To the Graduate Council:

I am submitting herewith a thesis written by George Edward Harlow, Jr. entitled "The Structural Geology of a Part of the Pulaski Thrust Sheet Near Boone Dam: Sullivan and Washington Counties, Tennessee." I have examined the final 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.

Nicholas B. Woodward

Nicholas B. Woodward, Major Professor

We have read this thesis
and recommend its acceptance:

Leon W. Byerly

Richard W. Arnseth

Accepted for the Council:

Lawrence Minkel

Vice Provost
and Dean of The Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at The University of Tennessee, Knoxville, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of the source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Myong E. Harlan J.

Date 8-26-87

THE STRUCTURAL GEOLOGY OF A PART OF THE PULASKI THRUST SHEET NEAR BOONE DAM: SULLIVAN AND WASHINGTON COUNTIES, TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

George Edward Harlow, Jr.

December 1987

ACKNOWLEDGEMENTS

I wish to express my gratitude to Dr. Nick Woodward for his guidance and patience during the past three years. Thanks also to Dr. Don Byerly and Dr. Rick Arnseth for their help in preparing the final draft. Appreciation is also extended to Ranger Marty Silver and Warrior's Path State Park, without whose cooperation this study could not have been made. I am especially appreciative of my Mom and Dad, whose continued guidance and support allowed me to pursue my college education. Finally, I wish to thank my wife, Susan, for her patience and encouragement during the past three years.

ABSTRACT

In the vicinity of Boone Dam, Tennessee, the Pulaski thrust sheet contains the Dunham Ridge and Spurgeon imbricates. The area contains complex structures that include a reentrant in the Dunham Ridge fault, and bifurcation of the Spurgeon fault.

Several reports in the past noted the presence of a broad, northwest-trending lineament zone that extends through the present study area. In addition, Jackson (1982) suggested that the lineament zone was related to a buried, transverse decollement ramp, down to the southwest.

Mapping of the study area suggests that the reentrant in the Dunham Ridge fault is the result of lateral ramping in its footwall. Also, the bifurcation of the Spurgeon fault is a result of imbrication in its footwall.

Fabric data and structural geometries within the area suggest the Pulaski thrust system was originally emplaced at a low angle, in a hinterland to foreland manner. Footwall deformation beneath the Pulaski thrust is modeled as a duplex, with the Pulaski as its roof thrust. Folds associated with emplacement of the large sheet were tightened and modified by minor thrusts during this duplex formation. Rock fabrics are sparse compared to the Valley and Ridge areas along strike, again suggesting dominantly

passive folding over underlying structures rather than buckle folding associated with Pulaski thrust sheet motion and imbricate emplacement.

TABLE OF CONTENTS

CHAPTER		PAGE
1	INTRODUCTION	1
	Statement of Problem	1
	Location and Extent of Study Area	1
	Previous Investigations	2
	Present Investigation	6
2	STRATIGRAPHY	9
	Introduction	9
	Description of Rock Units	13
	Conasauga Group	13
	Knox Group	16
	Middle Ordovician Section	19
3	STRUCTURAL GEOLOGY	22
	Regional Setting	22
	Local Structure	26
	Description of Structural Features	28
	Pulaski Fault Block	28
	Dunham Ridge Fault Block	31
	Imbricate Slice of the Spurgeon Fault	32
	Spurgeon Fault Block	33
4	MESOFABRIC AND MICROFABRIC ELEMENTS	34
	Introduction	34
	Pulaski Fault Block	35
	Dunham Ridge Fault Block	43
	Spurgeon Fault Block	48
5	STRUCTURAL GEOMETRY OF THE FIELD AREA	56
	Introduction	56
	Faults	56
	Folds	64
	Cleavage	70
	Discussion	72
6	CONCLUSIONS	87

LIST OF REFERENCES 89

APPENDIXES 95

A. Structural Thin-Section Descriptions 96
B. Road Log And Description Of Stops..... 99

VITA 103

LIST OF FIGURES

FIGURE		PAGE
1.	Map Showing Location of Study Area and Index to Quadrangles	3
2.	Compilation Map of Studies Within the Pulaski Sheet in Northeast Tennessee	5
3.	Map Showing Study Area and Location of Geologic Traverses	8
4.	Generalized Stratigraphic Column at Study Area	10
5.	Facies Diagram of the Conasauga Group (after Rodgers, 1958, p. 46)	12
6.	Crumpled, Thinly Bedded, Shaly Dolostone of the Lower Member of the Honaker Formation. Exposure Along Clinchfield Railroad, 600 meters (2000 feet) East of Fordtown	15
7.	Lower Shale Member of the Nolichucky Formation. Exposure Located Along the Clinchfield Railroad, 900 meters (3000 feet) East of Fordtown	17
8.	Nodular, Medium Bedded, Coarsely Crystalline Lenoir Limestone. Exposure Located 210 meters (700 feet) Southeast of Oak Grove Church	20
9.	Typical Exposure of Claystones of the Sevier Shale. Exposure Located 360 meters (1200 feet) Northeast of Oak Grove Church	21
10.	Major Structural Features of the Study Area	29
11.	Major Structural Features of Northeast Tennessee	30
12.	Index Map of Outcrop Locations	36
13.	Structural Position of Outcrop Locations	37
14.	Photograph of Polished Slab of the Nolichucky Formation Showing Thick Accumulations of Growth Fibers Along Bedding	38
15.	Photomicrograph of the Nolichucky Formation Showing Wall Rock Incorporated Within Growth Fibers, and Rare Inclusion Trails	39

16. Photograph of Polished Slab of a Crush Breccia Developed in the Conococheague Limestone Adjacent to the Colonial Heights Fault 41

17. Photomicrograph of the Conococheague Limestone Showing Thick Residue Accumulations Along Stylolites That are Offset by Cross-Cutting Fractures 42

18. Bedding Wedges Developed in the Medium Bedded Limestones and Dolostones of the Honaker Formation. Exposure Located 750 meters (2500 feet) East of Fordtown 44

19. Photomicrograph of the Maynardville Limestone Showing En Echelon Veins That Kink Bedding Laminations 46

20. Photograph of Polished Slab of the Conococheague Limestone Showing Large, Calcite-Filled Extension Veins 47

21. Photograph of Extension Faults and En Echelon Vein Arrays Developed in the Siltstones of the Nolichucky Formation. Exposure Located 900 meters (3000 feet) East of Hales Chapel 49

22. Photomicrograph of the Siltstone Member of the Nolichucky Formation Showing Obliquely Inclined Antitaxial Fibers 51

23. Photomicrograph of the Siltstone Member of the Nolichucky Formation Showing Minor Layer Parallel Shear Zones 52

24. Photomicrograph of the Siltstone Member of the Nolichucky Formation Showing Pressure Shadow Development 54

25. Schemmatic Representation of the Formation of the Colonial Heights Thrust by Fault Propagation Folding 57

26. Stratigraphic Separation Diagrams for Segments of the Colonial Heights Thrust, Dunham Ridge Thrust, and Spurgeon Thrust in the Study Area, and Shows the Position of the Stratigraphic Separation Diagrams With Respect to the Geologic Map in Figure 27 59

27. Location Map for Stratigraphic Separation Diagrams A-A', B-B', and C-C' 60

28. Bedding-Fault Geometries at Several Points Along the Dunham Ridge and Spurgeon Faults 61

29. Photograph of the Hinge Zone of a Large, Sub-Horizontal Anticline. Exposure Located on the West Bank of the Holston River, Below the Lake Crest Subdivision 65

30. Map Location of Folds Developed in the Strata of the Study Area 66

31. Photograph of a Syncline Exposed in the Quarry Face Below the Baker Bluff Subdivision 68

32. Down-Structure View of the Chevron-Folded Spurgeon Hanging Wall Series Indicates Slight Thickening of the Conasauga Group in the Hinge Areas 69

33. Location and Orientation of Cleavage Within the Study Area 71

34. Map Location of the Kingsport Lineament Zone, Seismic Section A-A', Cross-sections B-B' and C-C' of Geyer et al. (1982), and Cross-sections 18 and 21 of Woodward et al. (1985) 74

35. Strike-oriented Seismic Section A-A' of Geyer et al. (1982) 75

36. Cross-sections B-B' and C-C' of Geyer et al. (1982), and Cross-sections 18 and 21 of Woodward et al. (1985) 77

37. Stereonet Plot of Cleavage and Bedding Attitudes Within the Spurgeon Fault Block 81

38. T1-Tx Diagram for the Study Area 85

LIST OF PLATES

PLATE

1. Geologic Map of the Boone Dam, Tennessee Area..... In pocket

2. Structure Section C-C'..... In pocket

3. Structure Sections A-A', B-B', and D-D'..... In pocket

CHAPTER I

INTRODUCTION

Statement of Problem

The primary purpose of this study is to describe the macroscopic structural geometry of a part of the Pulaski thrust sheet, and to establish the deformation styles and mechanisms there. Two important structural features which were investigated within the Pulaski sheet are: (1) large scale folding in the hanging wall blocks of both the Dunham Ridge and Spurgeon faults, and (2) local discontinuous cleavage present in the cores of some of these folds.

Fabric data combined with the mesoscopic and macroscopic structures will be used to establish the most probable kinematic sequence of deformation responsible for the present structural configuration of the Pulaski sheet in this area.

Location and Extent of Study Area

The area of study is located within the Valley and Ridge province of northeast Tennessee, approximately nine

miles southeast of Kingsport (Fig. 1). It incorporates 22 square miles of area within the Sullivan Gardens and Boone Dam TVA 7.5 minute quadrangles. The Valley and Ridge province here is characterized by imbrication of the strata into a number of southeast-dipping thrust sheets. This study is centered along the Sullivan-Washington County boundary, entirely within the Pulaski thrust sheet. In this area the Pulaski sheet is cut by the Dunham Ridge and Spurgeon faults, thereby defining three smaller sheets involving Middle Cambrian to Middle Ordovician age rocks.

Previous Investigations

Safford (1869) and Keith (1905, 1907) produced the earliest maps of the area, based on geologic reconnaissance studies. Spurgeon Island, within the study area, has been the site of geologic investigation by a number of individuals of the Geologic Branch of the Tennessee Valley Authority. These investigations were made to find a suitable site for the construction of Boone Dam. Eaton (1935) made the primary reconnaissance report, which was followed by a report by Prouty (1944). These reports, based entirely upon surface data, were supplemented by Grant and Benziger's (1949) study that utilized core boring data. However, these early investigations were limited both by an

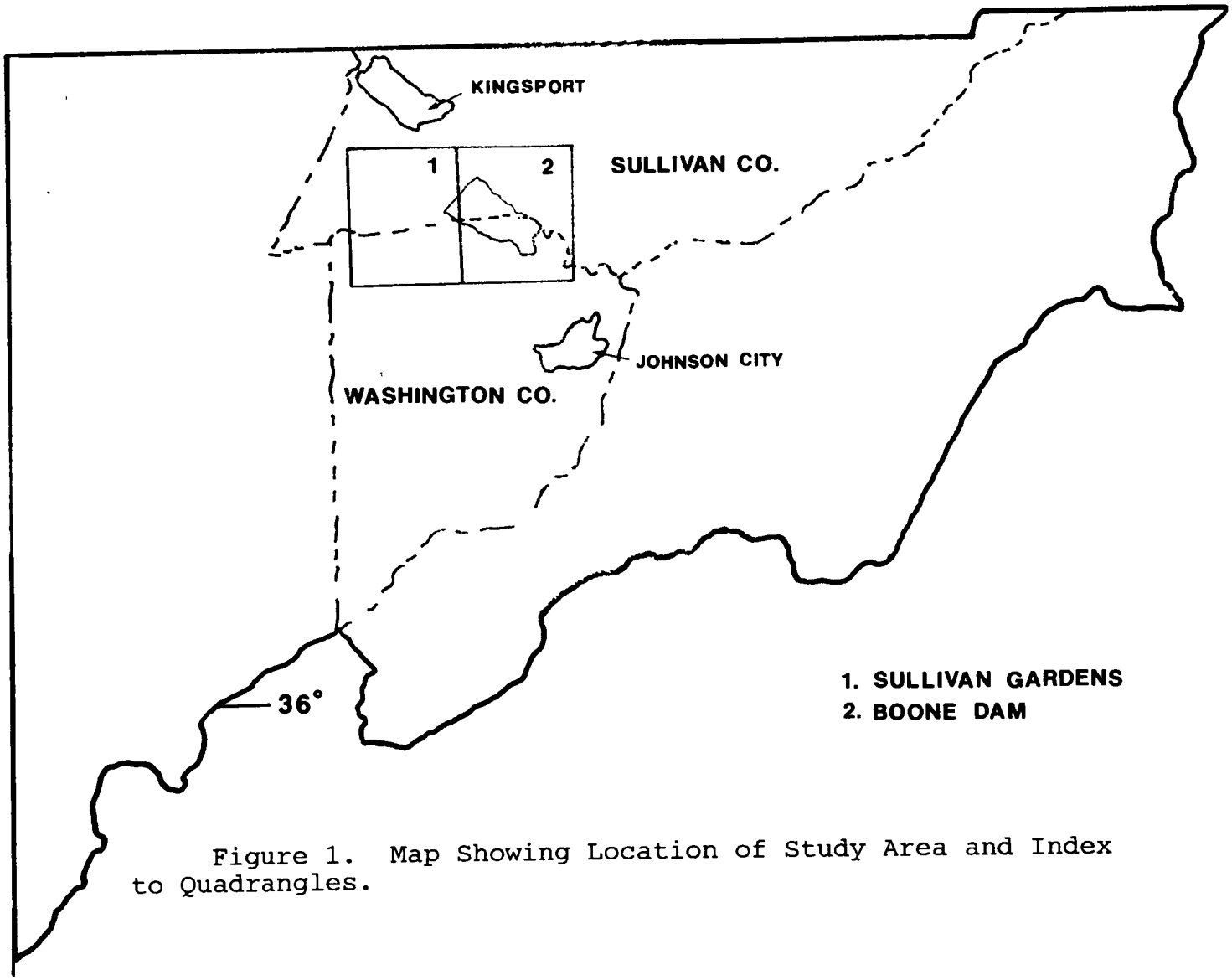


Figure 1. Map Showing Location of Study Area and Index to Quadrangles.

inaccurate knowledge of the local stratigraphy and structure, and by the local nature of their concerns. Rodgers' (1953) compilation map of East Tennessee corrected many of the previous stratigraphic and structural misinterpretations. Although limited by his large scale, Rodgers' stratigraphic and structural interpretations for the area in question are basically correct.

Byerly (1966) studied the Pulaski fault southwest of the study area, in Greene County (Fig. 2), and noted that the minimum horizontal displacement along the fault is three miles and may possibly be six miles or more. Pugh (1966) studied the structure of the Pulaski fault block in Sullivan County, north of the study area (Fig. 2). He observed that the Honaker occurs in the hanging walls of the Pulaski, Dunham Ridge, and Spurgeon thrusts, with Honaker through Sevier occurring in the footwalls. Little (1969) described the lithology and structural geology between the Dunham Ridge and Spurgeon faults, in an area just southwest of the study area (Fig. 2). He noted that the Dunham Ridge block in this area is dominated by anticlines and synclines, with limbs that generally dip steeply to vertically. He also observed that both the Dunham Ridge and Spurgeon faults have decollements in the lower member of the Honaker, and seemed to have originated at depth from the same decollement.

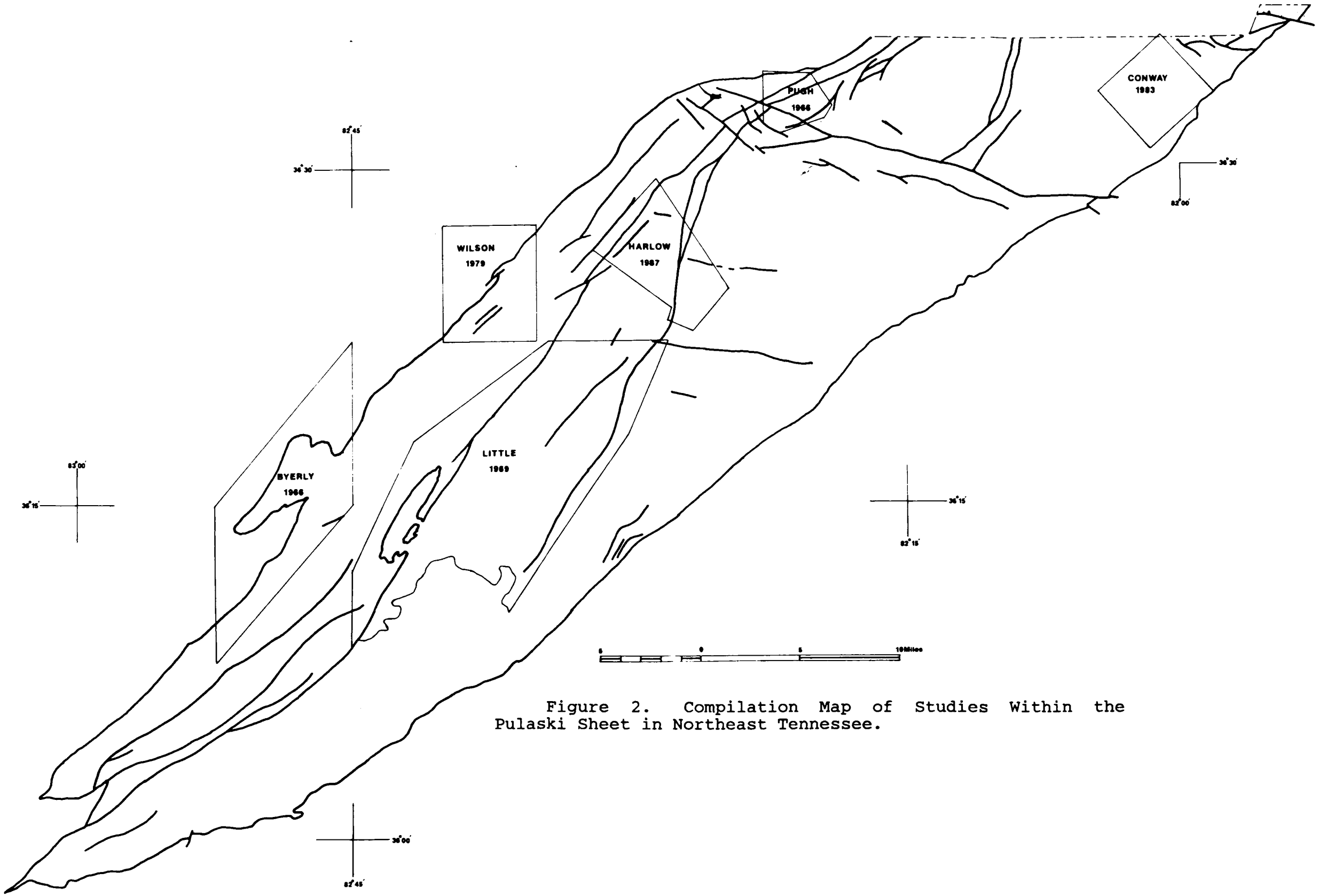


Figure 2. Compilation Map of Studies Within the Pulaski Sheet in Northeast Tennessee.

More recently, Conway (1983) stated that the emplacement of the Pulaski thrust sheet folded and uplifted the earlier, overlying Holston Mountain thrust sheet. His study included a detailed look at cleavage-fold geometries and fold mechanisms within the northeastern part of the sheet. He concluded that the relationships between cleavage-bedding angles, fold interlimb angles, and cleavage fan angles, indicate that flexural flow or slip, strongly influenced by heterogeneous pressure solution shape modification, was the likely fold mechanism. He also suggested that the orientations of cleavage traces were primarily controlled by the maximum contraction directions of local finite strain ellipsoids.

Finally, Roeder, Gilbert, and Witherspoon (1978) and Woodward (1985) constructed cross-sections through this area of the Appalachian Valley and Ridge fold and thrust belt.

Present Investigation

This investigation represents the first detailed examination of the structural geology of this area. It was undertaken to place mesofabric data into the context of the regional geometric framework, and has implications for the hinterland to foreland emplacement of the Valley and Ridge thrusts of northeastern Tennessee. In the absence of

drilling or geophysical data, the study is based upon surface control data derived from detailed geologic traverses through the area. Four main traverses were made, along: (1) the South Fork of the Holston River, (2) Tennessee State Highway 36, (3) the Clinchfield Railroad, and (4) U.S. Interstate 181 (Fig. 3). Where necessary, these traverses were supplemented by geologic reconnaissance. Bedding attitudes, the orientations of all mesofabric data, and formation contacts were plotted on a 1/12,000 topographic map. The field work for this study was done during the summers of 1984 and 1985.

