticline dips an average of 65°. The dip of the southeast limb increases from 45° to 90° with decreasing distance to the Fall Branch thrust fault to the southeast. The Fall Branch fault, whose trace closely parallels the axial planes of the Cemetery folds, exhibits decreasing stratigraphic displacement in a northeasterly direction. At its southern extension in the study area, the

Fall Branch fault brings Conococheague, Maynardville, Nolichucky, and upper Honaker into contact with lower to middle Conococheague of the footwall block. In its middle segment, northwest of Gabtown, upper Honaker overrides Maynardville, Nolichucky, and upper Honaker. Continuing northeastward, the trace of the Fall Branch fault is lost in the deep soils of the weathered Honaker.

Jackson Ridge Anticline

The Jackson Ridge anticline extends 4.4 kilometers (2.8 miles) through the southeastern portion of the Fall Branch area. At its northern extent the anticline folds three formations, the Conococheague Limestone, the Maynardville Limestone, and the Nolichucky Formation, and strikes roughly N 55° E. The strike of the anticlinal axis changes near benchmark T 105 resulting in the southern half striking approximately N 30° E. The Jackson Ridge anticline is asymetrical; the northwest limb dips 75°, and the southeast limb dips 45° (Plate I - section B-B'). To the northeast, where the Nolichucky is exposed in its core, the anticline is expressed topographically as a linear ridge of some 60 meters (200 feet) relief (See Figure 15). Farther to the southwest, where folded Conococheague is exposed on the nose of the fold, there is no discernable topographic expression.

Associated with the Jackson Ridge anticline are several small folds. The largest of these is a plunging syncline whose axis lies southwest of the southern extent

Figure 15. Nolichucky exposed in the core of the Jackson Ridge anticline east of benchmark T 105.

of the Jackson Ridge anticline. The trough of this asymetrical syncline (northwest limb strikes N 50° E and dips 45°, whereas southeast limb strikes N 30° E and dips 75°) exposes approximately 244 meters (800 feet) of the lower Jonesboro Limestone in its trough (Plate I - section A-A'). A small anticline occurs west of the Jackson Ridge anticline at Gabtown. This fold is doubly plunging, less than 1.5 kilometers (0.9 mile) in length, and involves only the Conococheague at the surface. Sharing a common limb with this anticline is a larger syncline which extends northeastward between Jackson and Howard Ridges and beyond the study area to the northeast. This syncline plunges to the southwest and dies out between Gabtown and the Greene County line. At its northeastern exposure this syncline strikes roughly N 50° E; the northwest limb dips 55° and the southeast limb, which is shared with the Jackson Ridge anticline, dips 75°.

Southeast of the Jackson Ridge anticline, a pair of folds (a syncline and an anticline) appear solely within the Conococheague. The strike of these two folds is the same as that of the Jackson Ridge anticline and their limbs dip 35-45°.

Interpretation

Structure sections on Plate I illustrate the writer's interpretation of the behavior at depth of the faults and folds in the Fall Branch area. In projecting the structure at depth, the writer assumes constant thicknesses of the units involved and that movement along major fault planes are largely restricted to incompetent units. The structure sections were drawn along guidelines set out by Dahlstrom (1969) in his paper on balanced cross sections.

The Pulaski fault, as is indicated by its sinuous trace just north of Fall Branch, has a low dip where the fault plane has not been folded. In the southwestern part of the study area, the trace of the Pulaski becomes straighter, suggesting a higher angle of dip than has been calculated to the northeast. As previously mentioned, the dip of the Pulaski fault plane is 20° in the vicinity of Sulphur Springs.

The oldest rock unit brought to the surface by the Pulaski is the middle Cambrian Honaker Formation. The minimum horizontal displacement along the Pulaski fault is calculated to be 1753 meters (5750 feet) by the presumed thicknesses of the displaced units. An argillareous zone in the lower Honaker is believed to have served as the initial glide plane of the Pulaski before it stepped upward into the Sevier Shale.

The Mill Creek fault is believed to be the result of the development of a drag fold in the hanging wall block of the Pulaski fault and subsequent faulting in the overturned beds of the Jonesboro Limestone. Minimum horizontal displacement along the Mill Creek fault is approximately 1300 meters (4260 feet). Movement along the Mill Creek fault probably occurred during the final stages of movement along the Pulaski fault.

After movement along the Pulaski had ceased, another episode of deformation warped the fault plane and led to the exposure of the Sulphur Springs window. Relatively parallel axial planes of the Sulphur Springs window anticline and other major folds in the area (Bald Hill syncline, Jackson Ridge, and Jackson Ridge anticline) suggest the contemporaneous development of these structures.

A final episode of deformation resulted in the bending of the axial planes of some folds, notably the Cemetery folds and the southernmost exposure of the Jackson Ridge anticline. Some final movement along the Pulaski led to the present "flap-like" appearance of the hanging wall block immediately north of Fall Branch. Also formed during this period were the Fall Branch thrust fault and the Cliffs fault which probably formed by shearing along the axial planes of anticlines. Evidence for the prior existence of the Fall Branch fault anticline can be seen in the dips of the Conococheague Limestone in the Fall Branch fault's footwall block.

Chronology of Deformation

1. Compressive stresses from the southeast resulted in the formation of the Pulaski fault with a glide plane in the basal Honaker. The Pulaski then stepped to a glide plane in the lower Sevier Shale. During the later stages of this deformational episode, a drag fold developed along the Pulaski in the northeastern part of the study area. The Mill Creek thrust fault developed in the overturned beds of Jonesboro Limestone, and the Honaker Formation was thrust upon the Jonesboro.

2. A second deformational episode resulted in the warping of the Pulaski fault plane and the formation of many tight, parallel folds.

3. The final period of deformation was characterized by the local bending of the axial planes of folds and the development of small displacement (relative to the Pulaski fault) thrust faults along the axial planes of some anticlines. Some final movement along the Pulaski resulted in the present "flap-like" appearance of the Pulaski thrust block near the center of the study area. Previously formed anticlines and synclines were more tightly folded during this period.

CHAPTER IV

ECONOMIC GEOLOGY

At present, there are no mining operations being conducted in the Fall Branch area. Potential resources include barite, zinc, shale, dolomite, and limestone.

Barite

A portion of the study area is referred to as the Fall Branch barite district, an area 3.2 to 4.8 kilometers (2 to 3 miles) wide and some 64 kilometers (40 miles) in length. The exact date of the discovery of barite in the area is not known, but the earliest reference was made by James Safford in 1869 (Maher, 1970). Plate I shows the location of several barite mines and prospects located by the writer. Barite occurs in the Mascot Dolomite, Jonesboro Limestone, and Honaker Dolomite within 1.6 to 2.4 kilometers (1 to 1½ miles) of the Pulaski fault. Two small mines at Tennessee Coordinates (749,200N, 2,285,850E) and (749,700N, 2,286,300E) just northeast of Lovelace Chapel, contain barite disseminated in Mascot Dolomite with a ratio of barite:dolomite of approximately 1:1. However, most barite occurrences in the area are found in residual soils, concentrated there as a result of the weathering of barite-bearing carbonates. These barites are crystalline in appearance, exhibit good cleavage, and have a fetid odor when broken. Figures 16 and 17 show residual-type barites from a gravesite in the Fall Branch Cemetery at Tennessee Coordinates (754,500N, 2,994,000E) and a prospect on the Pierce farm near Interstate 81 at Tennessee Coordinates (743,700N, 2,283,900E). Although occurrences of barite are numerous, the small size of the residual deposits and the low purity of unweathered deposits leads this writer to concur with a study made by Benjamin Gildersleeve and Roy Caldwell in 1935 for the Tennessee Valley Authority which concludes there are no large resources of barite in the area.

Zinc

Zinc was first discovered in the Fall Branch area in the early 1890's as attempts to develop recently discovered barite were being made. A mineralized zone over 2 meters (6 feet) thick was found at Tennessee Coordinates (737,300N, 2,995,700E), and from 1906 to 1910 the East Tennessee Mining Development Company developed two shafts and a series of open pits, extracting zinc ore in the form of sphalerite and its oxidized secondary mineral smithsonite. Specimens collected by the writer from these mines contain abundant dolomite and sphalerite with minor occurrences of barite and pyrite. Numerous shallow pits, believed to be old prospects, were found extending over 100 meters (300 feet) roughly along strike

Figure 16. White barite from Fall Branch Cemetery.

Figure 17. Black barite from Pierce farm, 600 m north of Kyle Hill.

in both directions away from the two mines. Although continuation of the mineralized zone is reported to extend for at least 2.8 kilometers (5 miles) (Secrist, 1924), the outlook for the future of zinc mining at Fall Branch is not promising, due to the mineralized zone's steep dip, limited thickness, and low zinc concentration.

Shale Units

The two shale units present in the Fall Branch area, the Nolichucky and the Sevier, are generally suitable for use in the manufacture of brick or for use as light-weight aggregate. Shallow soil cover and extensive cleavage development make these shales easily accessable to any potential economic development. Fourteen miles (22.5 kilometers) east-southeast of Fall Branch at Johnson City, Tennessee, General Shale, Inc. has mined the Sevier Shale for the manufacture of brick products for several years.