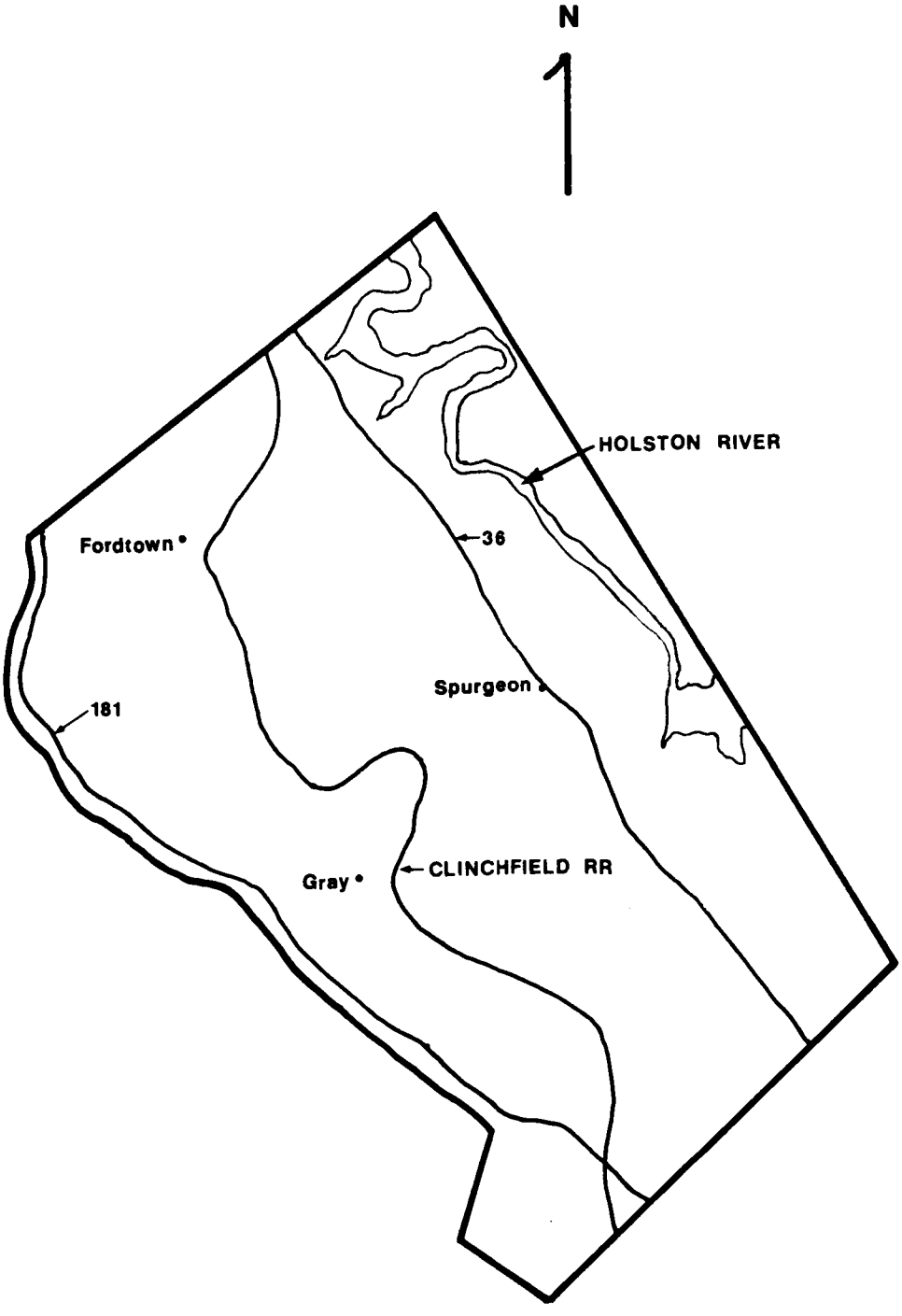


Figure 3. Map Showing Study Area and Location of Geologic Traverses.

CHAPTER II

STRATIGRAPHY

Introduction

Byerly (1966) and Rodgers (1953) both noted that the Pulaski fault marks a stratigraphic and a structural front. It separates cherty dolostones and limestones of the Knox in the footwall block from the less cherty limestones and dolostones of the Knox in the hanging wall block. It also divides the lengthy open folds of the Saltville thrust sheet from the tightly folded strata of the Pulaski thrust sheet. Descriptive information concerning the rocks in the present study area was largely derived from Little (1969) and Rodgers (1953), both of whom studied the rock units immediately to the southwest and the reader is referred to them for more lengthy and complete lithologic details.

The stratigraphic column of exposed sedimentary rocks in the area extends from the Middle Cambrian Honaker Formation (Conasauga Group) to the Middle Ordovician Sevier Shale (Fig. 4). Both the Conasauga and Knox Groups are present throughout the majority of the study area, however the Lenoir Limestone and Sevier Shale crop out in the core of only one large fold.

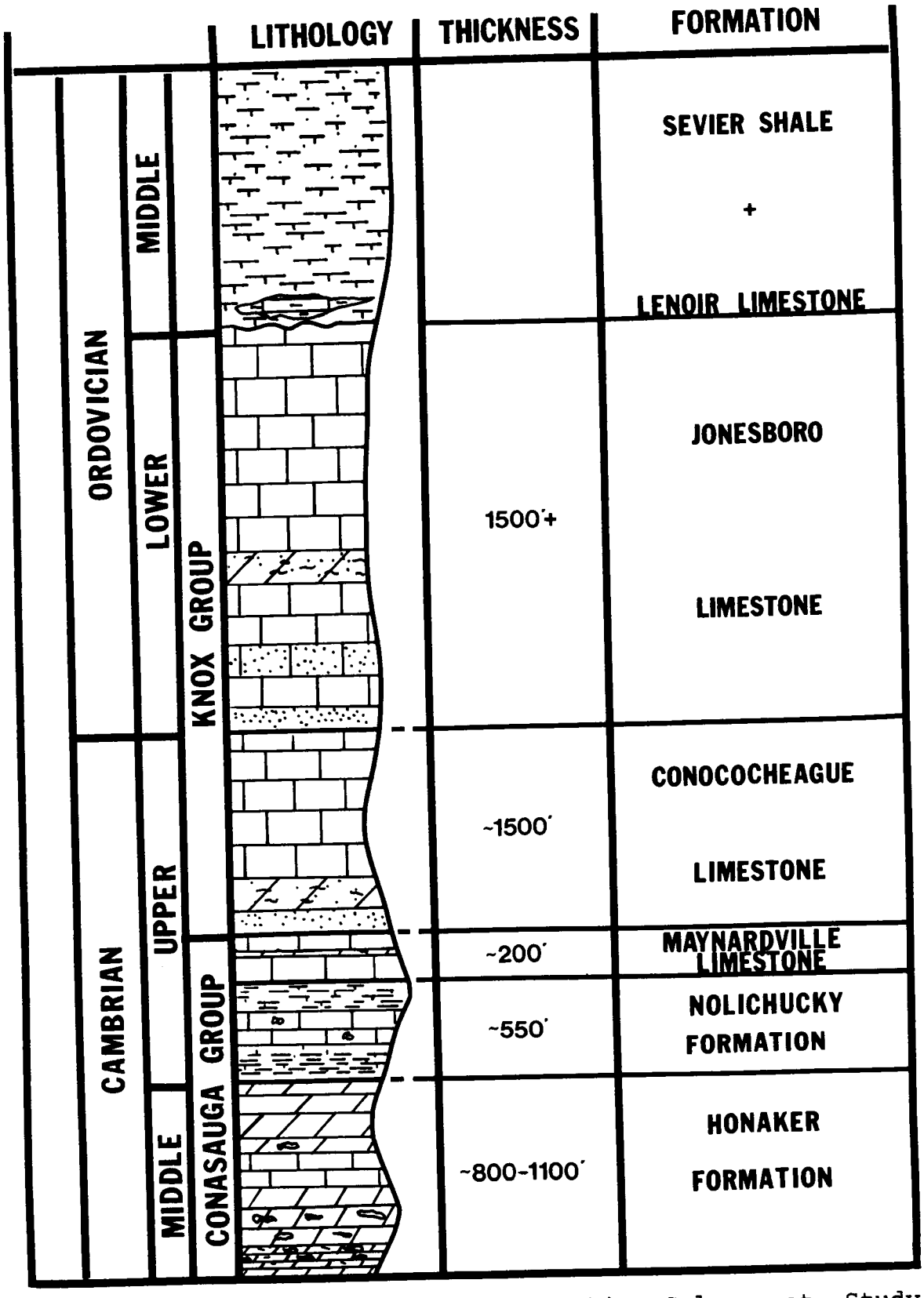


Figure 4. Generalized Stratigraphic Column at Study Area.

Topography in the area directly reflects differential erosion of various rock units. Hence, changes in the lithostratigraphy are usually reflected by corresponding changes in topography. Because of the high carbonate content of the units, exposures are limited and continuous exposures are usually lacking.

The Conasauga Group in this area belongs to the southeastern phase as described by Rodgers (1953), and is characterized by the merging of the Maryville and Rutledge Formations into the Honaker Formation (Fig. 5). The lowest and oldest beds exposed in the area are those of the Honaker Formation. They occur at the bases of thrust sheets and in the cores of tight anticlines. The lowest part of the formation is apparently faulted out along the thrusts, but the 335 meters (1100+ feet) present probably represents the majority of the unit (Little, 1969; Butts, 1933).

The Honaker was considered to be of Middle Cambrian age by previous workers (Butts, 1933; Keith, 1905). It is overlain successively by the Nolichucky Formation and Maynardville Limestone of Late Cambrian age (Rodgers, 1953). In northeast Tennessee, strata of the Conasauga Group were deposited during a major marine transgression along a carbonate-dominated, shelf margin, shoal and peritidal complex (Hasson and Haase, in press). This high-relief, carbonate shelf bounded the eastern margin of a NE-SW

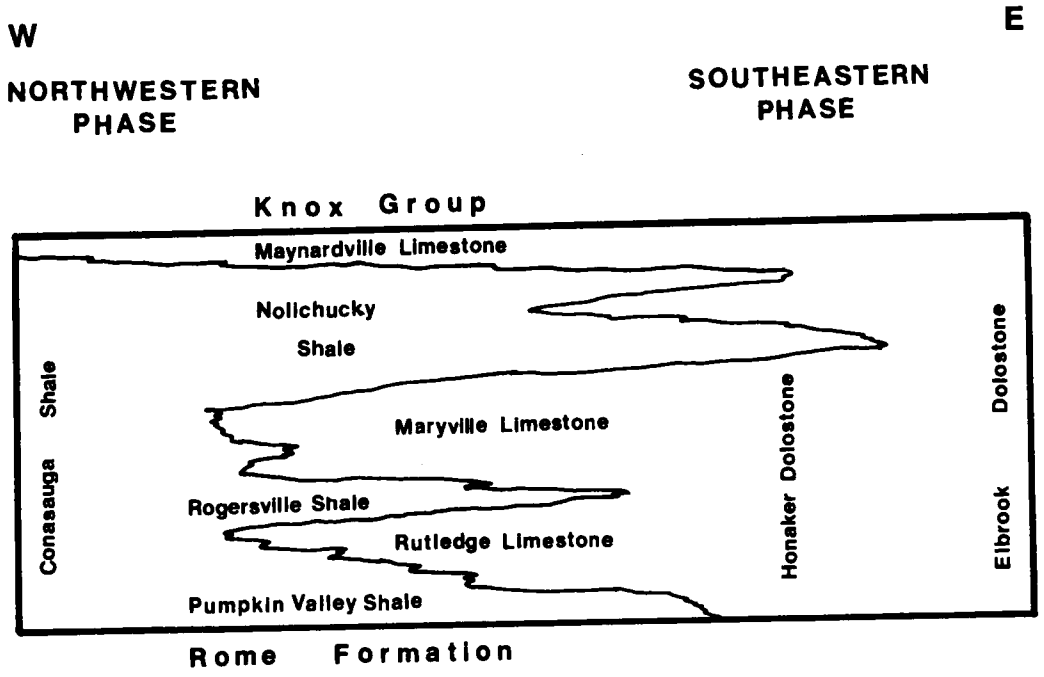


Figure 5. Facies Diagram of the Conasauga Group (after Rodgers, 1958, p. 46).

trending intrashelf basin, and consists dominantly of shaly limestone occasionally mixed with dolostone (Rodgers, 1968).

Above the Conasauga Group are the rocks of the Knox Group, which also belong to its southeastern phase (Rodgers, 1953). In this area it consists primarily of limestone that produces much less chert upon weathering than its northwestern counterpart (Rodgers, 1953; Oder, 1934). The Knox overlies the Maynardville Limestone and is bounded above by an unconformity between Lower and Middle Ordovician age rocks. Where data permit, it is divisible into two units consisting of the Upper Cambrian Conococheague Limestone and the Lower Ordovician Jonesboro Limestone.

The disconformity that marks the top of the Knox Group has been demonstrated to have several hundred feet of relief (Little, 1969). Above this the youngest rocks exposed in the study area occur. The group is represented by the Lenoir Limestone and the Sevier Shale.

Description of Rock Units

Conasauga Group

As previously noted, the Conasauga Group consists of three formations: (1) the Honaker Formation, (2) the Nolichucky Formation, and (3) the Maynardville Limestone.

The basal part of the Honaker consists of approximately 61 meters (200 feet) of thinly-bedded, shaly dolostone that often exhibits a highly crumpled appearance when in proximity to faults (Fig. 6). This is overlain by several hundred feet of interbedded limestones and dolostones, usually medium- to thick-bedded and often argillaceous. Nodular and bedded chert is commonly present in the dolostones, and is more common in the Honaker than in the Conococheague. Large amounts of this chert contain fossil cryptozoans (Rodgers, 1953). The upper 61 meters (200 feet) of the formation consists mostly of light gray to white, saccharoidal dolostones. Previous workers (Little, 1969; Byerly, 1966) reported that the dolostones of the upper Honaker exude a petroliferous odor when broken. These massive, saccharoidal dolostones are in marked contrast to the basal shales of the overlying Nolichucky Formation.

Within the area the Nolichucky Formation is composed of rocks which are grouped into four units on the basis of lithology. The youngest and uppermost unit was named the Maynardville Limestone by Bridge (1953) and raised to formational rank by Rodgers (1956). The underlying clastic rocks (Nolichucky Formation proper) consist of an upper siltstone member, a middle intraclastic and oolitic limestone member (the Bradley Creek member of Hasson and Haase, in press), and a basal shale member. The lowest unit consists of light blue-gray shale approximately 61 meters

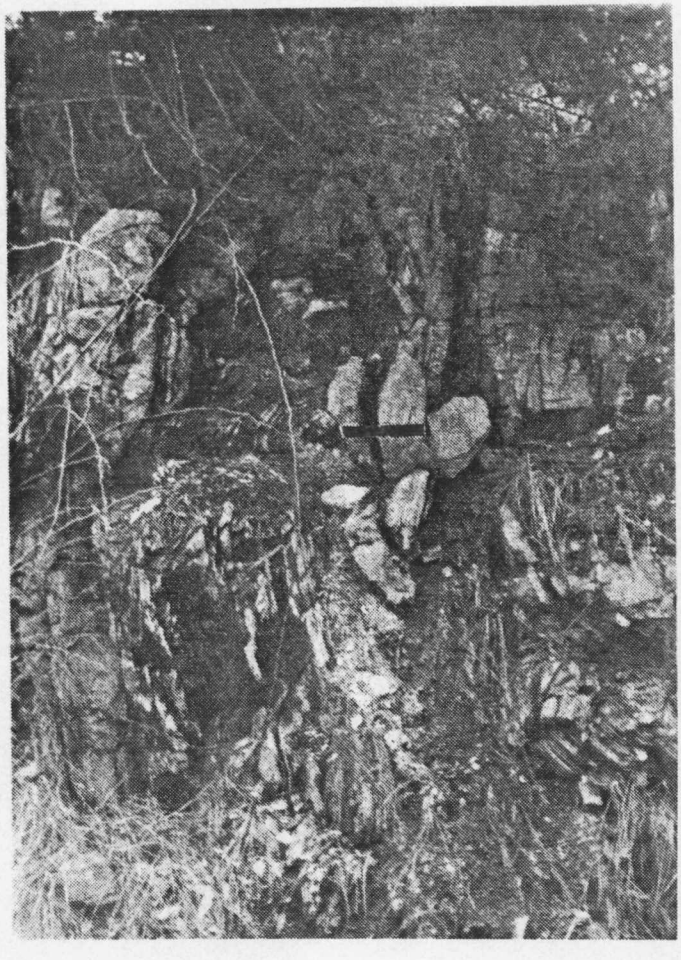


Figure 6. Crumpled, Thinly Bedded, Shaly Dolostone of the Lower Member of the Honaker Formation. Exposure Along Clinchfield Railroad, 600 meters (2000 feet) East of Fordtown (bar = 1.0 foot).

(200 feet) thick (Fig. 7). This grades upward into an approximately 46 meter (150 foot) thick limestone zone, consisting of: (1) basal shaly limestone, (2) massive, mottled limestone, and (3) an upper massive, coarsely crystalline, blue-gray limestone. The upper member is composed of medium- to thick-bedded siltstone intercalated with occasional thin dolostone beds (Byerly, 1966). The boundary between the Maynardville Limestone and the overlying Conococheague Limestone is marked by a change from beds of limestone to beds of dolomitic sandstone and dolostone.

Knox Group

The Knox Group as used in this report consists of all strata above the Maynardville Limestone and below the Lenoir Limestone or its equivalent, the basal Sevier Shale. It belongs to the southeastern phase as described by Rodgers (1953) and consists of two formations, the Conococheague and Jonesboro Limestones. These are separated, where possible, at a prominent group of sandstone beds.

The Conococheague Formation occupies the same lower stratigraphic position as the Copper Ridge Formation of outcrop belts farther to the northwest. However, the Copper Ridge consists mainly of cherty dolostones and some

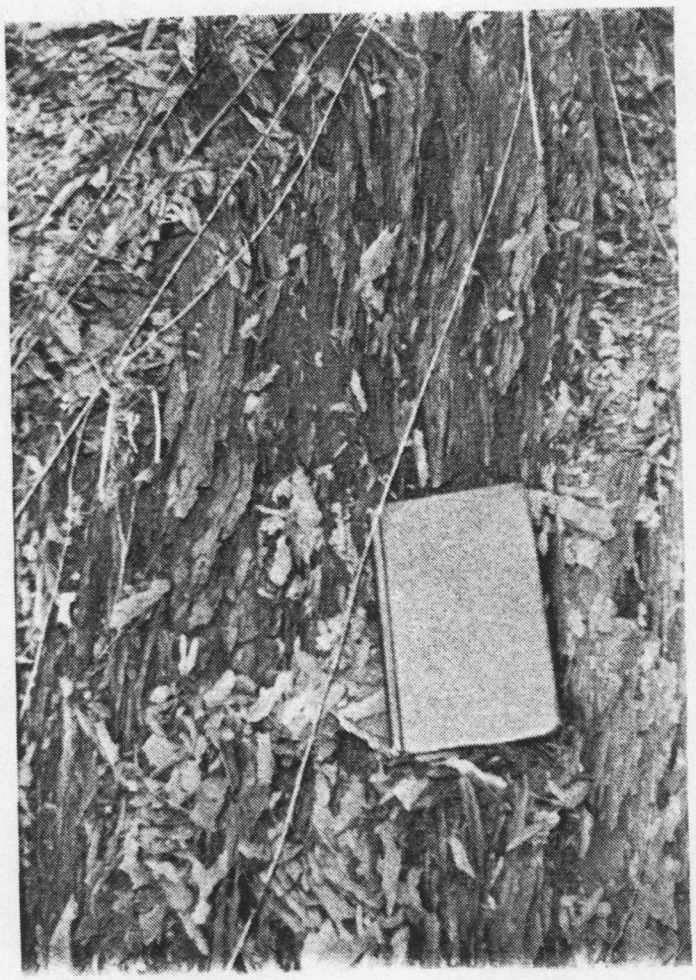


Figure 7. Lower Shale Member of the Nolichucky Formation. Exposure Located Along the Clinchfield Railroad, 900 meters (3000 feet) East of Fordtown (field notebook = 6.75 in. x 4.25 in.).

sandstones, whereas the Conococheague contains mostly chert-free limestone. This change in lithologic character from dolostones to limestones prompted the use of the Pennsylvania name in preference to the Tennessee name (Bridge, 1956; Rodgers, 1953; Grant and Benziger, 1949). The Jonesboro Formation consists of all strata above the Conococheague and below the Lenoir Limestone. Lithologically, in this area, the two formations of the Knox Group are quite similar. Stratigraphic investigation of these rocks is hampered by a scarcity of exposure, and the fact that the Knox underlies open, rolling country characterized by abundant karst topography.

Rodgers (1953) noted, and observations by the author confirm, the lithologic variability represented within the Knox. It contains dark blue-gray limestones mottled with reticulated partings of dolomite. They are interbedded with light gray dolostones, unribboned limestones, oolitic limestones, intraformational conglomerates, dolomitic sandstones , and arenaceous limestones. Previous workers in this vicinity (Little,1969; Byerly,1966; Rodgers, 1953) obtained thicknesses for the Knox ranging from 732 to 975 meters (2400 to 3400 feet).

Middle Ordovician Section

The Middle Ordovician section is composed of two formations, the Lenoir Limestone and the Sevier Shale. The Lenoir Limestone consists of coarsely crystalline, medium-bedded, argillaceous, nodular limestone (Fig. 8). The upper contact is gradational with the overlying Sevier Shale, which consists of medium gray, thinly-bedded, silty, calcareous claystones. Most exposures are deeply weathered to a buff colored, highly fissile, shale (Fig. 9). A maximum of several hundred feet of the Sevier Shale is present in the study area, although more substantial thicknesses are observed immediately east of the study area in the footwall of the Holston Mountain thrust.



Figure 8. Nodular, Medium Bedded, Coarsely Crystalline Lenoir Limestone. Exposure Located 210 meters (700 feet) Southeast of Oak Grove Church (dime for scale).