Possible problems to the economic exploitation of these units are the limited thicknesses of the upper and lower Nolichucky (<45 meters) and the presence of sandstone beds at irregular intervals within the Sevier.

Carbonate Units

The Honaker Dolomite, Maynardville Limestone, Conococheague Limestone, Jonesboro Limestone, and Mascot

Dolomite are all suitable for use as crushed stone and can be classified as potential resources. Two small abandoned quarries in the Conococheague between Howard and Jackson Ridges at Tennessee Coordinates (750,600N, 3,003,000E) supplied the Washington County Highway Department with road metal in the early 1970's. One additional small quarry in the area was located in the Jonesboro west of Mitchell Cemetery at Tennessee Coordinates (740,100N, 3,003,500E) but no information is available on its operation.

A major problem in developing the carbonate resources is the selection of a site with a uniformly shallow soil cover. The Conococheague and Jonesboro Limestones tend to be less extensively weathered than the other Fall Branch carbonate units and would probably be the choice for any future mining operations. Large areas of outcrops with little or no soil cover which might be suitable for quarrying can be found northeast of Kincheloe Cemetery (Conococheague), in the southeast corner of the study area (Jonesboro), and in the northeast corner of the study area (Jonesboro).

CHAPTER V

CONCLUSIONS

The following are the conclusions drawn from a study of the geology of the Fall Branch, Tennessee area.

1. The Nolichucky Formation can be divided into three distinct members in this area: a lower shale member; a middle intraclastic and oolitic limestone member; and an upper silty shale member.

2. The Sevier Shale possesses a distinct middle member of alternating sandstones and shale beds in this area which allows a subdivision of the Sevier into a lower shale member, a middle sandstone and shale member, and an upper shale member.

3. The Pulaski fault extends across the study area and has a dip of approximately 20° at the surface. This low dip and absence of rocks in the study area older than the Honaker Formation suggest thin-skinned deformation.

4. A basal argillaceous zone in the Honaker served as the initial glide plane for the Pulaski fault before it stepped upward into the Sevier Shale.

5. Folding of the Pulaski fault plane has led to exposure of a window of Sevier Shale northeast of Fulwiler Hill near Sulphur Springs.

6. The Mill Creek fault is a low angle thrust fault that formed within the Jonesboro Limestone in a drag fold along the Pulaski fault.

7. The Cliffs fault and the Fall Branch fault are small displacement thrust faults which formed during the final stages of deformation by shearing along the axial plane of anticlines. This final deformational episode also resulted in the present "flap-like" appearance of the Pulaski thrust block near the center of the study area.

8. Potential mineral resources in the study area include limestone, dolomite, barite, shale, and zinc.

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APPENDIXES

APPENDIX A

DESCRIPTION OF MEASURED SECTION

The following is a description of a measured section of an outcrop exposed along a road cut through Irvin Hollow at Tennessee Coordinates (747,800N, 2,998,000E). The rocks, which strike N 45° E and dip 70° SE, include the upper few feet of the Honaker Dolomite, the Nolichucky Formation, the Maynardville Limestone, and a portion of the lower Conococheague. Rock color is determined by comparing dry specimens with the Geological Society of America Rock-Color Chart (Goddard, *et al.*, 1963) under a constant light source. Thicknesses were calculated by direct measurement using a flexible tape measure. Terminology of bedding thickness is as follows:

Unit Thickness	Stratigraphic Term
<.25 centimeters	Thinly laminated
.25- 1.0 centimeters	Thickly laminated
1.0 - 2.5 centimeters	Very thin-bedded
2.5 -10.0 centimeters	Thin-bedded
10.0 -30.0 centimeters	Medium-bedded
30.0 -91.0 centimeters	Thick-bedded
>91.0 centimeters	Very thick-bedded

(after Ingram, 1954)

The section is described from the lowermost beds upward. A columnar section is included as Figure 18 on page 63.

Scale: 1 inch equals 1 meter

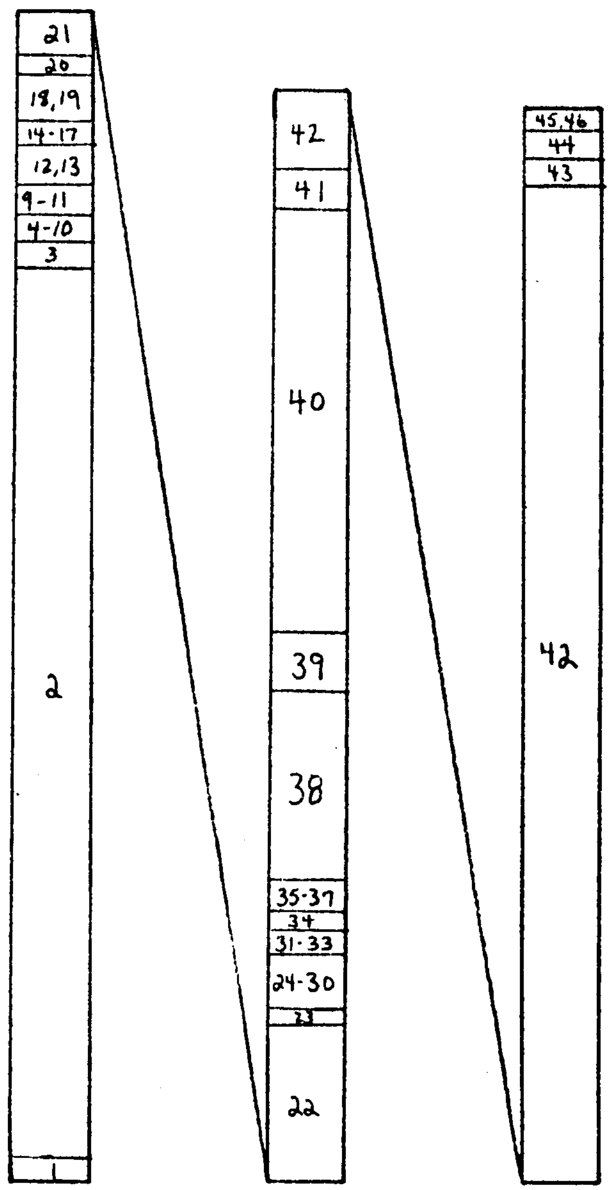

Figure 18. Columnar section of measured section of the Nolichucky Formation. Numbers within the column indicate unit numbers used in Appendix A descriptions.

Upper Cambrian Series
Knox Group
Conococheague Limestone (partial section 1.6 meters)

Top of Measured Section.

Unit		Meters
68.	Sandstone, dolomitic, thick-bedded, grayish orange to dark yellowish orange (10 YR 7/4 to 10 YR 6/6); grains well rounded and well sorted; locally crossbedded.	1.6
	Total of Conococheague in measured section	1.6

Upper Cambrian Series
Conasauga Group
Maynardville Limestone (76.1 meters)

Unit		Meters
67.	Covered interval, probably like unit 66.	1.9
66.	Limestone, fine-grained, medium light gray to light gray (N6 to N7), thick-bedded, weathering to light gray (N7).	0.5
65.	Covered interval.	7.9
64.	Limestone, fine-grained, thin-bedded, medium dark gray to medium gray (N4 to N5) weathering to light gray to very light gray (N7 to N8); 2.5 centimeter layer of coarse-grained medium gray (N5) limestone at base weathers to light gray (N7); fractures calcite filled.	0.5
63.	Covered interval.	21.0
62.	Limestone, fine-grained, thin-bedded to thickly laminated, dark gray to medium dark gray (N3 to N4) with grayish orange (10 YR 7/4) shale partings; upon weathering, limestone becomes medium light gray to light gray (N6 to N7) and shale stands out in relief to give a "ribboned" appearance.	1.5
61.	Covered interval.	1.7

Unit		Meters
60.	Limestone, fine-grained, very thin-bedded, medium dark gray (N4) interbedded with light olive gray (5 Y 6/1), thickly laminated, silty limestone; bedding surfaces undulatory; fractures calcite filled; upon weathering, limestone becomes light olive gray (5 Y 6/1) and silty beds stand out in relief.	2.3
59.	Covered interval.	0.6
58.	Limestone, fine-to medium-grained, very thick-bedded, medium dark gray to medium gray (N4 to N5) weathering to light gray (N7); fractures calcite filled.	1.4
57.	Covered interval.	6.0
56.	Limestone, fine-grained, very thin-to thin-bedded, medium gray to medium dark gray (N5 to N4) with light olive gray (5 Y 6/1) shale partings up to 1 mm in thickness; numerous small fractures are calcite filled; upon weathering, limestone becomes light gray (N7) and shale stands out in relief.	1.1
55.	Covered interval.	13.4
54.	Limestone, fine-grained, very thin-bedded, medium dark gray (N4) weathering to medium light gray (N6) to very light gray (N8) in the upper portion of the unit, interbedded with light olive brown to moderate yellowish brown (5 Y 5/6 to 10 YR 4/2) shale; pyrite filled vugs dispersed throughout the limestone.	0.6
53.	Covered interval.	3.8
52.	Limestone, fine-grained, thin-to very thin-bedded, medium dark gray (N4) weathering to light gray (N7) interbedded with thinly laminated light olive gray (5 Y 5/2) shale; 3 centimeters of medium gray (N5) silty limestone at base of unit.	1.4
51.	Limestone, fine-to medium-grained, thick-bedded, medium dark gray to medium gray (N4 to N5) with shale partings; limestone weathers to light gray (N7).	1.2