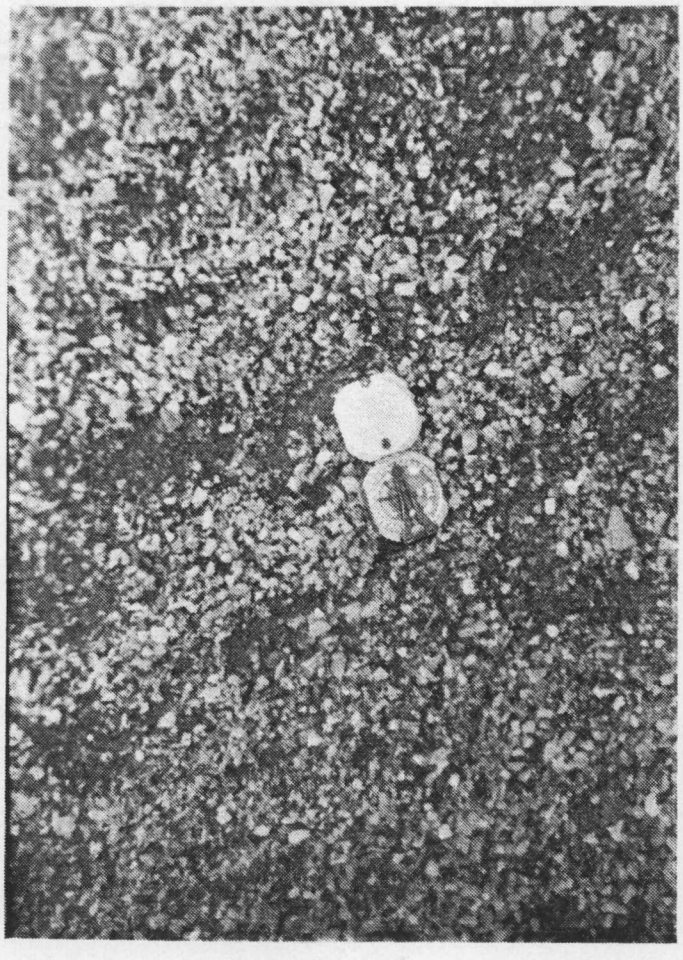


Figure 9. Typical Exposure of Claystones of the Sevier Shale. Exposure Located 360 meters (1200 feet) Northeast of Oak Grove Church.

CHAPTER III

STRUCTURAL GEOLOGY

Regional Setting

The area of study is situated in the Valley and Ridge province of East Tennessee. Topographic relief in the area is low and averages between 30 and 61 meters (100 - 200 feet). The most conspicuous features in the area consist of a series of long, narrow hills with smooth, semielliptical crestlines. Trending NNE-SSW these low ridges are usually separated by rolling, open terrain. There is also a large karst plain developed in the central portion of the area (see Plate 1).

Some of the formations exhibit a topographic expression which is helpful in mapping. The following is a description of the geomorphology encountered during a traverse across a typical stratigraphic sequence.

The lower Honaker underlies narrow, rounded ridges and weathers to a deep, clay soil with abundant cryptozoan chert nodules. The upper part of the Honaker forms broad, open valleys and upon weathering produces a chert-free clay soil.

The lower siltstone member of the Nolichucky commonly forms a low bench on the northwest flank of the ridges,

adjacent to the broad, open valleys of the upper Honaker. It weathers to a fine, thin soil. The upper siltstone member of the Nolichucky, and the Maynardville Limestone, form narrow, linear ridges that rise 30-61 meters (100-200 feet) above the adjacent valleys.

The soluble Conococheague and Jonesboro Limestones, of the Knox Group, underlie open, gently rolling country characterized by extensive karst topography. Erosion of these rocks produces a deep orange-red residuum containing very little chert.

The strata of the Sevier Shale are found in the hinge zone of one large arcuate syncline in the eastern part of the study area. The Lenoir Limestone forms a bench along the side of a stream valley which is incised into the claystones of the Sevier Shale. Upon weathering, these rocks produce a light yellowish-brown soil containing numerous shale chips.

In many instances soil type and topography provide the only clues to the underlying strata in the area. Even so, the prominent sandstone beds that mark the contact between the Conococheague and Jonesboro Limestones commonly cannot be traced in the residuum over open terrain. Lithologic contacts that were documented by outcrops during mapping were extrapolated over the poorly exposed areas by the use of the Soil Survey Map of Washington County, Tennessee

(Elder, et al., 1958), and the Soil Survey Map of Sullivan County, Tennessee (Matzek, et al., 1953).

The structure of the Valley and Ridge province of Northeast Tennessee was described and discussed by King (1950), Rodgers (1953), and others. The region is characterized as a fold- and thrust-belt comprised of a series of northeast trending thrust faults which create overlapping southeast-dipping panels of strata. This thin-skinned decollement style (see following discussion) of thrusting occurred during the Late Paleozoic Alleghenian orogeny, as shown by the largely unmetamorphosed fossiliferous sequences involved in the deformation (Hatcher and Odom, 1980).

Investigations in the Valley and Ridge and Blue Ridge provinces of Southwest Virginia and Northeast Tennessee have resulted in two schools of thought concerning the behavior of folds and faults at depth, and the relative ages of these folds and faults. Cooper (1961, 1964, 1968) maintained that major Appalachian structures are the result of active involvement of the basement crystalline rocks. This "thick-skinned" or "basement" theory was greatly influenced by concepts developed by workers in the Alpine Mountains (Rodgers, 1964).

The concept of "thin-skinned" deformation was first proposed for the Appalachian Valley and Ridge by Rich (1934). Rodgers proposed the name for this style of

deformation in 1949. He maintained that both thrust faults and folds flatten out at depth, becoming asymptotic to a regional decollement in the Lower Cambrian Rome Formation, above uninvolved or passively deformed crystalline rocks. The integration of geophysical data subsequently verified that deformation of the cover strata took place largely independent of the basement rocks (Tegland, 1978). However, in some instances the basement may exert passive control on Valley and Ridge deformation. Johnson (1970) noted that Willis (1893) proposed that minute changes in the initial dip of the basement may determine places where folds will form. Recent workers (Geyer, et al., 1982; Jacobeen and Kanes, 1975) observed that changes in the amount of basement relief may initiate ramping of westward moving thrust plates. However, Woodward, Walker, and Lutz (in press) maintain that structural style variations are the result of either areal changes in individual stratigraphic horizons or changes in the stacking sequence of structural/stratigraphic units.

The second concern regarding Valley and Ridge structure pertains to the progression or sequence of thrust development. Milici (1975) maintained that the intersection of major structural blocks in the Southern Appalachians show that the oldest structures are to the west or "foreland", and therefore formed in a "break-back" pattern of deformation. In contrast, many workers in this area

(Wilson, 1979; Little, 1969; Byerly, 1966) noted the presence of folded thrust faults. Jones (1971) argued that this pattern is expected in any thrust belt where the stratigraphic package is inhomogeneous and higher thrusts are emplaced prior to the underlying ones in a hinterland to foreland thrust progression. Recent mapping in East Tennessee (Woodward and Beets, in press) also infers a forward thrust progression.

Local Structure

Several workers studied the Pulaski thrust sheet in Northeast Tennessee (Fig. 2, p. 5). These investigations share common generalizations on the structure of the large sheet, among them: (1) the lower member of the Honaker Formation serves as the basal decollement for all thrusts, (2) the thrust surfaces dip to the southeast and are often folded, (3) wrench or tear faults commonly disrupt the sheet, (4) folds within the sheet usually exhibit a similar geometry, and (5) all the features observed within the Pulaski sheet suggest thin-skinned deformation.

Roeder et al.'s (1978) and Woodward et al.'s (1985) balanced, structure cross-sections illustrate subsurface interpretations for northeast Tennessee. Both favor a hinterland to foreland thrust progression, and their cross-sections have similar depths to basement. However,

Roeder et al.'s (1978) subsurface interpretation for the Pulaski sheet is geometrically different than that of Woodward et al.'s (1985). To account for the folded thrusts and numerous tight folds observed at the surface, Roeder postulates several blind imbricates off the regional basal decollement in the Rome Formation. In contrast, Woodward draws the Pulaski sheet as a tightly folded thin sheet above a sub-Pulaski duplex. The Pulaski thrust acts as the roof thrust for the duplex and only Honaker through Sevier strata are present in the horses.

In the Tennessee counties of Sullivan and Washington, the Pulaski thrust sheet includes the Pulaski, Dunham Ridge, and Spurgeon faults. In this report the Pulaski sheet is divided into blocks based on the major faults in the area. The hanging wall of each fault is referred to as a fault block. The Pulaski thrust sheet is bounded on the northwest by the trace of the Pulaski fault, and on the southeast by the trace of the Holston Mountain fault. The Honaker Formation is the oldest unit brought up along any of the faults or anticlines in this area, whereas it is common for the Rome Formation to be brought up along thrust faults to the northwest (Rodgers, 1953).

In the area of this report segments of both the Dunham Ridge and Spurgeon faults were mapped. Each segment was approximately 6.45 kilometers (four miles) in length. In addition two discontinuous thrusts were observed, one each

in the Pulaski and Dunham Ridge fault blocks. These roughly parallel the trace of the Dunham Ridge fault. Finally, two east-west trending wrench or tear faults disrupt the larger sheet in this area. Although generally minor in terms of right-lateral displacement these tears mimic the more extensive Cross Mountain fault that is located several miles to the northeast.

Description of Structural Features

The major geologic structural features of this area may be divided into the following elements: (1) the Pulaski fault block, (2) the Dunham Ridge fault block, (3) the frontal imbricate slice of the Spurgeon fault, and (4) the Spurgeon fault block (Fig. 10).

Pulaski Fault Block

In Tennessee, the trace of the Pulaski fault extends from near the vicinity of Reedy Creek School in Sullivan County to a point in eastern Cocke County (Fig. 11). The trace of the Pulaski fault is west of the present study, therefore the entire Pulaski block is not present--and has not been addressed in this study. In the study area the Honaker Formation is the basal unit exposed in the block. Gently plunging, northeast-trending folds are the dominant

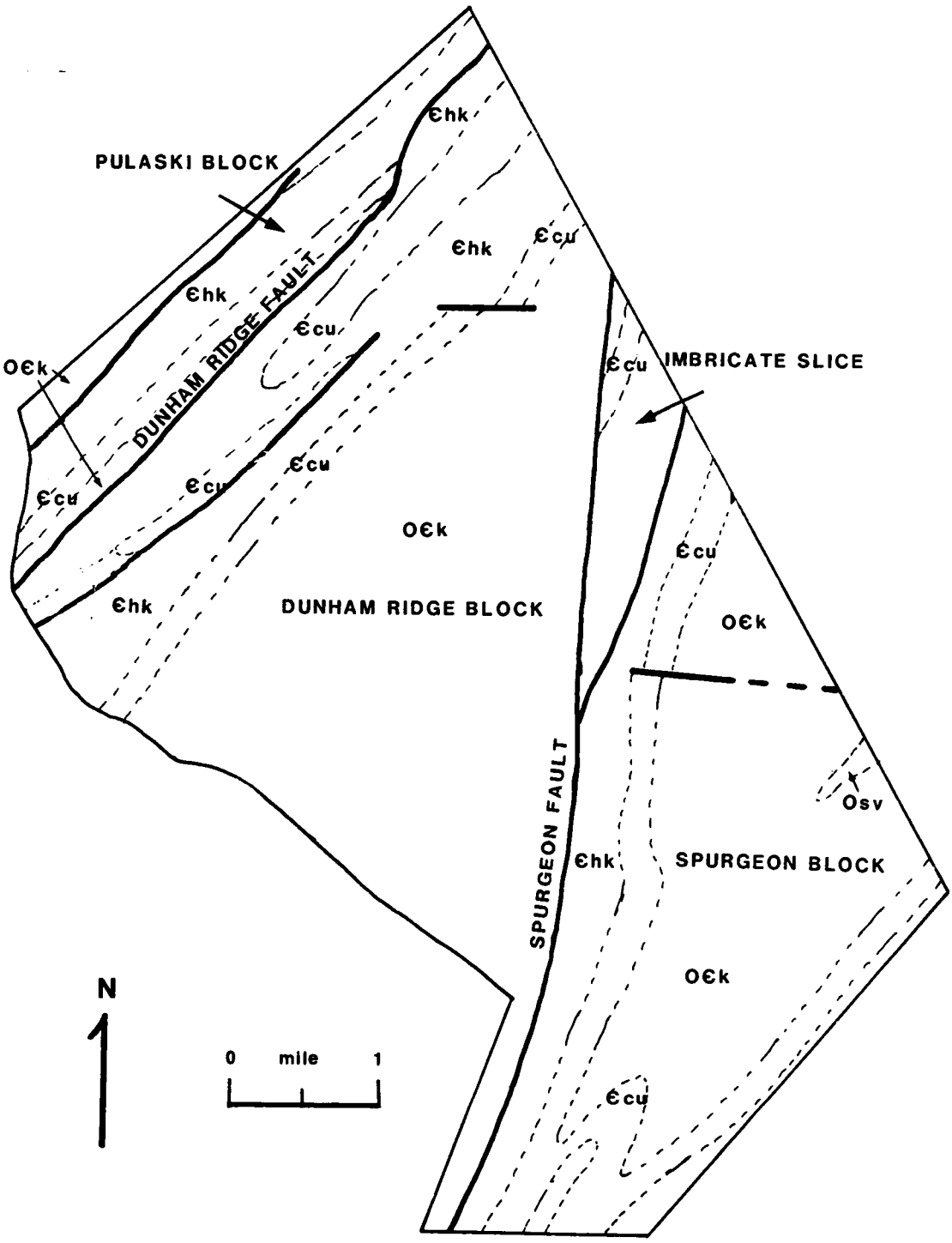


Figure 10. Major Structural Features of the Study Area.

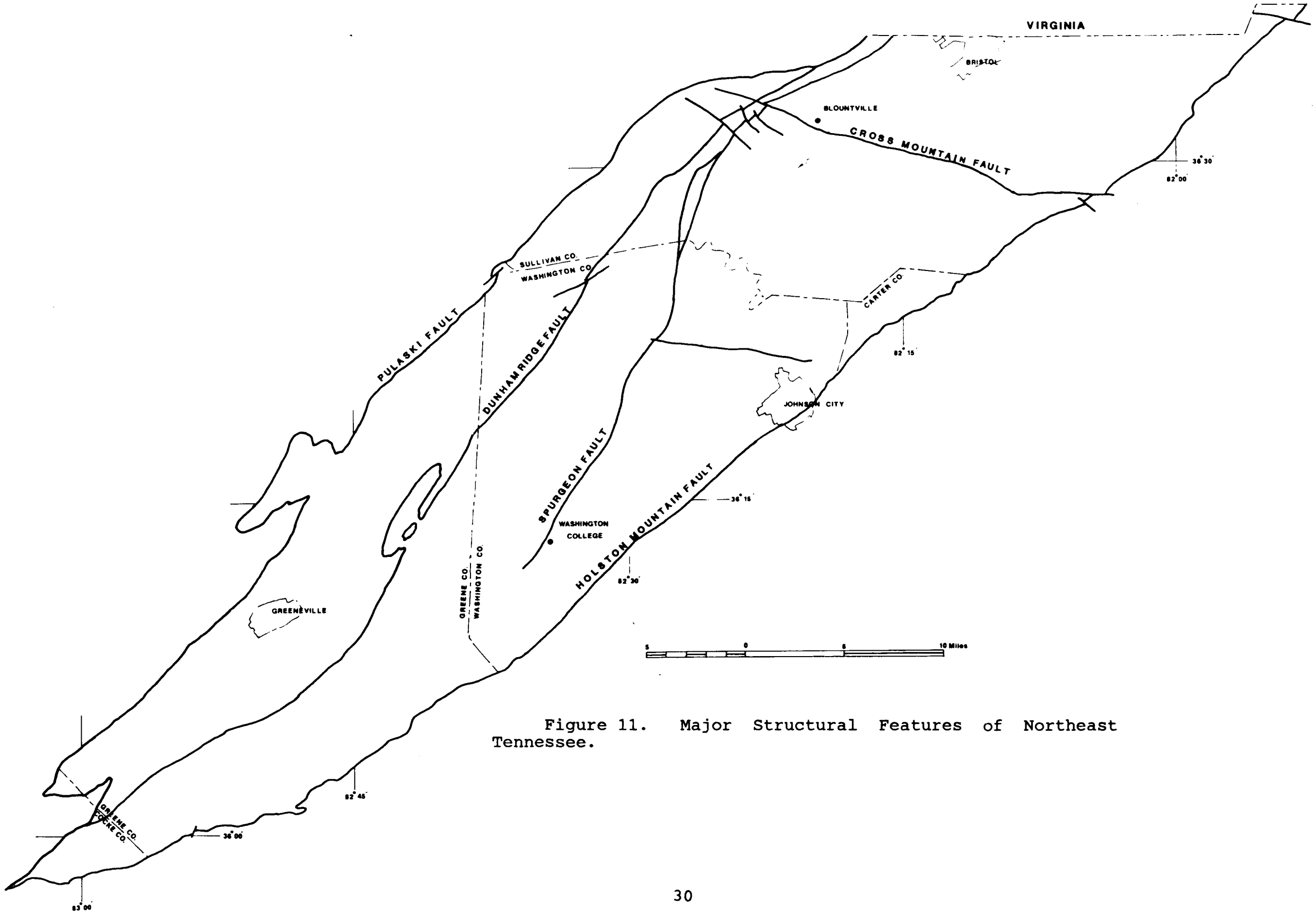


Figure 11. Major Structural Features of Northeast Tennessee.

structure developed in the block. However, two discontinuous thrusts disrupt the folded strata, one near the center of the block and another in the trailing edge.

Dunham Ridge Fault Block

The trace of the Dunham Ridge fault branches from the Pulaski fault near the Greene-Cocke County line to the southwest, roughly parallels the Pulaski fault northeastward through the study area, and merges with the Pulaski fault again north of Blountville, in Sullivan County, Tennessee (Fig. 11).

The Dunham Ridge thrust places Honaker strata against the Conococheague Limestone in the footwall. One exception occurs at the northwestern edge of the study area where the fault trace crosses the South Fork of the Holston River. There the Honaker in the hanging wall is faulted against, successively, the Maynardville, Nolichucky, and Honaker formations of the Pulaski fault block. The Dunham Ridge fault here overlies the southeast flank of an anticlinal structure developed in the footwall. Northeast of the study area, along the trace of the fault, the Honaker in the hanging wall is faulted against, successively, the Honaker, Nolichucky, Maynardville, and Conococheague formations (see Geologic map of Tennessee--East sheet, Hardeman, et al.,

1966). This "bulge" in the trace of the Dunham Ridge thrust is approximately 3.2 kilometers (two miles) in length and gently arcuate in shape.

The dip of the fault plane is difficult to determine in the area. It was observed in outcrop in only one instance, along the South Fork of the Holston River. Here the fault is quite steep, with an estimated dip of 70-80 degrees to the southeast. The linear nature of the fault indicates it remains steep, and the "bulge" is a down-structure view of two lateral ramps.

The Dunham Ridge fault block is dominated by gently plunging anticlines and synclines, with steeply dipping limbs and similar fold styles. These large-scale folds plunge to the northeast, and have axes that roughly parallel the Dunham Ridge fault. The folds in the leading edge of the block exhibit a wavelength of approximately 600+ meters (1800 feet). These short-wavelength folds are tighter than the large, more open folds developed in the trailing edge of the fault block. The trailing edge folds have wavelengths of approximately 2400 meters (8000 feet).

Imbricate Slice of the Spurgeon Fault

The "imbricate slice" that Rodgers (1953) implied to be the result of bifurcation of the Spurgeon fault is probably a horse plucked from the footwall during emplacement of the

Spurgeon fault. It is relatively small (11 kilometers long x one kilometer thick), and not far traveled. Within the horse the Conococheague is exposed at several locations and dips to the southeast at a fairly uniform value of 45 degrees.

Spurgeon Fault Block

The trace of the Spurgeon fault begins on the northwest flank of an anticline in the vicinity of Washington College, Washington County, Tennessee (Fig. 11). From here it extends northeastward, through the study area, and ends in Washington County, Virginia (Calver, et al., 1963). The Spurgeon places lower Honaker rocks over strata of the Conococheague . The footwall package is folded into a large, anticlinal structure that plunges gently to the north.

In the area of this report the Spurgeon fault block is folded into a gently plunging, northeast trending, chevron fold. Knox Group strata crop out in the cores of this fold, with the Lenoir Limestone and Sevier Shale also cropping out in the northern limit of the area.

CHAPTER IV

MESOFABRIC AND MICROFABRIC ELEMENTS

Introduction

Although minor structures are often the result of local stress fields, they usually occupy domains within larger geologic structures. Recognition of these small-scale structures, coupled with an understanding of their modes of occurrence, can provide clues to the emplacement and deformation of a thrust sheet.

Previous fabric studies within the Pulaski sheet noted up to three cleavages developed in the siltstones of the Sevier Shale (Roper, 1979). In contrast, the limestones and dolostones of the underlying Conasauga and Knox Groups did not exhibit a penetrative fabric (Roper, 1979; Little, 1969; Byerly, 1966).

A wide variety of mesofabric and microfabric elements are observed in the tightly folded strata of the present study area. These features consist of en echelon vein arrays, calcite-filled fractures, minor faults, spaced cleavage, pressure shadows, slickensides, and microscopic shear zones. The penetrative deformational fabrics are best developed in the siltstones and shales of the Nolichucky

Formation, although some are observed in some of the carbonate rocks of the Knox Group.