Unit		Meters
50.	Limestone, fine-grained, thin-bedded, medium dark gray (N4) interbedded with thickly laminated dark yellowish orange to moderate yellowish brown (10 YR 6/6 to 10 YR 5/4) shale; pyrite filled vugs up to 6 mm in diameter present in limestone; upon weathering, limestone becomes light gray (N7) and shale stands out in relief.	1.7
49.	Covered interval.	0.8
48.	Shale, calcareous, thin-to very thin-bedded, olive gray (5 Y 4/1) with several beds (up to 1.5 centimeters thick) of medium gray limestone within the unit; shale chips abundant in residuum.	2.2
47.	Same as unit 45.	0.7
46.	Covered interval, probably like unit 45.	0.6
45.	Shale, thinly laminated, dusky yellow green (5 GY 7/2) grading upward into medium olive gray (5 Y 4/2) thickly laminated to very thin-bedded dolomitic shale.	0.6
44.	Covered interval.	1.5
43.	Limestone, silty, medium gray to medium light gray (N5 to N6), medium-bedded with shale partings; weathers to yellowish gray (5 Y 7/2).	1.2
	Total of Maynardville	76.1

Upper Cambrian Series
Conasauga Group
Nolichucky Formation (117 meters)

Upper Shale Member (29.4 meters)

Unit		Meters
42.	Shale, calcareous, silty, thin-to medium-bedded, light brownish gray to medium light gray to medium gray (5 YR 6/1 to N6 to N5) weathering to medium dark gray to olive gray (N4 to 5 Y 4/1); unit is highly weathered with abundant shale chips in the residuum; much of unit is iron stained moderate yellowish brown to dark yellowish orange (10 YR 5/4 to 10 YR 6/6).	6.3
41.	Limestone, fine-grained, silty, medium gray to medium light gray (N5 to N6), thickly laminated to thin-bedded near the top, with brownish gray to dark greenish gray (5 YR 4/1 to 5 GY 4/1) shale partings.	2.0
40.	Shale, silty, grayish orange (10 YR 3/4) to dusky yellow (5 Y 6/4); exposures highly weathered, mostly covered.	21.1
	Total of Upper Shale Member	29.4

Middle Limestone Member (41.2 meters)

Unit		Meters
39.	Oolite, medium gray (N5), very thick-bedded; approximately 10% less ooids than unit 38; contains limestone lenses up to 1½ centimeters (½") thickness which vary greatly in lateral extent; dark yellowish brown shale partings more abundant in upper half of unit, but less abundant than in unit 38; weathers to light gray (N7).	3.0
38.	Oolite, medium gray (N5), very thick-bedded with occasional shale partings; rounded ooids to 2 mm in diameter, larger ooids concentrated in upper half of unit; pyrite crystals (up to 2 mm across) and pyrite filled vugs scattered in upper half of unit; weathers to light gray (N7).	9.4

Unit		Meters
37.	Oolitic limestone, medium gray (N5), medium-bedded; fractures calcite filled; ooids average 2 mm in diameter; weathers to medium light gray (N6).	0.6
36.	Limestone, fine-to medium-grained, medium dark gray (N4), very thin-bedded and interbedded with thickly laminated moderate yellowish brown (10 YR 5/4) shale which stands out upon weathering; limestone weathers to medium light gray (N6).	0.6
35.	Limestone, medium-grained, medium dark gray, dense, very thin-bedded and interbedded with thickly laminated dusky yellow to moderate yellowish brown (5 Y 6/4 to 10 YR 5/4) shale; occasional limestone clasts disseminated throughout the unit; limestone weathers to medium light gray (N6).	0.5
34.	Limestone like upper half of unit 31.	1.0
33.	Limestone, medium-to coarse-grained, medium gray (N5), weathering to medium light gray (N6).	0.04
32.	Limestone like upper half of unit 31, with more shale laminae.	0.7
31.	Limestone, fine-grained, medium gray (N5), thin-to very thin-bedded, interbedded with thickly laminated dark yellowish brown (10 YR 4/1), moderate reddish brown (10 YR 4/6), and dusky blue (5 PB 3/2) shale in the upper half of the unit; limestone weathers to a medium light gray to light gray (N6 to N7).	0.4
30.	Limestone, fine-to medium-grained, medium light gray, very thin-bedded, interbedded with thinly laminated pale yellowish brown (10 YR 6/1) shale; upon weathering, limestone appears a mottled medium dark gray (N4) and shale laminae stand out in relief; calcite slickensides are present.	0.5