Pulaski Fault Block

At an exposure located adjacent to the intersection of Tennessee route 36 and the exit ramp off Interstate 81 south (Loc. 1, Fig. 12), the rocks of the Nolichucky are thrust over strata of the Knox. This movement is along a small, discontinuous thrust in the trailing edge of the Pulaski fault block, herein referred to as the Colonial Heights thrust (Fig. 13). The interbedded siltstones and sandstones of the Nolichucky strike north 68° east and dip 77° northwest. The rocks are highly jointed, and slickensides are observed on some bedding surfaces. A sample (# 1-Cn) collected from the Nolichucky here exhibits a 2.2 centimeter thick accumulation of growth fibers along its bedding plane (Fig. 14). The fabric of the rock is dominated by numerous closely-spaced fractures. A thin-section of this sample (# 1-Cn, see Appendix A) shows slivers of wall rock incorporated within the growth fibers (Fig. 15). Occasional rare inclusion trails approach some growth fiber edges asymptotically (Fig. 15).

These fibers or slickensides are located on the northwest limb of a large anticline developed in the Dunham Ridge footwall. They are oriented perpendicular to the

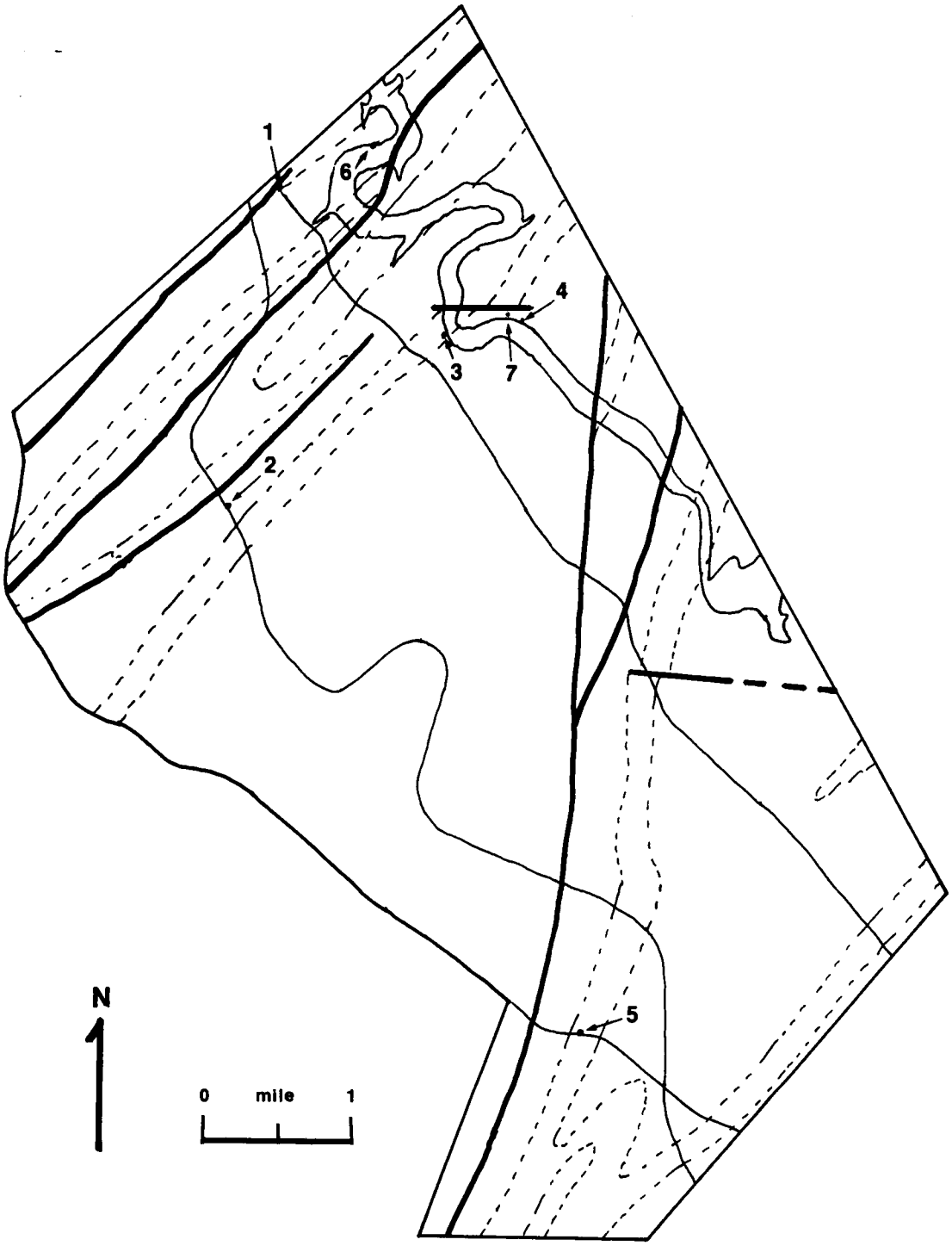


Figure 12. Index Map of Outcrop Locations.

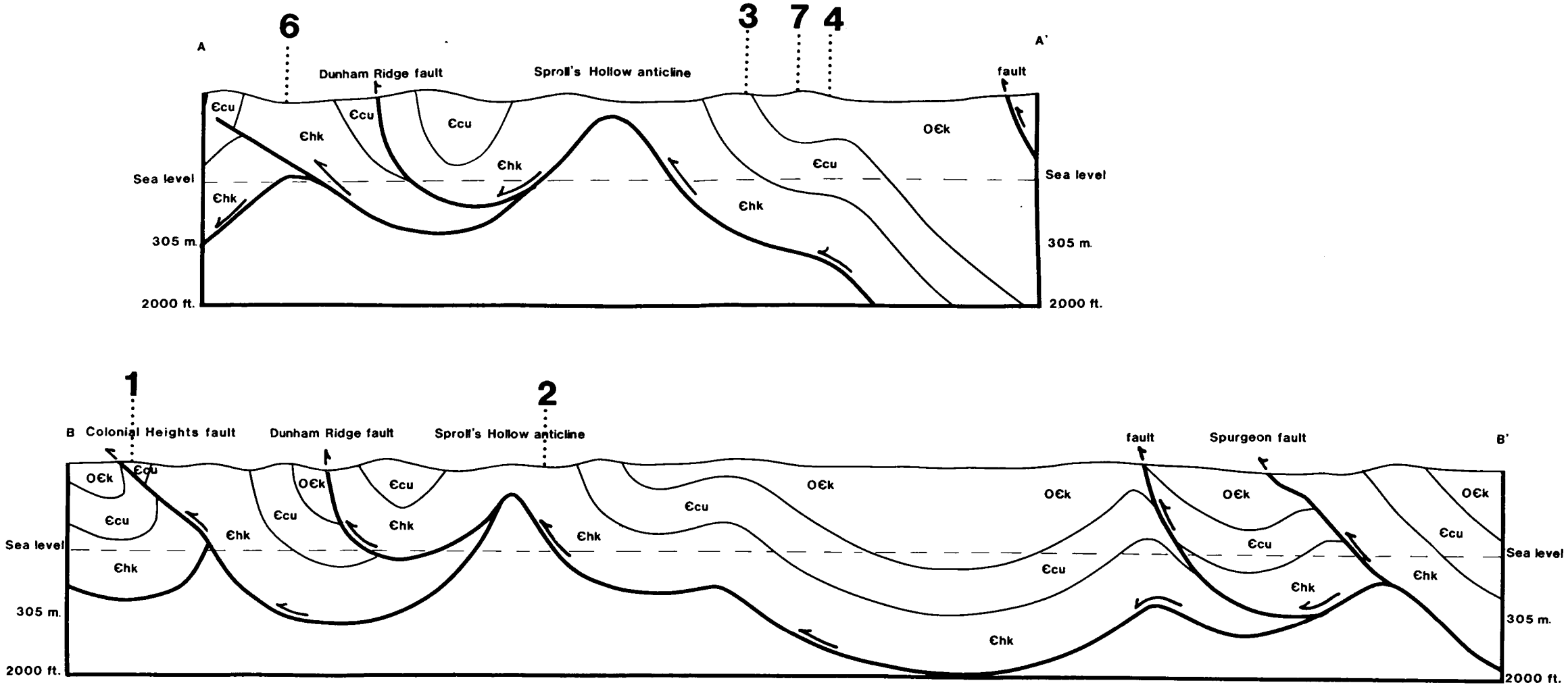


Figure 13. Structural Position of Outcrop Locations.

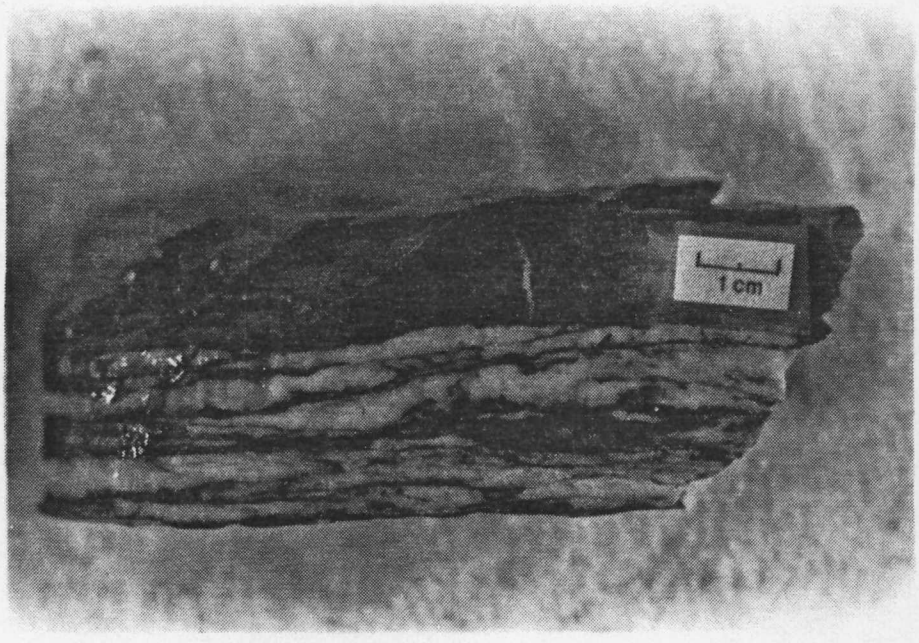


Figure 14. Photograph of Polished Slab of the Nolichucky Formation Showing Thick Accumulations of Growth Fibers Along Bedding.

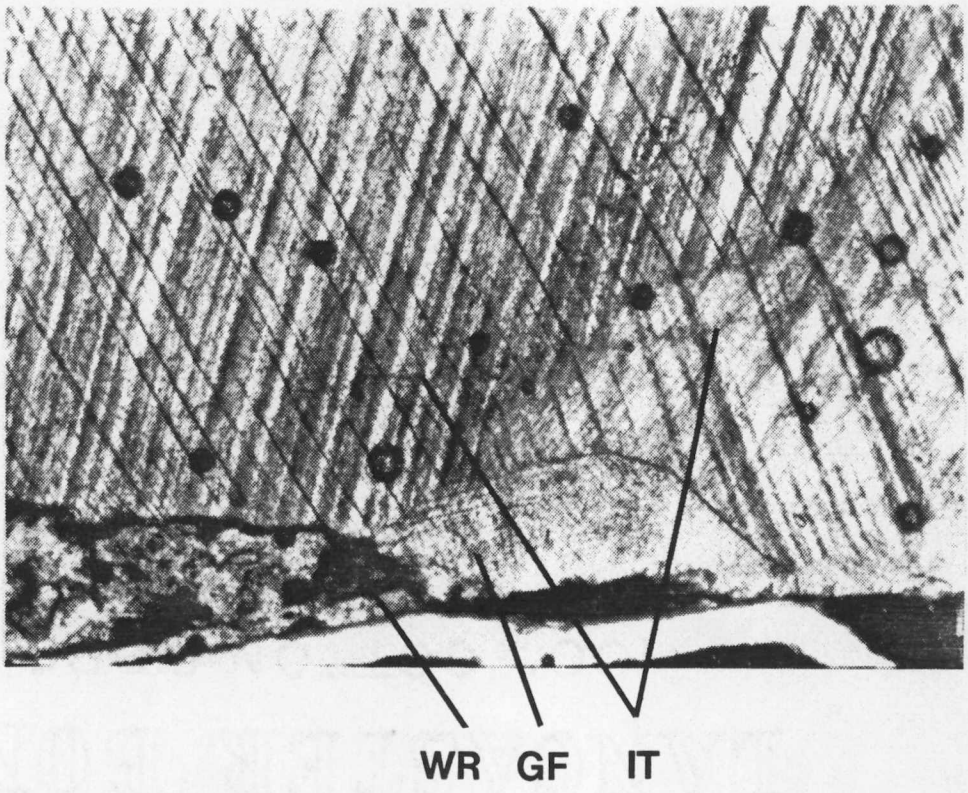


Figure 15. Photomicrograph of the Nolichucky Formation Showing Wall Rock (WR) Incorporated Within Growth Fibers (GF), and Rare Inclusion Trails (IT). (Bedding is Horizontal; Magnification = 2X, Field of View = 1.5 mm).

axis of the fold. Price (1967) noted that fiber sheets with this orientation are often formed on fold limbs in response to intrastratal slip during flexural slip folding.

Ramsay and Huber (1983) noted that the progressive development of growing fibers often takes place by the crack-seal mechanism, and inclusion trails may be preserved inside individual fibers. These inclusion trails mark successive detachments between the fiber and its wall. Subsequent shear movement along bedding planes may lead to the formation of a series of overlapping fiber sheets whose orientation is slightly oblique to the walls of shear.

The underlying rocks of the Knox Group strike north 55° east and dip 88° southeast. These rocks are highly fractured, displaying numerous calcite-filled veins in various orientations. A sample (#1-OCk) of the rocks here is best termed a crush breccia. Extensive microfracture fabric forms shattered angular grains floating in a matrix of fine-grained calcite (Fig. 16). Thick accumulations of opaque, insoluble residue along stylolites are offset by fractures (Fig. 17). Thus at least one episode of pressure solution preceded the microfracturing that formed some of the breccia grains. Three generations of cross-cutting fractures are observed (Fig. 17). The vein fillings in these fractures range from coarse (0.5 mm), highly twinned calcite, to fine (0.05 mm) calcite similar to the matrix

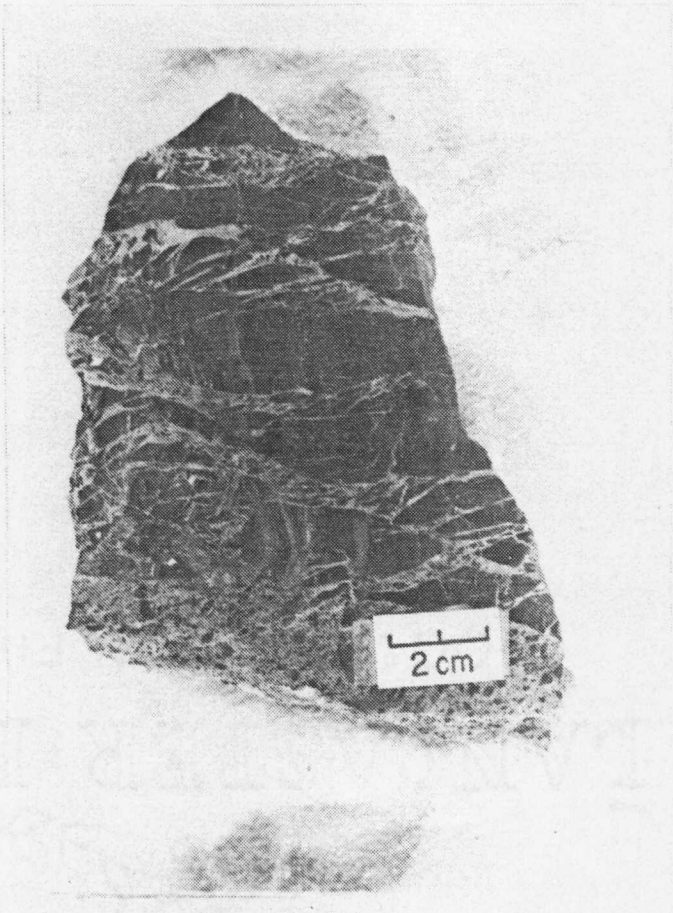


Figure 16. Photograph of Polished Slab of a Crush Breccia Developed in the Conococheague Limestone Adjacent to the Colonial Heights Fault.

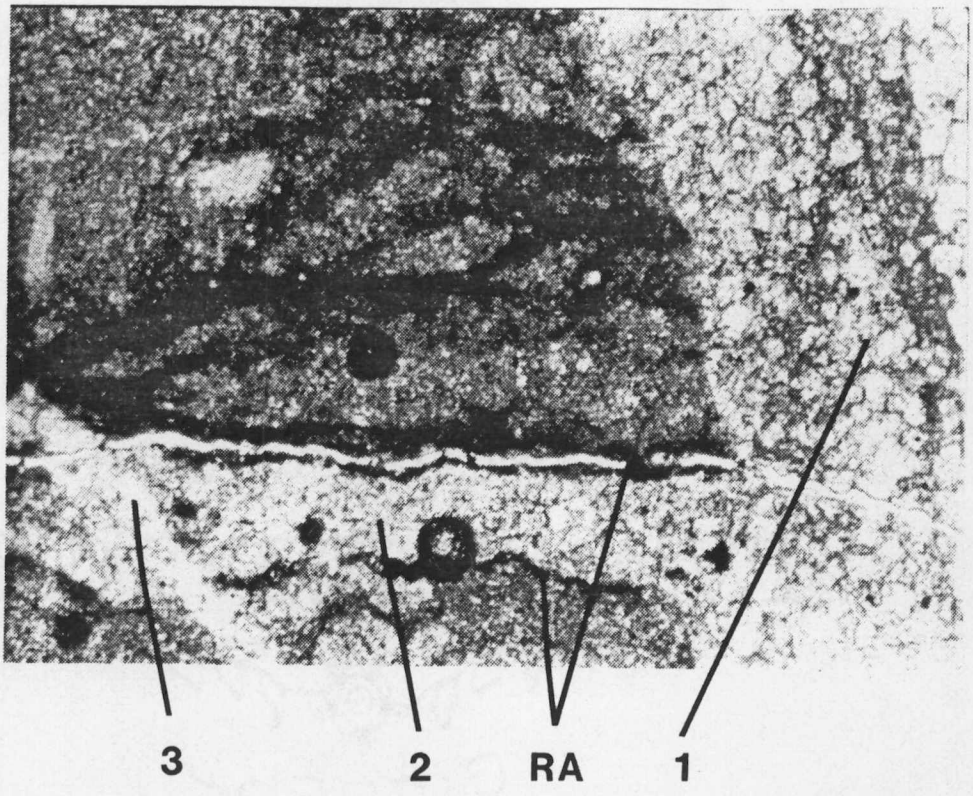


Figure 17. Photomicrograph of the Conococheague Limestone Showing Thick Residue Accumulations (RA) Along Stylolites That are Offset by Cross-Cutting Fractures (#'s 1, 2, and 3). (Magnification = 2X; Field of View = 1.5 mm).

enveloping the breccia grains. The highly twinned nature of some of the calcite vein material indicates that these veins have been deformed.

Dunham Ridge Fault Block

Approximately 330 meters (1100 feet) of the Honaker Formation is exposed along the Clinchfield Railroad 750 meters east of Fordtown (Loc. 2, Fig. 12, p. 36). The rocks at this location are in the hanging wall of a small thrust behind the leading edge of the Dunham Ridge fault block, (herein referred to as the Sproll's Hollow thrust, Fig. 13, p. 37). Intense folding in the lower shaly member of the Honaker occurs in proximity to the thrust, and is restricted to the thinly-bedded, basal Honaker. The massive Honaker carbonates exhibit numerous bedding wedges (Fig. 18). These rocks are overturned, strike north 48° east and have dips ranging from 80° to 85° northwest.

In the basal Nolichucky, also exposed at this location, bedding orientations are variable but usually strike north 73° east and dip 83° southeast. Numerous bedding wedges and small, kink-type folds disrupt the strata here. Cloos (1961, 1963) noted that wedging is due to bedding plane slips and is usually restricted to competent beds between



Figure 18. Bedding Wedges Developed in the Medium Bedded Limestones and Dolostones of the Honaker Formation. Exposure Located 750 meters (2500 feet) East of Fordtown (field notebook = 6.75 in. x 4.25 in.).

incompetent ones, although it can cut across several lithologies.

A Maynardville Limestone sample (#1-Cmn) was collected from the southeast limb of a large anticline exposed along the Holston River near Baker Bluff (Loc. 3, Figs. 12 and 13, pp. 36 and 37). Two types of calcite-filled fractures are observed in a thin-section of the sample (#1-Cmn, see Appendix A). The first type is perpendicular to bedding, offsetting thin bedding laminations up to one millimeter (Fig. 19). The second type of fracture forms a series of sigmoidal en echelon veins (Fig. 19). These veins are oriented at an angle of 50° to bedding, kink bedding laminations, and offset them up to two millimeters (Fig. 19).

A Conococheague Limestone sample (#2-OCk) from near Baker Bluff, was collected from the southeast limb of a large syncline (Loc. 4, Fig. 13, p. 37). This fold is well exposed in a quarry located 180 meters (600 feet) north of the intersection of the Holston River and the natural gas pipeline (Loc. 4, Fig. 12, p. 36). Numerous calcite-filled fractures are present in the core of this syncline. The fractures constitute all the fabric observed in the coarse, carbonate conglomerates present in this area (Fig. 20).