Unit		Meters
29.	Limestone, fine-grained, medium dark gray (N4 to N5), thickly laminated to very thin-bedded, weathering to medium light gray (N6); grades upward into thin-bedded medium gray (N5) limestone with medium light gray (N6) shale partings; bedding contacts undulatory; iron oxide indicates presence of iron minerals.	0.4
28.	Limestone, fine-grained, medium light gray (N6) weathering to light gray (N7); 6.4 centimeter layer of thinly laminated medium light gray (N6) calcareous shale at top of unit; bedding contacts undulatory.	0.4
27.	Limestone, fine-grained, silty, light olive gray (5 Y 6/1 to 5 Y 5/2), thickly laminated; upper portion less silty, grades into unit 28.	0.2
26.	Limestone, fine-grained, medium light gray (N6), very thin- to thin-bedded, interbedded with light olive gray (5 Y 6/1) calcareous shale; limestone weathers to a mottled medium gray color (N5).	0.4
25.	Shale, light olive gray (5 Y 5/2), thinly laminated, becoming more calcareous and fining upward, grading into unit 26; 5 centimeters of less thinly-bedded medium gray limestone at base of unit.	0.3
24.	Limestone, medium dark gray to medium gray, thick-bedded, weathering to medium light gray (N6) and fining upward; 2.5 centimeters of thinly laminated light olive gray (5 Y 5/2) shale at top of unit; upper contact sharp.	0.4
23.	Limestone, fine- to medium-grained, medium gray (N5), thin- to very thin-bedded with pale yellowish brown (10 YR 6/2) shale partings 1 mm in thickness; iron oxides suggest presence of iron minerals; fractures calcite filled; limestone weathers to light gray (N7)	0.5
22.	Limestone, fine-grained, medium dark gray (N4), very thick-bedded with very thin grayish orange (10 YR 7/4) shale laminations interspersed throughout the unit; upon weathering limestone becomes medium light gray to light gray (N6 to N7); shale thickens upward to grade into unit 23.	7.9

Unit		Meters
21.	Covered interval.	2.6
20.	Limestone, fine-grained, medium gray (N5), very thin-bedded, interbedded with grayish orange (10 YR 7/4), thickly laminated shale; fractures calcite filled; contacts within unit are sharp; upon weathering, limestone becomes light gray (N7) and shale laminae stand out in relief.	1.1
19.	Covered interval.	1.8
18.	Limestone, fine-grained, medium dark gray to medium gray (N4 to N5), thin-to very thin-bedded with pale yellowish brown, 1 mm thick shale partings which tend to stand out in relief; .5 centimeters intraclastic limestone layer near base, clasts elongate and rounded; upon weathering, limestone becomes medium gray (N5) lower in the unit and light gray (N7) in the upper portion of the unit.	0.6
17.	Limestone, fine-grained, intraclastic, medium gray (N5), thin-bedded; average clast size is 6 x 3 mm; weathers to light gray (N7).	0.2
16.	Covered interval.	0.4
15.	Limestone, fine-grained, medium dark gray to medium gray (N4 to N5), thin-bedded with moderate yellowish brown (10 YR 5/4) shale laminations every 1.5 to 2.5 centimeters; limestone weathers medium light gray to light gray (N6 to N7).	0.2
14.	Covered interval.	0.4
13.	Alternating very thinly laminated, moderate yellowish brown (10 YR 5/4) shale and thin-to very thin-bedded medium dark gray (N4), fine-to medium-grained limestone; upon weathering, limestone becomes medium gray to medium light gray (N5 to N6) and shale beds stand out in relief.	1.2