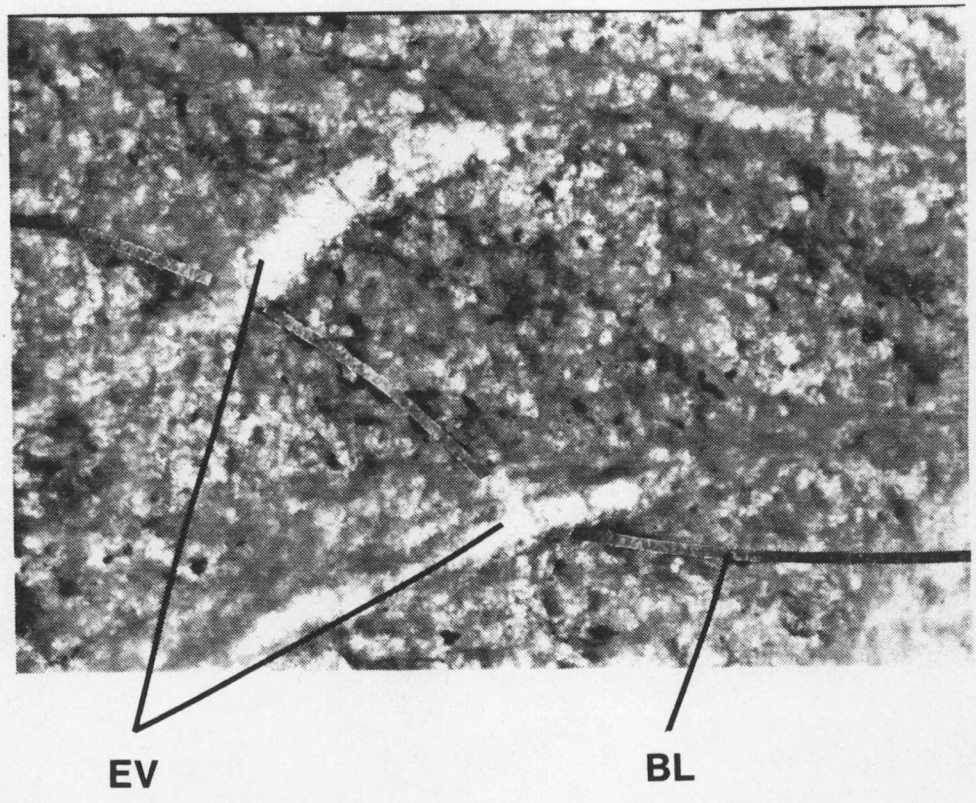


Figure 19. Photomicrograph of the Maynardville Limestone Showing En Echelon Veins (EV) That Kink Bedding Laminations (BL). (Magnification = 2X; Field of View = 1.5 mm).

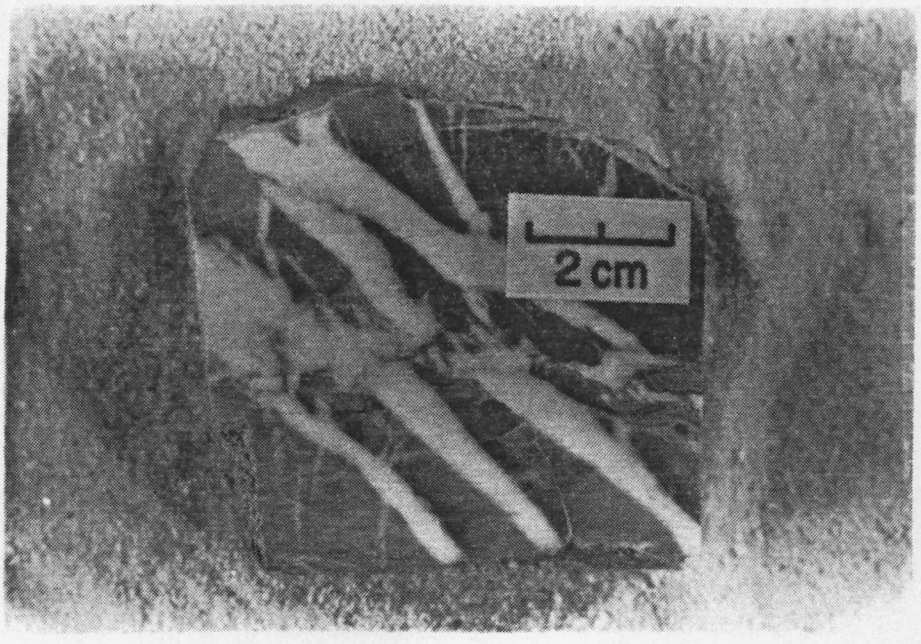


Figure 20. Photograph of Polished Slab of the Conococheague Limestone Showing Large, Calcite-Filled Extension Veins.

Spurgeon Fault Block

The Nolichucky Formation is exposed on the south side of U.S. Interstate 181, approximately 900 meters (3000 feet) east of Hales Chapel (Loc. 5, Fig. 12, p. 36). The exposure is located on the northwest limb of a chevron-style fold developed in the Spurgeon thrust sheet (Loc. 5, Fig. 13, p. 37). Mesoscopic features consist of minor conjugate extension faults and en echelon vein arrays (Fig. 21).

Ramsay and Graham (1970) suggested that en echelon veins are related to incremental dilation in zones of simple shear deformation. Hancock (1972) and Roering (1968) related the formation of en echelon veins to principal stress directions in response to secondary or primary stress fields, respectively. Beach (1975) studied the relationship between dilation and vein geometry. He noted that all strongly sigmoidal veins occur in arrays in which pressure solution was also active.

Two samples, #2-Cn collected from siltstone "ribbon rock" and #3-Cn collected from a limestone, exhibit dissimilar deformation fabrics. A thin-section of the first specimen (#2-Cn, see Appendix A) displays a wide variety of strain features. These range from extension fractures to closely-spaced, stylolitic cleavage selvages oriented 8-16° to bedding. Bedding strikes north 24° east and dips 65°

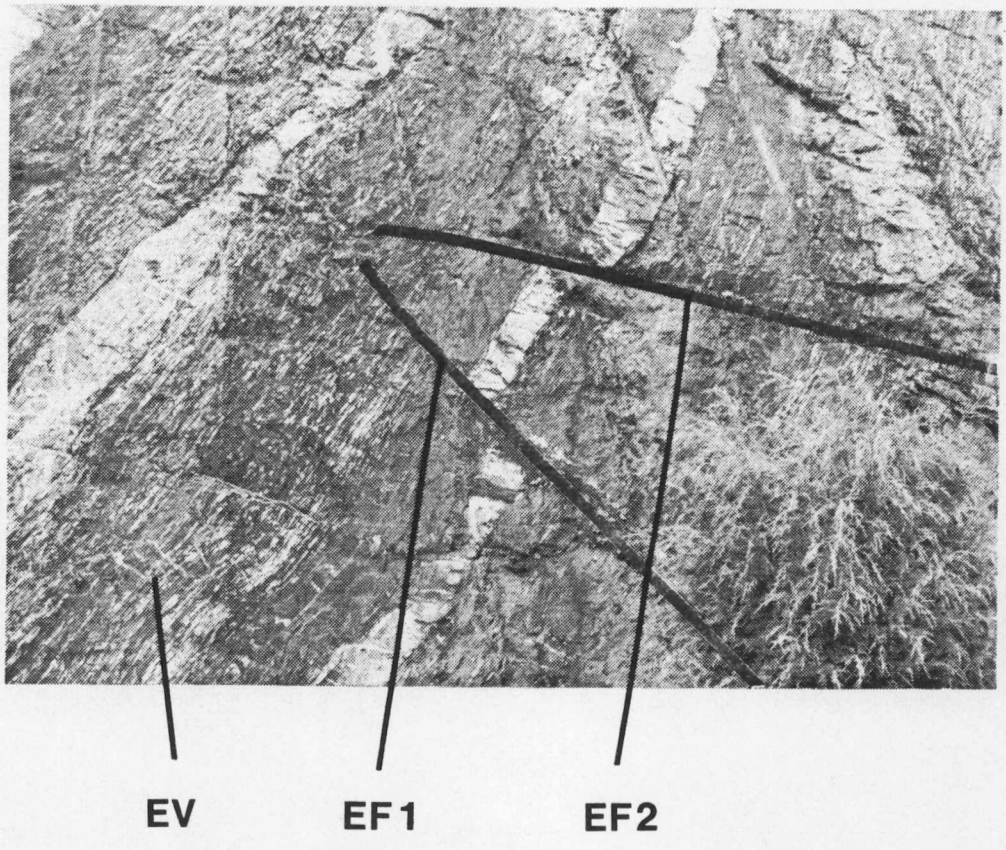


Figure 21. Photograph of Extension Faults (EF1 and EF2) and En Echelon Vein Arrays (EV) Developed in the Siltstones of the Nolichucky Formation. Exposure Located 900 meters (3000 feet) East of Hales Chapel.

southeast, whereas the cleavage is oriented north 39° east with a dip of 82° southeast.

Extension veins, in the form of antitaxial fibers, are present in the fine-grained parts of the siltstone. Ramsey and Huber (1983) noted the fiber patterns of extension veins can be used in a general way to evaluate changing incremental extension directions. In vein fillings with antitaxial fiber growths the crystal fibers are in optical continuity across the vein, and grow from a median suture line toward the vein walls. Therefore, the directions of the earliest increments are recorded by the fiber orientations at the median surface, and those of the last increments by the fiber orientations at the vein walls (Durney and Ramsay, 1973). Since the direction of fiber growth is probably controlled by the orientation of the least principal stress at the growth surface (Wilson, 1982), some of the fiber veins in #2-Cn indicate preliminary minor extension perpendicular to the vein walls, followed by a strong positive elongation (Fig. 22). This results in the formation of obliquely inclined veins, and is indicative of a rotating stress field. Minor, bedding plane shear zones (up to 5.2 mm wide) are observed to contain slivers of adjoining wall rock (Fig. 23). These are probably the result of flexural slip between the compositional layers in the "ribbon rock". Under stress, an initial shear

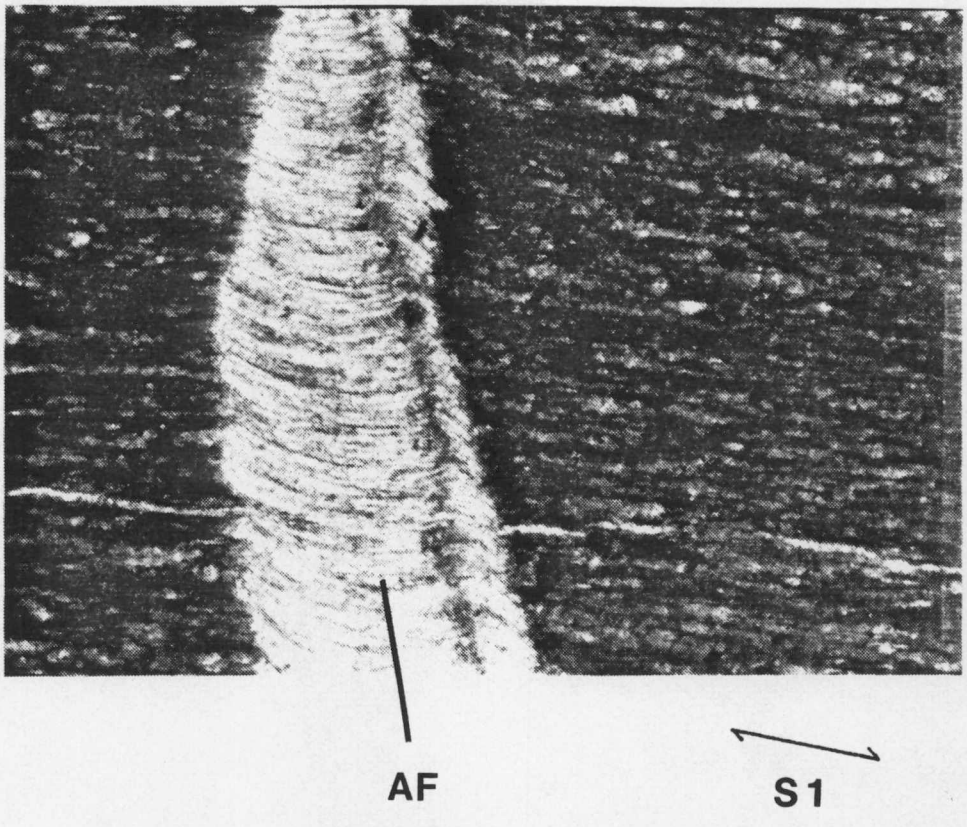


Figure 22. Photomicrograph of the Siltstone Member of the Nolichucky Formation Showing Obliguely Inclined Antitaxial Fibers (AF). (Bedding is Horizontal and S1 = Cleavage. Magnification = 2X; Field of View = 1.5 mm).

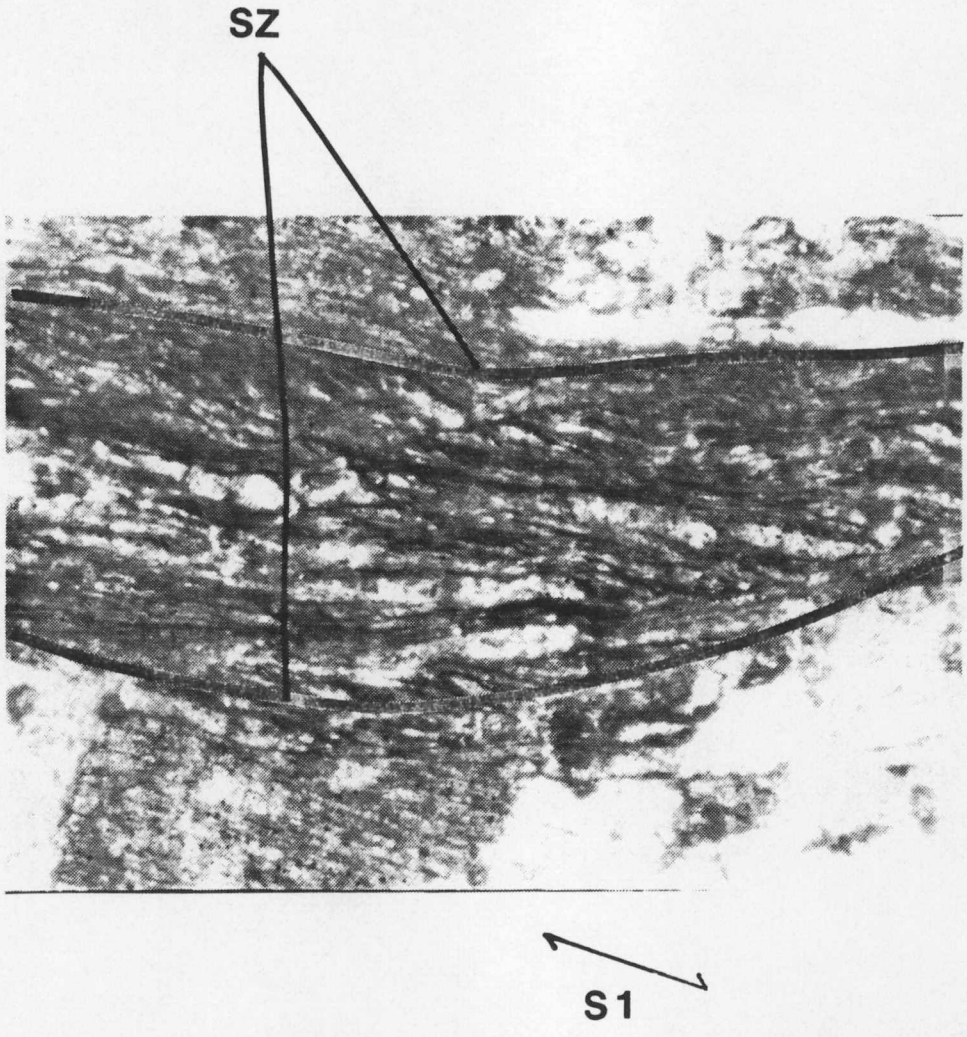


Figure 23. Photomicrograph of the Siltstone Member of the Nolichucky Formation Showing Minor Layer Parallel Shear Zones (SZ). (Bedding is Horizontal and S1 = Cleavage. Magnification = 2X; Field of View = 1.5 mm).

fracture develops parallel to the layering. The fracture has an irregular surface consisting of minute highs and lows. The conditions of high water pressure that exist at shallow crustal depths (Price, 1966) prevents the planing of the fracture surface, and allows the growth of crystal fibers (Durney and Ramsay, 1973).

The spaced, stylolitic cleavage observed in thin section is refracted across the compositional layering, and is more closely spaced in the silty layers than in the coarser carbonate ones. This imparts a "horsetail" geometry to the cleavage, and results in microlithon formation with a variable four millimeter spacing.

Occassional isolated grains of the coarser carbonate are observed within the silty layers. They usually exhibit well developed pressure shadows approximately one millimeter in length (Fig. 24). This is common in deformed rocks that contain particles of a competent composition isolated in a host material. Uneven strains are often set up around this grain, and it is common for the matrix to pull away from the particle in the direction of maximum elongation, resulting in the formation of a pressure shadow (Durney and Ramsay, 1973).

The second specimen from this location (#3-Cn, see Appendix A) is from one of the coarser limestone beds interbedded with the siltstones. The general lack of fabric

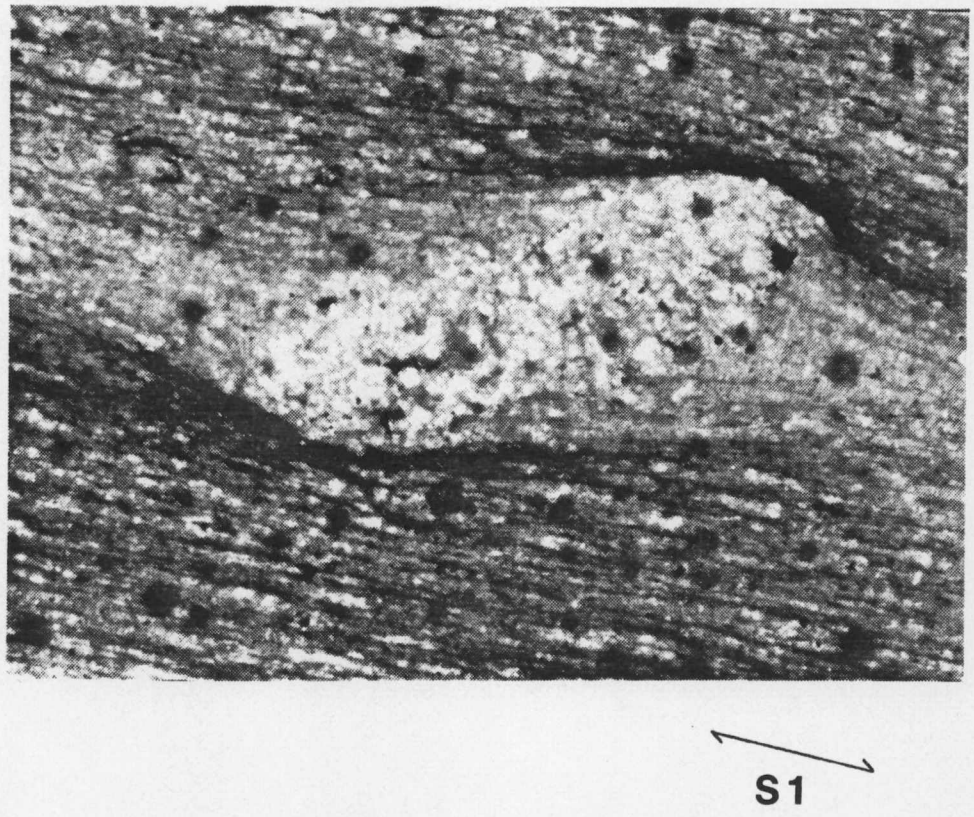


Figure 24. Photomicrograph of the Siltstone Member of the Nolichucky Formation Showing Pressure Shadow Development. (Bedding is Horizontal and S1 = Cleavage. Magnification = 2X; Field of View = 1.5 mm).

within these beds is in marked contrast to the pervasive fabric observed in the previously discussed siltstones. Extension veins filled with intensely twinned calcite, and minor, bedding-parallel stylolites constitute the only fabric observed.

CHAPTER V

STRUCTURAL GEOMETRY OF THE FIELD AREA

Introduction

As previously stated, this study was initiated with a twofold purpose: (1) to ascertain the structural geometry of the Pulaski sheet in this area, and (2) to establish the deformational styles and mechanisms responsible for its present configuration. The first objective was accomplished by mapping. The second objective, however, was more difficult and required the integration of the mapping data with other fabric data gathered throughout the field area.

The structural geometry of the field area is best described by a discussion of the following elements: (1) faults, (2) folds, and (3) cleavage.

Faults

The Colonial Heights fault, developed in the immediate footwall of the Dunham Ridge thrust, may have formed by fault-propagation folding. Early folding initiated at the tip of the minor thrust was truncated as the fault propagated upwards to the surface (Fig. 25). The thrust

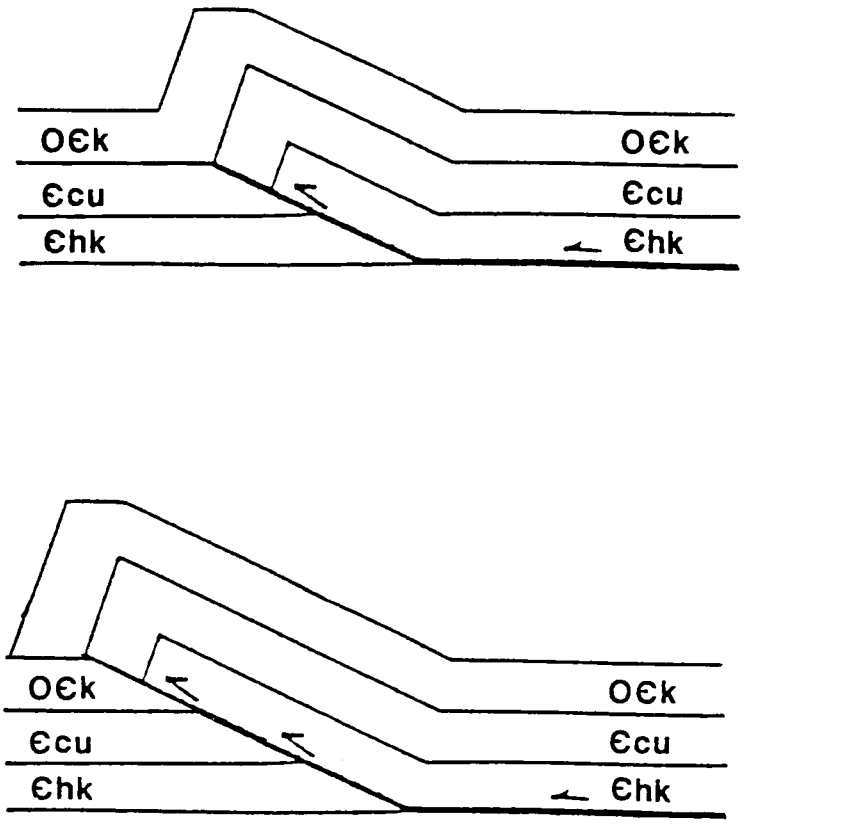


Figure 25. Schemmatic Representation of the Formation of the Colonial Heights Thrust by Fault Propagation Folding.

strikes north 40° east and dips vertically to steeply to the southeast. A stratigraphic separation diagram of the thrust indicates that it cuts up stratigraphic section along strike in the hanging wall towards its northeastern surficial termination (A-A', Fig. 26). However, the observed continuation of the truncated anticline to the northeast probably indicates the fault continues also, and is rooted below the surface (Fig. 27). The thrust appears to be a splay off the Pulaski fault, and probably joins the Pulaski basal decollement at depth (see Plates 2 and 3).

The Dunham Ridge thrust strikes north 50° east and dips vertically to steeply southeast throughout most of the field area. However, in the northern part of the area, the trace of the fault has a swing to the north and then back to the northeast. The stratigraphic separation diagram of the thrust (B-B', Fig. 26) illustrates that the swing to the north occurs where the fault cuts down stratigraphic section, along strike, in both the hanging wall and the footwall (Fig. 27). However, the geometrical relationship between the fault and bedding orientations of hanging wall and footwall rocks, along this segment of the thrust, indicates it cuts up-section in the direction of transport (Fig. 28).

The Sproll's Hollow fault, located just above and southeast of the Dunham Ridge thrust, places Honaker strata

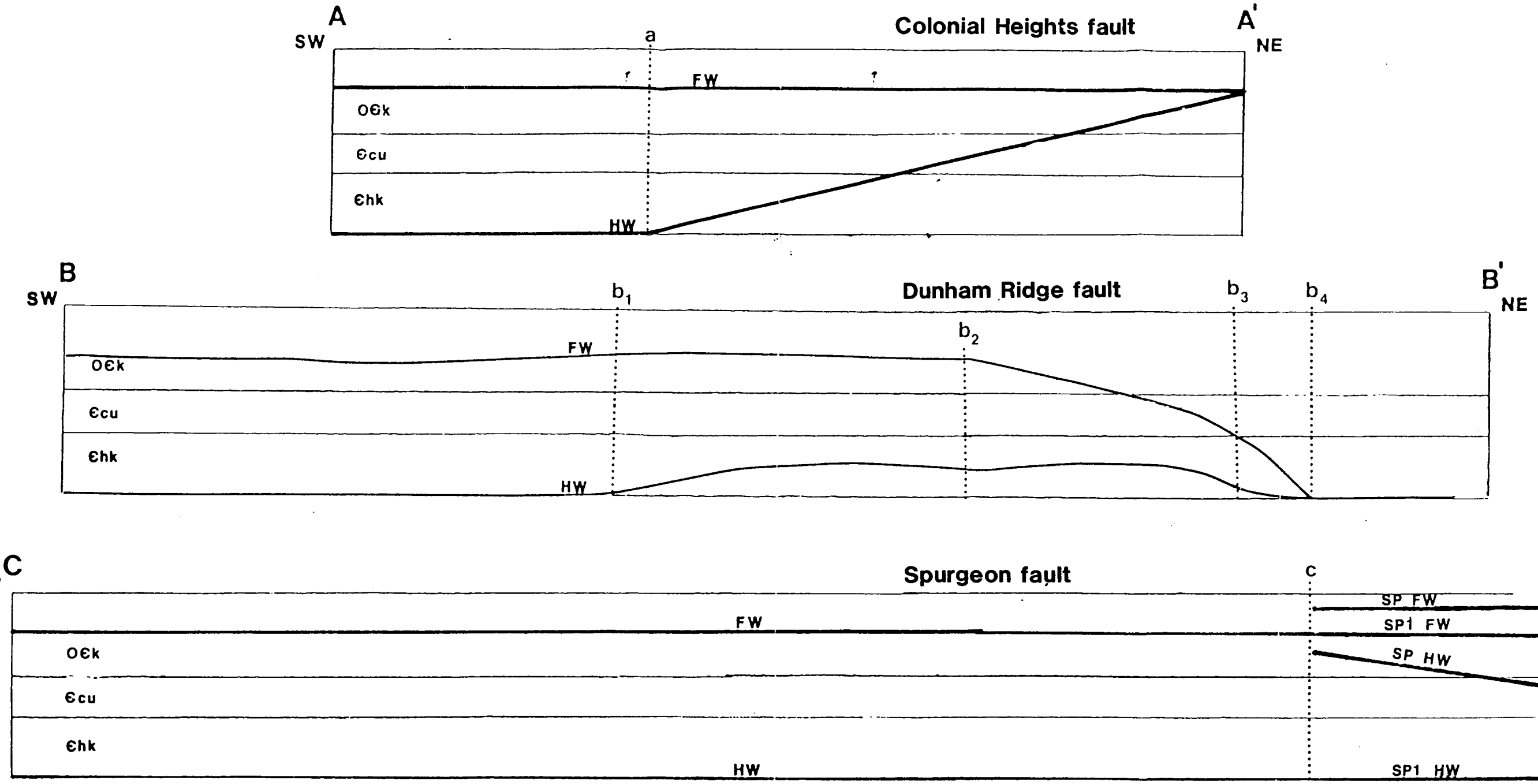


Figure 26. Stratigraphic Separation Diagrams for Segments of the Colonial Heights Thrust (A-A'), Dunham Ridge Thrust (B-B'), and Spurgeon Thrust (C-C') in the Study Area, and Shows the Position of the Stratigraphic Separation Diagrams With Respect to the Geologic Map in Figure 27.

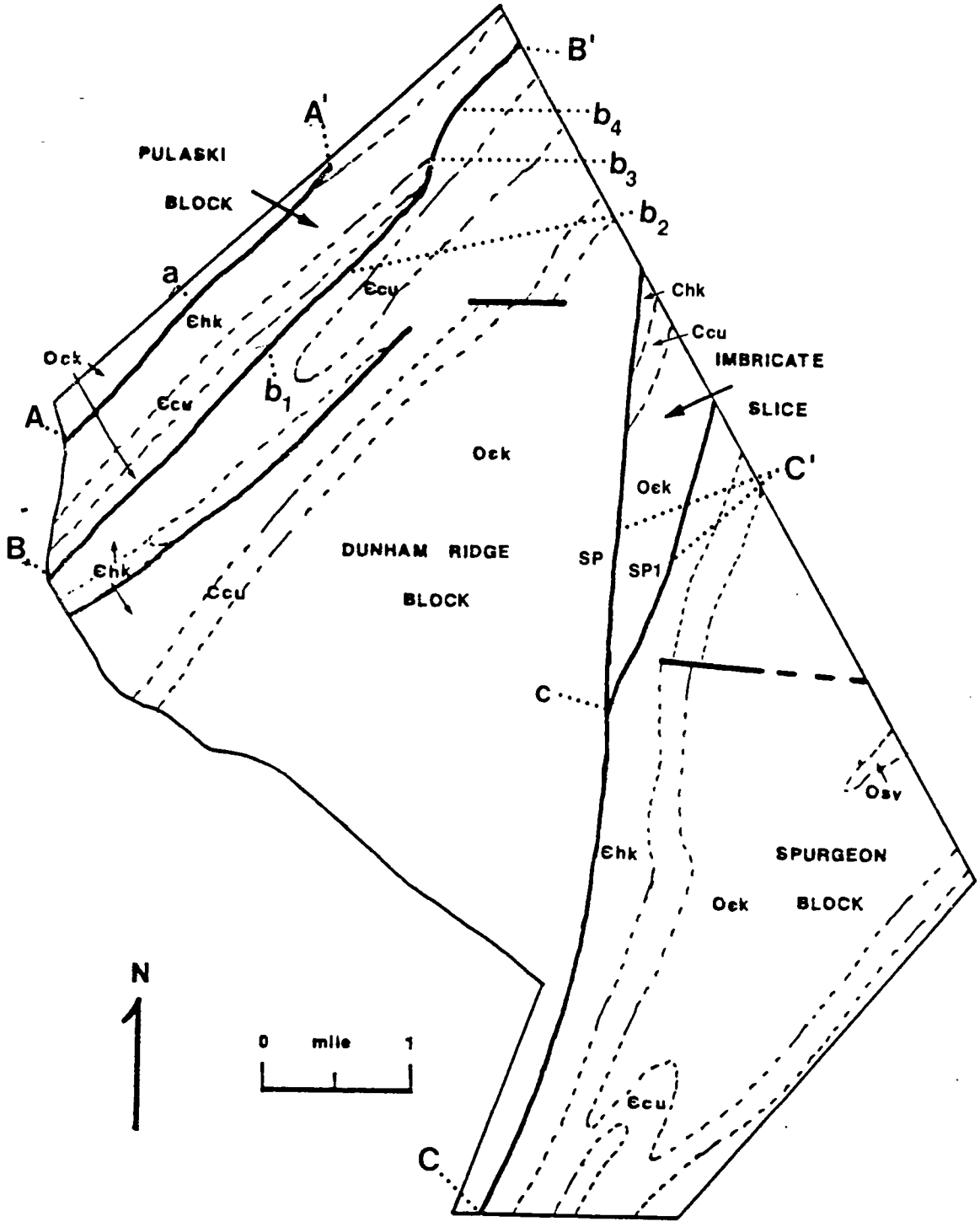


Figure 27. Location Map for Stratigraphic Separation Diagrams A-A', B-B', and C-C'.

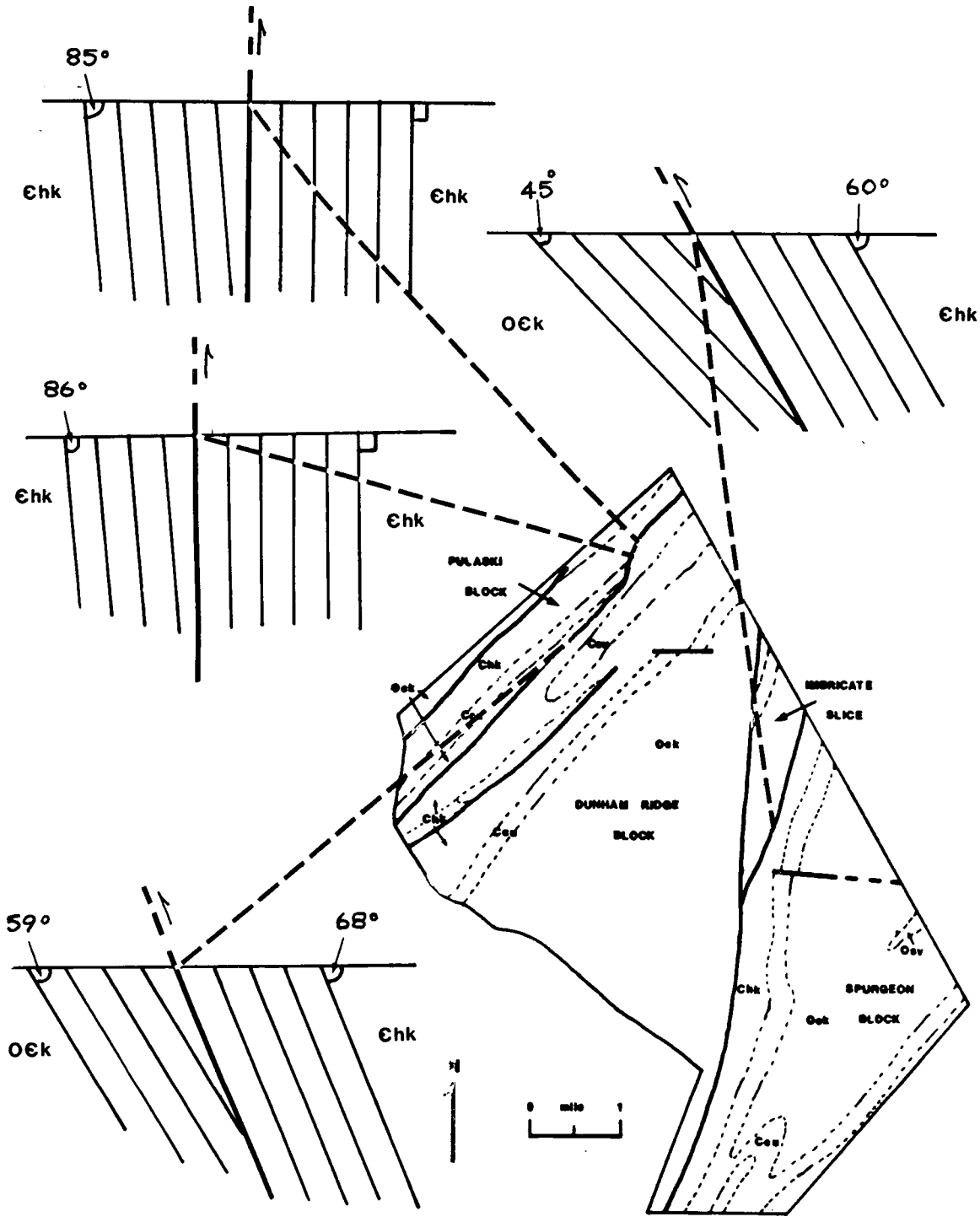


Figure 28. Bedding-Fault Geometries at Several Points Along the Dunham Ridge and Spurgeon Faults.

over the rocks of the Nolichucky Formation. It strikes north 45° east and has a vertical dip. It is probably a splay off of the Dunham Ridge and may have formed as a result of room problems in the core of the adjacent syncline (see Plates 2 and 3).

The Spurgeon fault has a bedding plane decollement in the basal Honaker. It strikes north 45° east in the southern part of the field area, and strikes north 10-20° east throughout the remainder of the study area. This orientation is oblique to that of the Dunham Ridge fault, resulting in a decrease in the distance separating the two as one proceeds south to north. This convergence appears to be the result of a change in the dip of the Spurgeon fault rather than a change in its structural position, and is most likely due to uplifting of the fault in the southern part of the field area by the underlying anticline in the Dunham Ridge block. In contrast to the Dunham Ridge thrust, which definitely cuts down stratigraphic section along strike, a stratigraphic separation diagram for this segment of the Spurgeon indicates no change in its decollement level in the stratigraphy (C-C', Fig. 26). Bedding orientations for the rocks adjacent to the fault at several locations indicate the Spurgeon cuts up stratigraphic section in the transport direction (Fig. 28).

Two minor wrench faults constitute the remainder of the faults in the field area. They roughly trend east-west, although limited exposure prohibits tight control on their orientation. Their presence may have gone unnoticed were it not for the fact that they offset linear belts of the Nolichucky and Maynardville, in the Dunham Ridge and Spurgeon fault blocks. Transverse structures of this type frequently are the surficial reflection of buried lateral thrust ramps. The tear developed in the Dunham Ridge sheet is positioned southeast of and above the lateral ramp in the Colonial Heights sheet, and may have formed when its sheet was folded over that ramp. The tear in the Spurgeon sheet is located adjacent to the southern limit of the Spurgeon footwall imbricate, and may be related to the folding of the main sheet over the ramp formed by imbrication of the footwall.

A second, more remote possibility (see Discussion, pp. 72-76) is that the two faults are surficial reflections of a buried transverse decollement ramp developed in the Pine Mountain thrust sheet. Based on his seismic section, Jackson (1982) indicated that the Cross Mountain fault marked the approximate location of the top of this ramp, and formed when the overlying sheets above it were warped. Therefore, the tears in the present study area may reflect the southern limit of this buried structure.

Folds

The Dunham Ridge thrust overlies a large, horizontal anticlinal structure in the Colonial Heights thrust sheet. The fold axis trends north 45° east with a plunge of 4° northeast. The fold exhibits a similar geometry and is well exposed along the west bank of the Holston River, below the Lake Crest subdivision (Fig. 29; Loc. 6, Fig. 12, p. 36). Limb dips range from 45° northwest or southeast near the core of the fold to vertical at its outer reaches.

Several large folds are also developed in the Dunham Ridge fault block (Fig. 30). Again, these folds exhibit a similar geometry (see Plate 2). At the leading edge of the block the folds are developed in the rocks of the Conasauga Group. Axes trend north 37-48° east with little or no plunge (Fig. 30). A few minor folds are developed on the limbs of the larger structures. These have axes that usually trend north 50° east with plunges of less than 10° to either the northeast or southwest. Strata of the Knox Group are exposed across the trailing edge of the Dunham Ridge block. Despite poor exposure, changing dip directions indicate that these rocks are also folded, but not as tightly as the folds to the northwest in the Conasauga. A syncline observed in the quarry below Baker Bluff



Figure 29. Photograph of the Hinge Zone of a Large, Sub-Horizontal Anticline. Exposure Located on the West Bank of the Holston River, Below the Lake Crest Subdivision. (View to the Northwest).

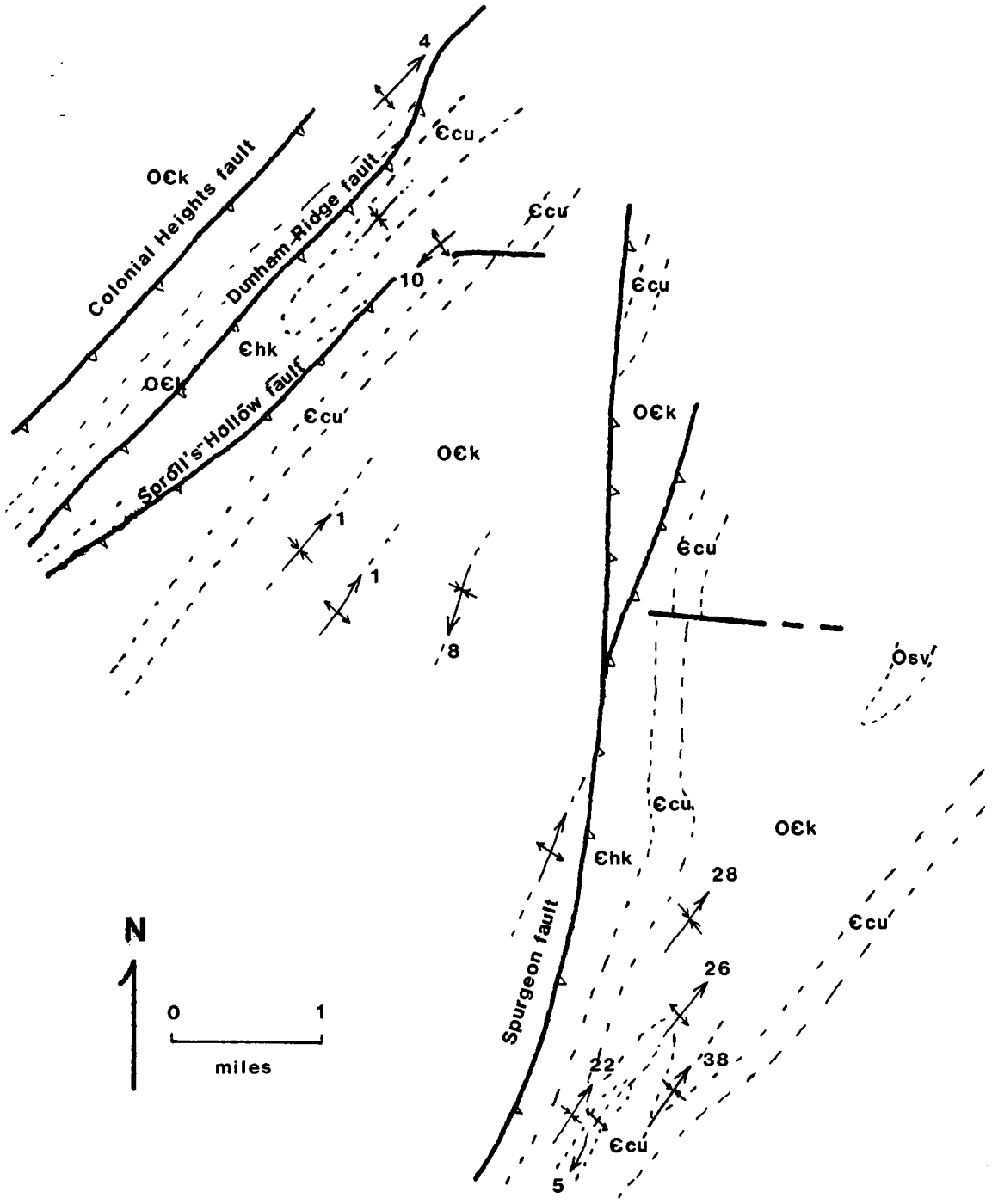


Figure 30. Map Location of Folds Developed in the Strata of the Study Area.

subdivision also appears to be present in exposures along the Clinchfield Railroad near Sinking Creek (Fig. 31; Loc. 7, Fig. 12, p. 36). The axis of this fold trends north 60° east and plunges 14° southwest. The northwest limb is steep, dipping 70° southeast to vertical, whereas the southeast limb is shallow, dipping 10-40° northwest. Rough estimates for other folds, indicated by exposures along the Railroad, give trends of north 33-50° east with plunges of 5-8° to either the northeast or southwest.