Unit		Meters
12.	Limestone, fine-grained, medium dark gray (N4), very thin-bedded, interbedded with thickly laminated, moderate yellowish brown shale; shale more prevalent in middle of unit; upon weathering, limestone becomes light gray to very light gray (N7 to N8) and shale laminae stand out in relief.	0.5
11.	Limestone, fine-grained, very thick-bedded, medium gray (N5) with dark yellowish orange to moderate yellowish brown (10 YR 6/6 to 10 YR 5/4), very thinly laminated shale every 3 to 10 centimeters.	0.7
10.	Calcareous shale, thinly laminated, dark yellowish brown (10 YR 4/2), interbedded with thickly laminated, medium gray (N5) limestone.	0.3
9.	Limestone, fine-grained, medium dark gray (N4), thin-bedded with laminae of brownish gray to light brownish gray (5 YR 4/1 to 5 YR 6/1) silty limestone; upon weathering, limestone becomes medium light gray to light gray (N6 to N7) and shale laminae stand out in relief.	0.6
8.	Calcareous shale, thickly laminated, moderate brown (5 YR 4/4); some laminae, which are more calcareous, are light olive gray (5 Y 6/1).	0.1
7.	Limestone, fine-grained, medium dark gray (N4), thin-bedded, beds separated by brownish gray (5 YR 4/1) shale laminae up to 2 mm thick; fractures calcite filled; upon weathering, limestone becomes light gray (N7) and shale laminae stand out in relief.	0.2
6.	Shale, grayish orange (10 YR 7/4), interbedded with brownish gray (5 YR 4/1) silty limestone; unit is very thin-bedded.	0.3
5.	Limestone, fine-grained, medium dark gray to dark gray (N4 to N3), very thin-bedded, interbedded with moderate yellowish brown to grayish orange (10 YR 5/4 to 10 YR 7/4) shale laminations up to 3 mm thick; limestone weathers to medium gray (N5).	1.2

Unit		Meters
4.	Limestone, fine-grained, dark gray (N3), thin-bedded with light olive gray (5 Y 6/1) shale laminations up to 2 mm thick; upon weathering, limestone becomes medium gray (N5) and shale laminae stand out in relief.	0.3
3.	Silty limestone, very thin-bedded, medium dark gray to medium gray (N4 to N5), weathering to moderate yellowish brown (10 YR 5/4).	1.3
	Total of Middle Limestone Member	41.2

Lower Shale Member (46 meters)

Unit		Meters
2.	Partially covered; shale, calcareous, light olive gray (5 Y 6/1), thin to thickly laminated; well developed cleavage; exposures highly weathered.	46.0
	Total of Lower Shale Member	46.0
	Total of Nolichucky	117.0

Middle Cambrian Series
Conasauga Group
Honaker Formation (1.2 meters)

Unit		Meters
1.	Dolomite, coarse-grained, medium gray to medium light gray (N5 to N6), medium-to thick-bedded; upper .2 meters intraclastic; weathers to light gray (N7) "blocky" appearance; upper contact sharp; base of unit in contact with extensive covered interval.	1.2
	Total of Honaker in measured section	1.2

Base of Measured Section.

APPENDIX B

THIN SECTION DESCRIPTIONS

The following are descriptions of thin sections of rock samples taken from the upper Honaker Formation, the Nolichucky Formation, and the lower Maynardville Limestone at Irvin Hollow. The slides are numbered according to the unit number assigned in Appendix A. Classification and nomenclature of these samples is as in Table 4, after Dunham (1962). An interpretation of these thin sections can be found in the text discussions of the Nolichucky Formation (page 15).

TABLE 4

CLASSIFICATION OF LIMESTONES BY DEPOSITIONAL TEXTURE

(after Dunham, 1962)

Contains Mud			Lacks Mud
Mud Supported		Grain Supported	
< 10% grains	> 10% grains		
Mudstone	Wackestone	Packstone	Grainstone

Upper Cambrian Series
Conasauga Group
Maynardville Limestone

Slide Number

46 Mudstone: homogeneous micrite.

43 Mudstone: micrite; occasional ripple marks; iron stained.

Upper Cambrian Series
Conasauga Group
Nolichucky Formation

Upper Shale Member

No thin sections made.

Middle Limestone Member

Slide Number

39-B Mudstone to Packstone: 25% ooids, many exhibiting radial structure in a micrite matrix, ooids have unimodal size distribution (1 mm); trilobite fragments; micrite matrix; stylolites common.

39-A Packstone: 50% recrystallized ooids; some intraclasts, rounded, show chemical precipitation on rim; trilobite fragments found in micrite matrix and in centers of occasional ooids; stylolites present.

38-C Packstone; 25% ooids, recrystallized and broken; micrite grains, trilobite fragments, and calcite rhombs served as ooid nuclei; 50% medium-grained rounded pellets, some of which show chemical precipitation on rim; numerous pelmatozoan and trilobite fragments; stylolites present.

38-B Packstone: 50% ooids, often recrystallized, slight size fluctuation occasionally show cocentric structure; possible recrystallization of micrite matrix; pellets, trilobites and pelmatozoan fragments; stylolites present.