A large anticline is also developed in the footwall of the Spurgeon thrust. It trends due north, with a plunge of 11° north, and is surficially represented by Buffalo Ridge just southeast of the field area. Formation of this anticline appears to have folded and uplifted the Spurgeon fault in this area.

The most notable folds in the field area are present in the Spurgeon fault block (Fig. 30). The axes for these folds trend north 37° and 48° east and plunge 26° and 40° northeast, respectively. This steep plunge is probably the result of the uplifting of the strata in the southern parts of the field area. A down plunge projection of this fold strongly indicates a chevron geometry (Fig. 32). Bedding on the northwest limb of the fold strikes north 24° east and dips 65° southeast. The southeast limb of the fold is steeper, with bedding oriented north 55° east and

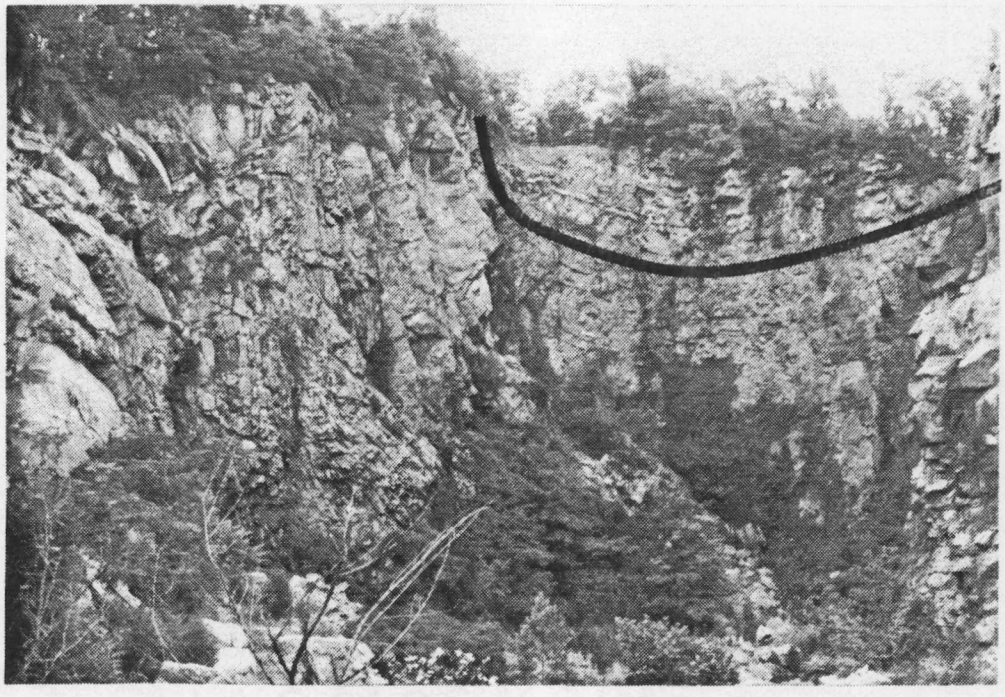


Figure 31. Photograph of a Syncline Exposed in the Quarry Face Below the Baker Bluff Subdivision. (View to the Northeast).

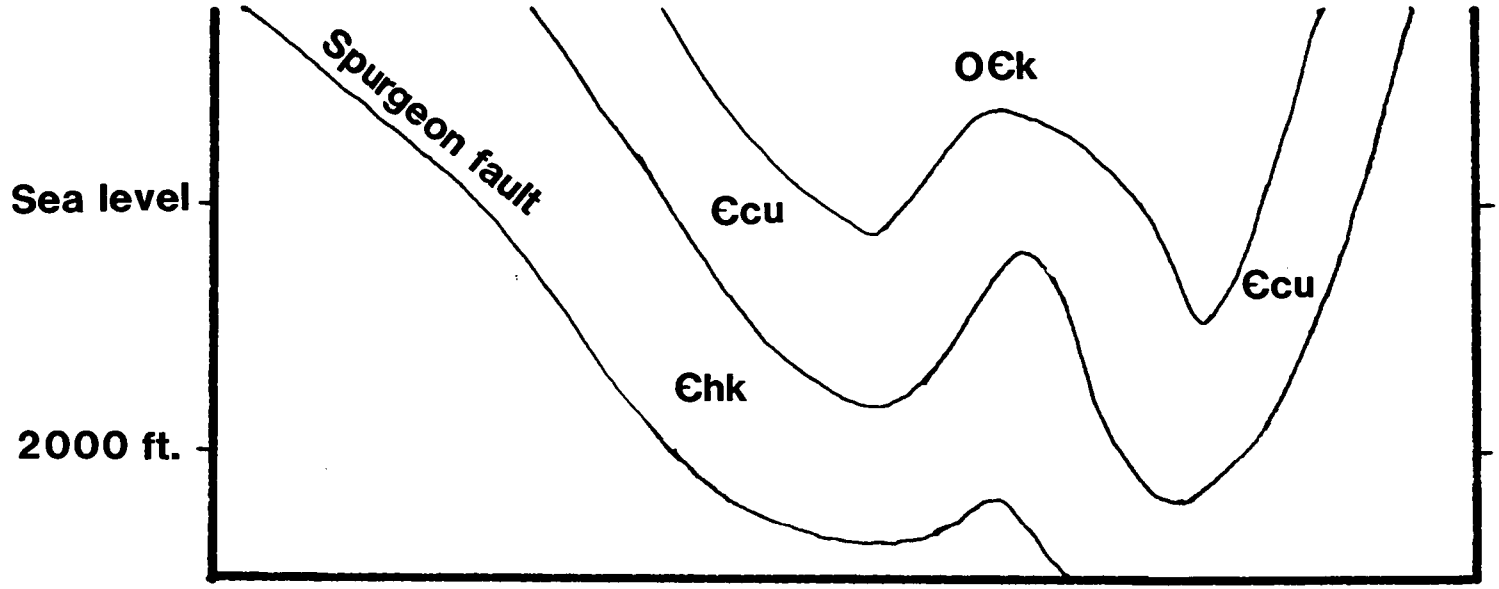


Figure 32. Down-Structure View of the Chevron-Folded Spurgeon Hanging Wall Series Indicates Slight Thickening of the Conasauga Group in the Hinge Areas.

dipping 82° northwest. The down plunge projection also indicates a slight thickening of the Conasauga Group in the hinge zone of the fold (Fig. 32).

Cleavage

Cleavage fabric developed in the strata of the study area exhibits two morphologies. Disjunctive, stylolitic cleavage, with a uniform 0.2 millimeter spacing and a microscopic, ramp-flat geometry, is present in the silty carbonates of the Conococheague Limestone. The siltstones and shales of the Nolichucky Formation exhibit an anastomosing, more closely-spaced cleavage fabric. These cleavage morphologies are best observed in the hinge area of the steep flanked, chevron-folded, Spurgeon fault block (Fig. 33). The axial planar attitude of the cleavage suggests that it formed synchronously with the folding (Fig. 33).

Anastomosing, stylolitic cleavage fabric is also developed in the Conococheague Limestone in the folded footwall of the Spurgeon thrust. The steeply southeast-dipping fabric exhibits an axial planar attitude to the footwall anticline, and appears to be roughly parallel to the trace of the Spurgeon thrust (Fig. 33).

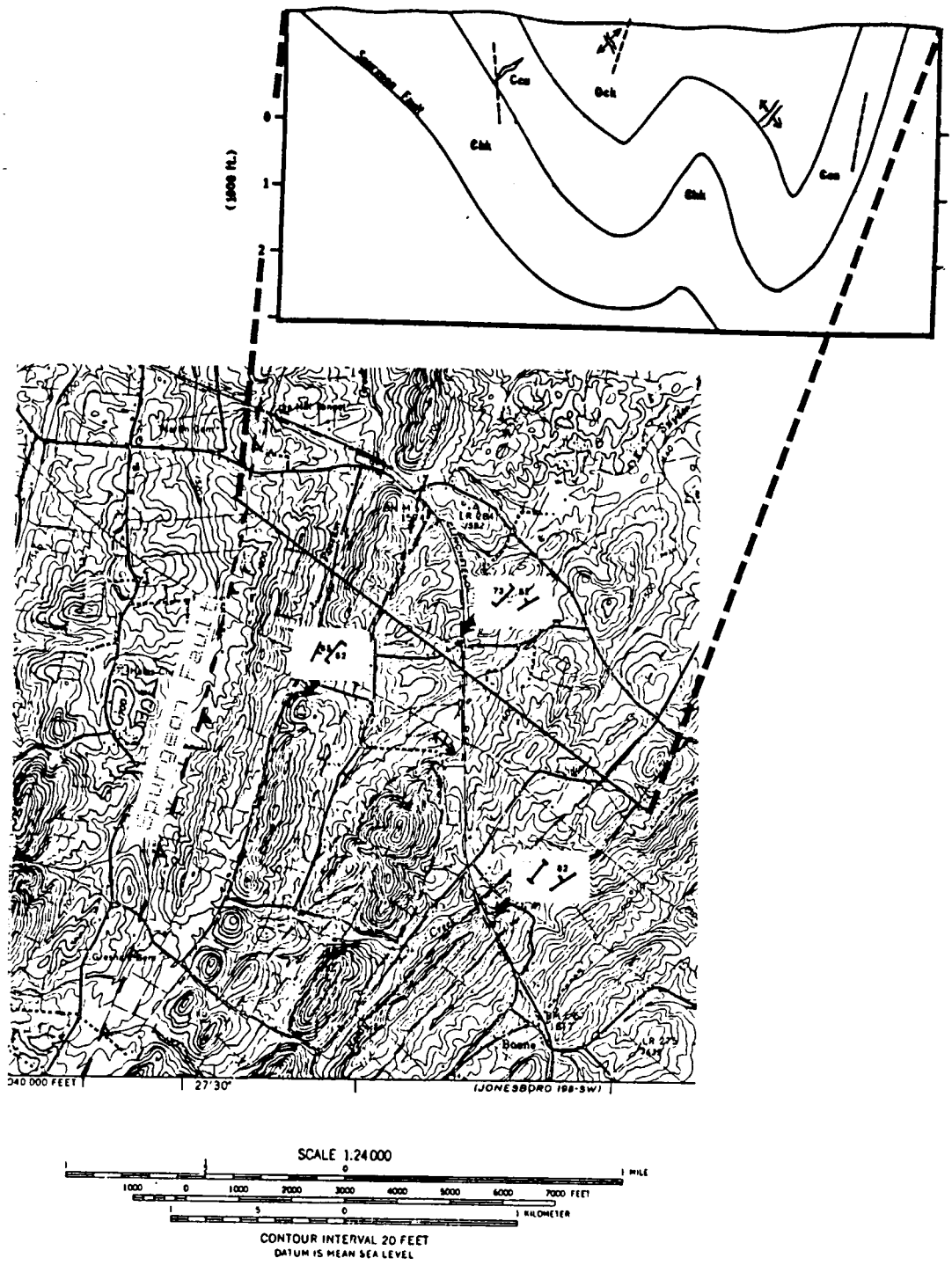


Figure 33. Location and Orientation of Cleavage Within the Study Area.

Discussion

Structure sections (see Plates 2 and 3) illustrate the writer's subsurface interpretation of the structural geology in the Boone Dam area. In projecting the structure at depth (balanced section C-C', Plate 2), the writer assumes constant bed thickness for the units involved. The structure sections are drawn according to the guidelines set forth by Dahlstrom (1969) for the construction of balanced cross-sections. For section C-C', depth to basement was obtained from Woodward, et al., (1985) and Roeder, et al., (1978), which generally agrees with the depth to base of deformation presented by Jackson (1982). Finally, the balanced section is built downward from the chevron-folded Spurgeon sheet. The profile of this fold was determined by down-plunge projection, and, in conjunction with the shape of other large folds observed at the surface, determined the folding style within the area.

The study area is located adjacent to the broad, northwest-trending Kingsport Lineament. Jackson (1982) noted that this cross-strike, structural discontinuity is marked by a complex zone of transverse decollement ramping and possible normal faulting of the basement. The lineament designates the boundary between Geyer, et al.'s, (1982) subprovinces II and III, and, according to their

interpretation is related to a buried, transverse decollement ramp, down to the southwest. Jackson's (1982) one published seismic line (A-A') appears to have been run along VA State Highway 58 adjacent to Big Moccassin Creek, just west of Clinch Mountain (Figs. 34 and 35). He interpreted the Copper Creek thrust to be at 9000 feet depth in the southwest part of the section, and, at 8600 feet depth in the northwest part of the section. The stratigraphic jump of the Clinchport thrust from Cambrian strata to Ordovician strata is also shown (Fig. 35). Since the Wallen Valley thrust reaches its surficial termination in the vicinity of Norton, VA. (Fig. 34), the down to the southwest lateral ramp must be developed in the trailing edge of the Pine Mountain sheet. The effect of this transverse ramp is to offset the Saltville longitudinal ramp south of the lineament, 12 miles to the northwest (Geyer, et al., 1982).

Geologic map patterns indicate that dips within the Copper Creek sheet shallow north of the Saltville structural reentrant. This may, in part, be a result of the addition of one or more thrust sheets at depth. Also, if the Kingsport Lineament and the structural reentrants associated with it are due to large-scale, transverse decollement ramping of the Clinchport thrust, this implies that the Pine Mountain sheet extends back beneath the Pulaski sheet.

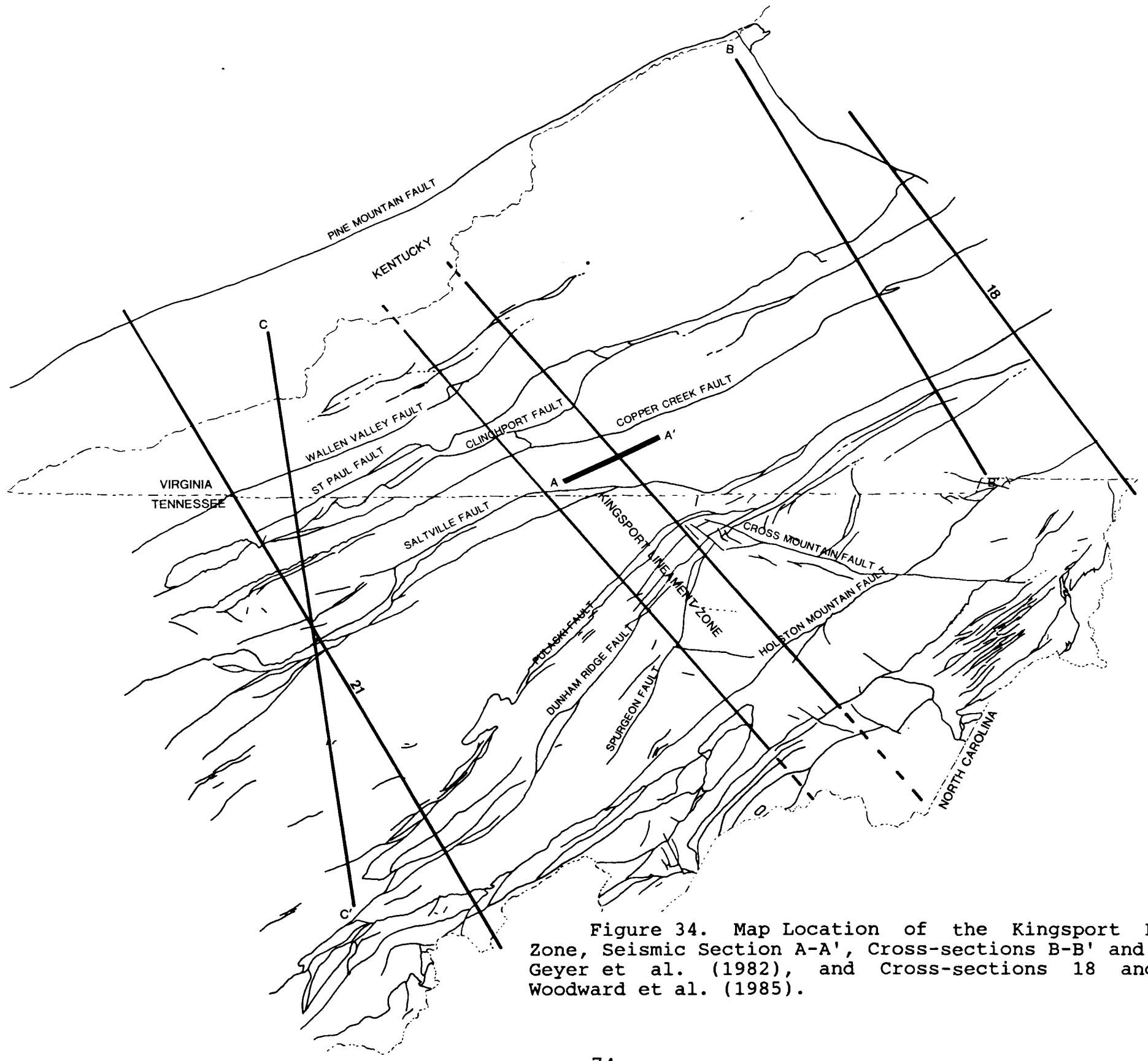


Figure 34. Map Location of the Kingsport Lineament Zone, Seismic Section A-A', Cross-sections B-B' and C-C' of Geyer et al. (1982), and Cross-sections 18 and 21 of Woodward et al. (1985).

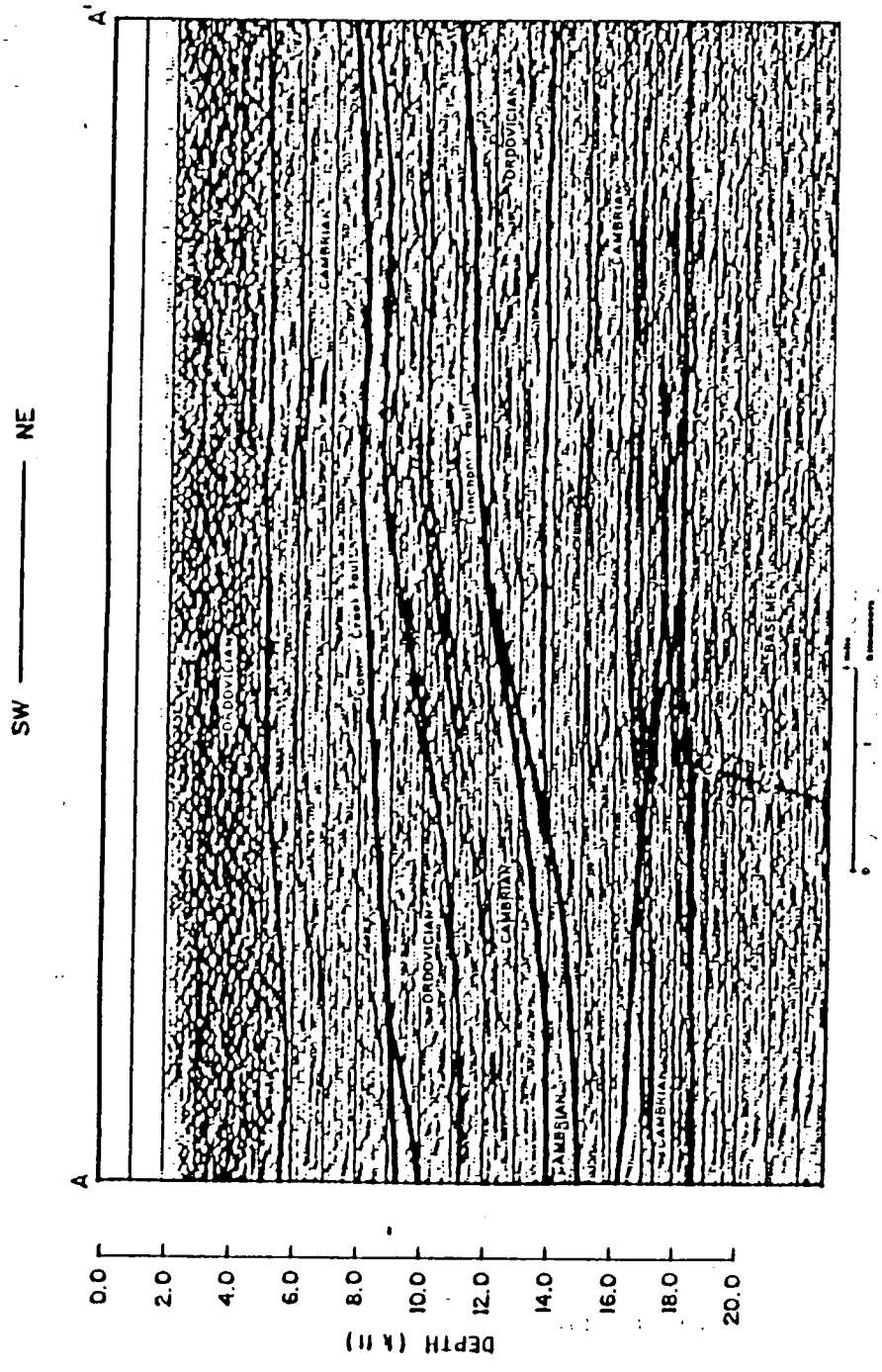


Figure 35. Strike-oriented Seismic Section A-A' of Geyer et al. (1982).