Slide Number

38-A	Packstone: 25% ooids ½ to 1 mm diameter, nuclei of which include micrite grains, trilobite and inarticulate brachiopod fragments; 50% recrystallized pelletal material, some show chemical precipitation on rim; both ooids and pellets show uniform size distribution; micrite matrix; some rounded intraclastic micrite; stylolites present.
37	Grainstone: recrystallized ooids and their fragments, some show relict cocentric laminations; less than 10% micrite matrix; some pelmatozoan fragments present; stylolites common.
35	Mudstone: 1.5-2 cm layers of micrite laminated with 2-5 mm laminae of micritic shale; some burrows, trilobite fragments sparse; occasional stylolites.
32	Mudstone: silty layered micrite.
31	Mudstone; silty layered micrite; occasional shale laminae; storm layering; no fossils; distinct strain pattern.
29-B	Mudstone with shale laminae; 5 mm layer of intraclastic limestone at base; clasts subrounded and generally elongate; one clast is 3 mm x 15+ mm; some crossbedding (ripple-marks?); trilobite and brachiopod fragments present; shale concentrations along occasional stylolites.
29-A	Mudstone with shale laminae; some shale dispersed throughout micrite; some cross laminations; sparse stylolites.
25	Mudstone with shale laminae; occasional burrows, no fossil fragments; scoured bases; some shale concentrated along sparse stylolites.
23-B	Mudstone with shale laminae; burrows and sparse trilobite fragments; stylolites tend to concentrate shale.
23-A	Mudstone with shale laminae; trilobite fragments and pellets present; recrystallization to dolomite along stylolites.

Slide Number

22-C	Packstone: 60+% intraclasts; clasts rounded, elongate, and composed of micrite; clast size ranges from <1 mm in diameter to one clast 2 mm x 35+ mm; pellets, pelmatozoan and trilobite fragments, and rare ooids; stylolites present.
22-B	Mudstone overlain by Packstone: mudstone contains dispersed shale and shale laminae; Packstone clasts composed of round to sub-round micrite, some recrystallization; burrows, pellets, and pelmatozoan fragments present; vertical stylolites.
22-A	Calcic Siltstone with Packstone layers; variations in silt concentrations result in a laminated siltstone with glauconite and burrows; 1 cm packstone layers; clasts sub-angular, composed of micrite; clasts range in size from 1 mm x 1 mm to 10 mm x 30 mm; some clasts show partial recrystallization.
20	Packstone: 50% rounded, elongate, occasionally recrystallized micritic intraclasts; wide size range in clast size; numerous pellets, some pelmatozoans, sparse trilobite fragments; stylolites present.
18-B	Packstone: 10% micrite matrix; trilobites, numerous pelmatazoans and sparse ooids present; 90+% intraclasts have very wide size range (<1 mm to 10 mm diameter); clasts rounded to subrounded and occasionally have some carbonate precipitation on rim; clasts composed of micrite, pellets, and (predominately) older packstone; older packstone contained clasts of micrite grains, pellets, trilobite and pelmatozoan fragments; this rock shows partial recrystallization to dolomite along stylolites; probably deposited in a muddy environment.
18-A	Mudstone: shale concentrations vary, tend to be concentrated along stylolites; burrows and trilobite fragments present.

Slide Number

17 Packstone: contains laminae of shaley micrite; 50% intraclasts, subrounded micrite, some of which are replaced by dolomite; pellets replaced by calcite, often broken; numerous burrows and trilobite fragments, occasional inarticulate brachiopod fragment; numerous stylolites; packstone appears to be the result of storm layering.

13 Mudstone with shale laminae; micrite with numerous burrows and a few trilobite fragments; recrystallization to dolomite along occasional stylolites.

12 Mudstone with shale laminae; micrite with numerous burrows; basal scouring of shale and of carbonate laminae.

9 Mudstone with shale laminae; micrite with neumerous burrows; no fossils.

7 Mudstone with shale laminae; burrowed micrite with numerous trilobite fragments which are confined within discrete layers; some soft sediment deformation; partial recrystallization to dolomite along sparse stylolites.

5 Mudstone: shale dispersed throughout burrowed micrite; shale concentrations and partial recrystallization to dolomite along stylolites.

3 Siltsone: angular (first cycle?) with micrite cement; sparse inarticulate brachiopod fragments; some glauconite; one lens of subrounded micrite intraclasts; wave ripples; concentration of silt along sparse stylolites.

Lower Shale Member

Slide Number

2 Shale with laminae of burrowed micrite; stylolites present; some soft sediment deformation.

Middle Cambrian Series
Conasauga Group
Honaker Formation

Slide Number

1-C Packstone: highly fractured, partially recrystallized to dolomite; pellets and trilobite fragments present; numerous stylolites.

1-B Packstone with shale laminae; highly fractured, partially recrystallized to dolomite; pellets and trilobite fragments present; shale concentrated along numerous stylolites.

1-A Packstone: highly fractured, recrystallization to dolomite; pellets and trilobite fragments present; occasional ooids 1 mm diameter; numerous stylolites.

VITA

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