Section B-B' of Geyer, et al., (1982) and section 18 of Woodward, et al., (1985) appear to be along the same basic section line, located just north of the Kingsport Lineament (Fig. 36). They are similar in most aspects, with the exception of the behavior of the Saltville thrust. Geyer, et al., (1982) drew the thrust with a shallow dip at the surface, then steepening at depth. Woodward, et al., (1985) drew the Saltville with a steep dip that shallows out at depth. Neither extend the Pine Mountain sheet back beneath the Pulaski sheet.

Section C-C' of Geyer, et al., (1982) appears to be located in the vicinity of section 21 of Woodward, et al., (1985) (Fig. 36). C-C' contains some of the same features observed in the Woodward, et al., (1985) section, but does not appear to be constructed parallel to the true tectonic transport direction.

Geyer, et al.'s, (1982) suggestion of a buried transverse decollement ramp is plausible, and would explain the structural reentrants observed in the area. However, based on their cross-sections this argument is hard to make any farther east than the outcrop trace of the Saltville thrust. Thus I do not think that deep transverse decollement ramping can explain the structure beneath the Pulaski thrust sheet.

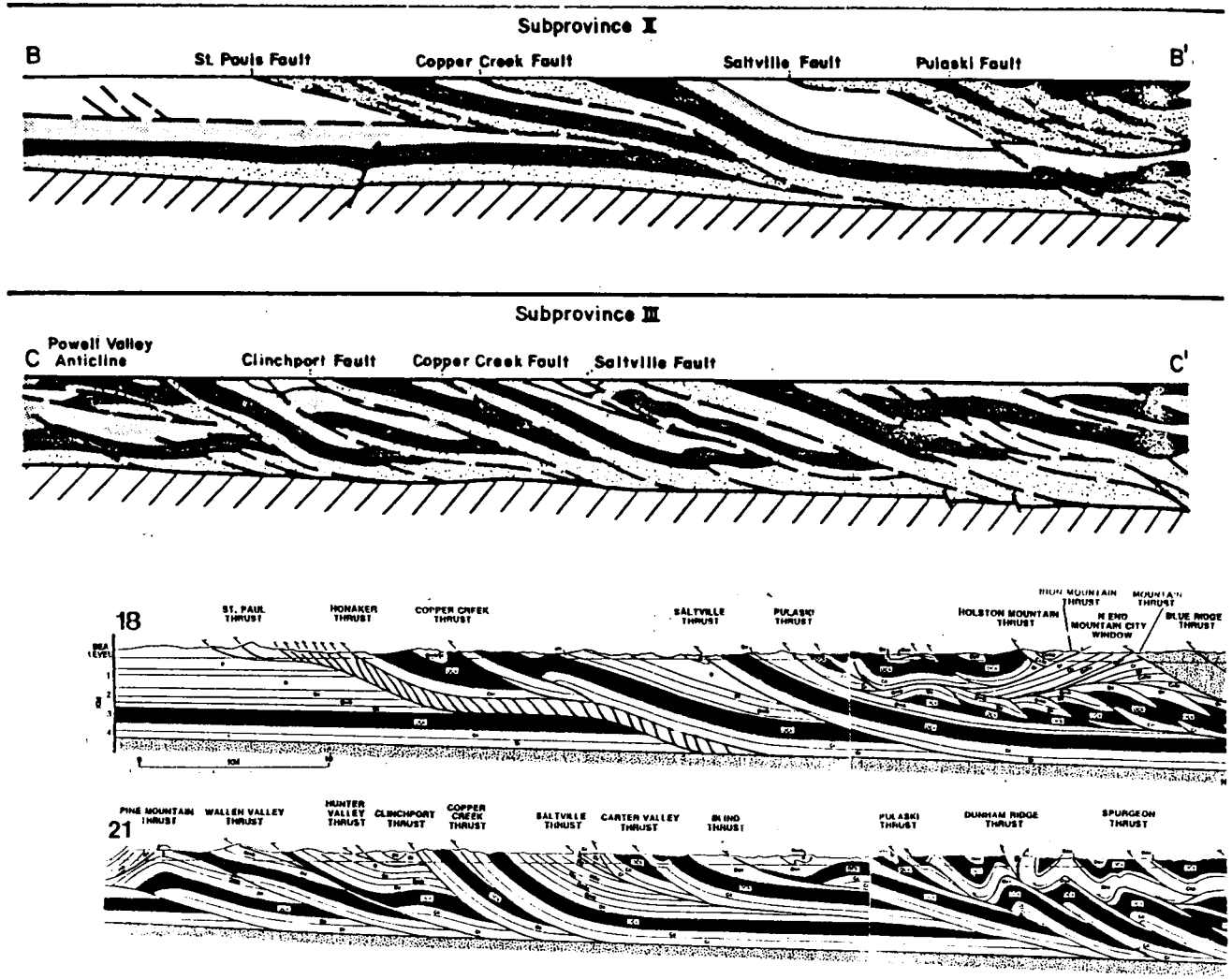


Figure 36. Cross-sections B-B' and C-C' of Geyer et al. (1982), and Cross-sections 18 and 21 of Woodward et al. (1985).

In the present study I interpret the Pulaski sheet to have been passively folded by the formation of a large lumpy roof duplex beneath it (see section C-C', Plate 2). Considering the steeply northeast-plunging nature of the Spurgeon sheet in the area, the Cross Mountain fault may reflect the loss of one or more of the duplex horses laterally. If so, the Cross Mountain fault is the result of folding of the Pulaski sheet over the sub-Pulaski duplex, not to folding over a deeper lateral structure.

The "bulge" in the trace of the Dunham Ridge thrust is the result of lateral ramping in its footwall. However, there is no conclusive evidence as to why the lateral ramping developed here. It is possible that the structure formed in response to stratigraphic variations within the Conasauga Group, which has numerous intertonguing shale and carbonate lithologies. However, the Conasauga Group is not well enough exposed laterally to test this hypothesis.

The tear fault in the Dunham Ridge sheet is probably related to the folding of the sheet over a footwall lateral ramp. No other oblique structures or fold plunge variations, related to this ramp, are observed. The lack of hanging wall representatives of this structure is due to the deep level of erosion in the area. As a result, the parts of the Dunham Ridge sheet that would have matched the footwall ramp are not preserved (Plate 2).

The tear fault in the Spurgeon sheet probably formed in response to the folding of the sheet over a ramp developed by imbrication in its footwall.

The folding in the area is tight and fold wavelengths are generally short. Currie, et al., (1962), through field observations and laboratory study, suggested a linear relationship exists between fold wavelength and the dominant stratigraphic/structural member thickness. Their study dealt specifically with buckle folding of sedimentary rocks under end loading. However, the author believes that the folding present in the study area is the result of a combination of tangential tectonic forces and imbrication of the footwall. Utilizing fold wavelengths obtained from the structure sections, and a thickness of 915 meters (3000 feet) for the Knox Group (the probable dominant member in the area), the folds in the present study area do not appear to be buckle folds. Fold wavelengths are also too short using the Knox plus the Maynardville or the Knox plus Conasauga Groups as the controlling member in the area, as the folds do not fall on the line of naturally occurring buckle folds.

It appears that the folds in the western limit of the area (Sproll's Hollow anticline, Plates 2 and 3) are fault-bend folds that have been subsequently modified by minor thrusting during fold tightening. The more easterly

folds have a longer wavelength, however, and are probably related to folding of the strata over duplex horses in the Pulaski footwall. These horses form the cores of anticlines observed at the surface, and prevented the folds from tightening.

The cleavage fabric developed in the rocks indicates that the cover strata was not simply passively folded by horse formation beneath the Pulaski sheet. The fabric is axial planar to folds and parallels faults, possibly indicating that it formed synchronously with, but in the later stages of folding, and has not been folded (Fig. 37). However, Woodward, Gray, and Spears (1986), and Reks and Gray (1983) both cited a late cleavage in the strata of the Pulaski sheet. This cleavage is present both northeast and southwest of the present study area. Reks and Gray (1983) noted many of the same fabric elements observed in the present study area (layer parallel slip features, spaced cleavage). As in the present study, the cleavage was oriented subparallel to regional fold axes and parallel to mesoscopic fold axial traces. Utilizing strain data obtained from pressure fringes and pencil structures, they found that removal of the strains failed to completely unfold the fold profiles. Their data suggested that cleavage was superimposed onto open to tight, existing folds. My data is insufficient to make any such conclusive statements. The

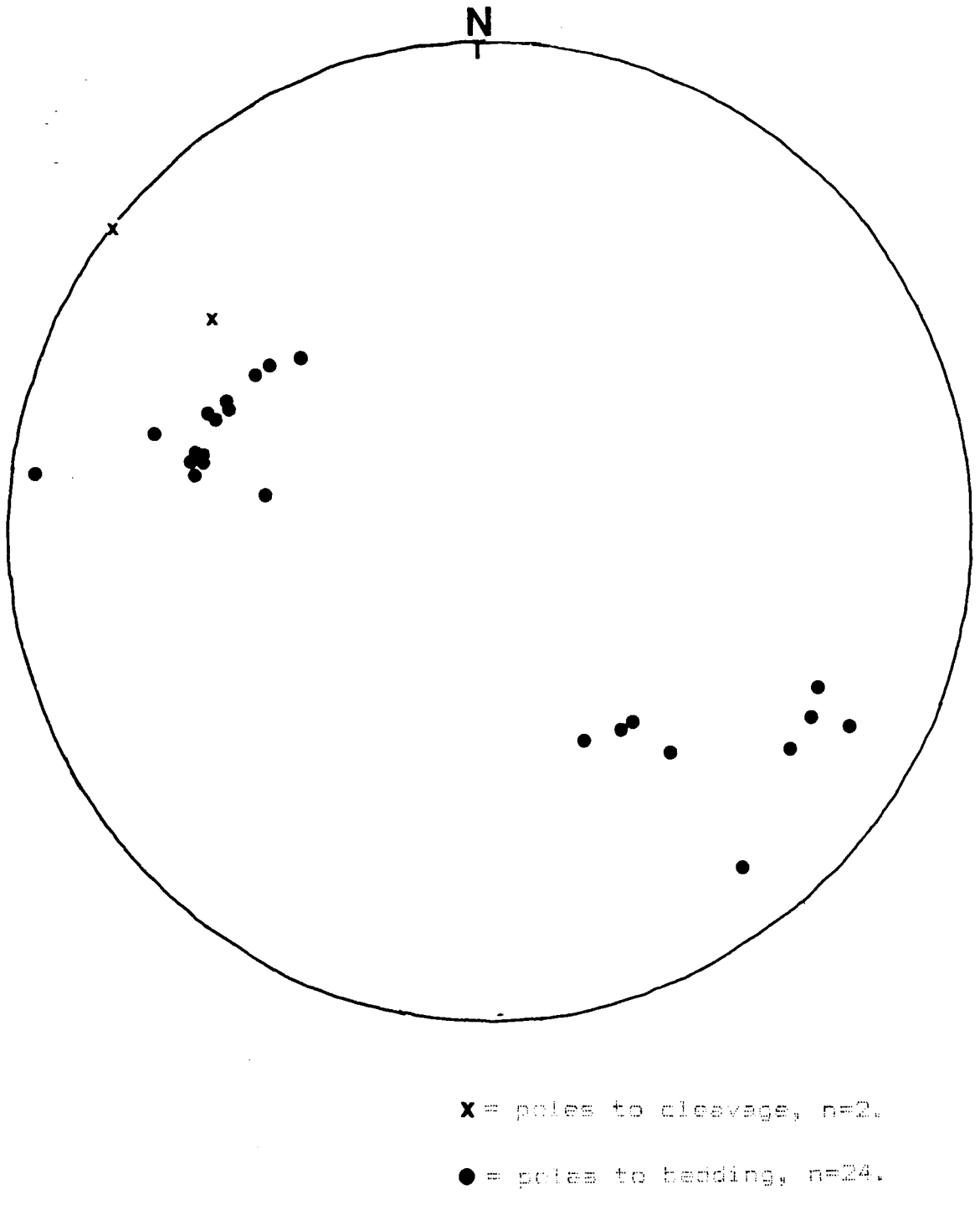


Figure 37. Stereonet Plot of Cleavage and Bedding Attitudes Within the Spurgeon Fault Block.

intensity of fabric development in this area is minimal compared to the areas discussed by Reks and Gray (1983) or Woodward, et al., (1986), and indicates much less late shortening.

Flexural slip appears to have been the dominate fold mechanism for this area. This is indicated by the microscopic shear zones, bedding-plane fiber growths, and numerous bedding-wedges developed in the strata. Internal bedding strains resulted in the slight thickening of Conasauga Group strata in the hinges of some folds (see section D-D', Plate 3).

To define a definite sequence of thrusting for an area as small as the present study is tenuous. Therefore, it is necessary to look at a larger area and discuss the sequence of thrusting and folding in general terms. Southwest of the present study, the Pulaski, Dunham Ridge, and Spurgeon faults all exhibit flap-like structures (Little, 1969), that are the result of large scale folding of the faults. The presence of these folded faults across the Pulaski block, and the apparent folding of the Holston Mountain fault by emplacement of the Pulaski sheet (Conway, 1983), satisfies the author that thrusting progressed in a hinterland to foreland manner. However, this does not imply several discrete thrusting episodes, but rather a progressive deformation associated with tectonic forces acting over a

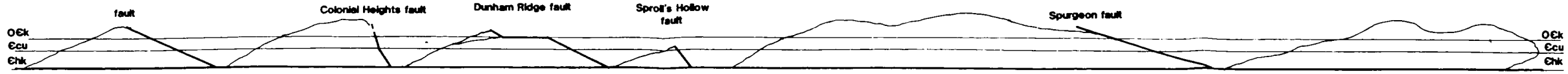
long period of time (Fig. 38). Therefore, the Spurgeon fault probably formed relatively early, followed by footwall imbrication and formation of the imbricate slice, and finally by the Dunham Ridge and Pulaski faults cutting up to the surface. Folding, associated with the emplacement of individual thrusts, occurred in the hanging walls of individual fault blocks.

Prior to the cessation of thrusting, folding of the Pulaski sheet was initiated by footwall imbrication and horse emplacement beneath it. The development of this "lumpy roof duplex" warped the cover strata, and the continued deformation resulted in the tightening of folds. The Colonial Heights fault appears to be the result of fault propagation folding, and formed when the thrust broke upwards, truncating the steeply dipping northwest limb of the Dunham Ridge footwall anticline. Room problems in the core of the large syncline behind the Sproll's Hollow anticline were encountered when the Pulaski roof sheet was folded over the lumpy roof duplex. This led to out-of-syncline thrusting, and the formation of the Sproll's Hollow fault. It is probable that the formation of these minor thrusts occurred during the waning stages of the folding of the large Pulaski sheet.

Finally, an axial planar, spaced to disjunctive, stylolitic cleavage began to form in the siltstones of the Nolichucky Formation and the carbonates of the Knox Group.

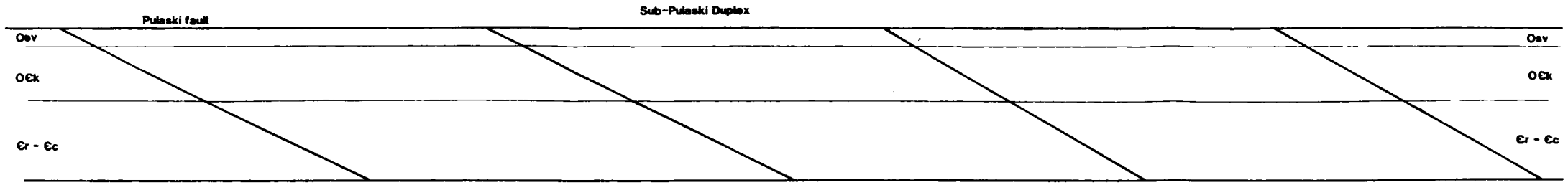
Figure 38. T1-Tx Diagram for the Study Area.

T1

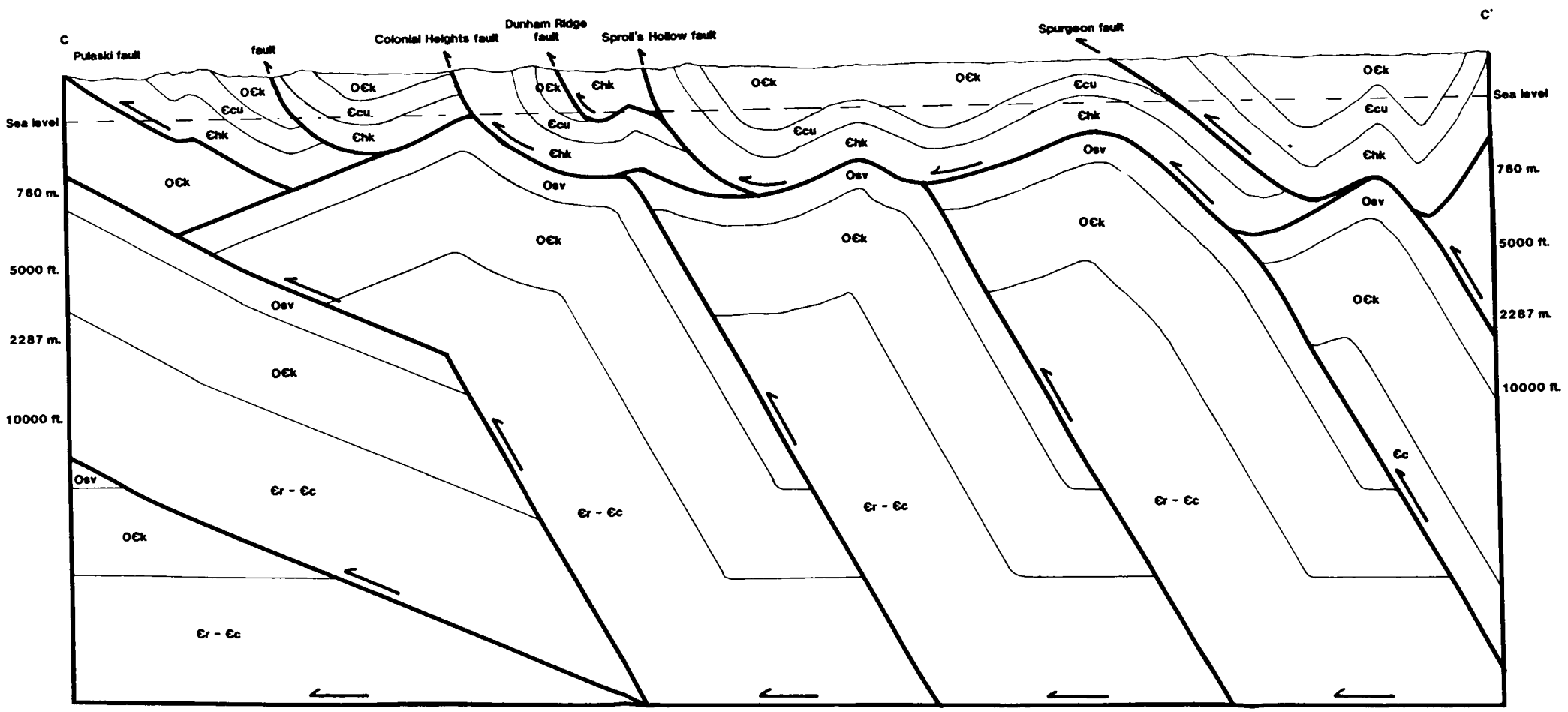


No Vertical Exaggeration

T2



T3



This cleavage either formed late in the folding or may have possibly been superimposed onto the fold after folding had ceased.

CHAPTER VI

CONCLUSIONS

The following conclusions are derived from the study of the structural features of the Boone Dam, Tennessee area.

1. The "bulge" in the trace of the Dunham Ridge fault is a down-structure view of a pair of lateral ramps developed in the footwall of the fault.

2. Deformation of the Spurgeon fault block resulted in the formation of axial planar, spaced to disjunctive, stylolitic cleavage in the siltstones of the Nolichucky Formation and the carbonates of the Knox Group. This cleavage probably formed in the latter stages of the formation of the large chevron-style fold.

3. The rotation in the trace of the Spurgeon fault is probably the result of uplifting of its frontal ramp in the southern part of the area. This uplift is indicated by somewhat anomalous fold plunges observed within the block.

4. The Colonial Heights and Sprolls Hollow faults are small displacement thrust faults. The Colonial Heights

fault probably formed by fault-propagation folding. However, the Sproll's Hollow fault is related to a large anticline-syncline pair, and formed as a result of room problems encountered in the core of the adjacent syncline when the Pulaski sheet was folded by emplacement of the lumpy roof duplex beneath it.

5. The tear faults in the study area are probably related to structures developed in the footwalls of their respective sheets, and do not reflect deeper structures in the Pulaski sheet footwall.

6. The minimal intensity of fabric development in the area, in relation to areas to both the northeast and the southwest, indicates much less late shortening of the Pulaski sheet. Late shortening instead led to formation of the sub-Pulaski duplex, which passively folded the Pulaski sheet.

LIST OF REFERENCES

REFERENCES

Bridge, J., 1956, Stratigraphy of the Mascot-Jefferson zinc district, Tennessee: U. S. Geol. Survey Paper 277, 76 pp.

Butts, C.W., 1933, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, 56 pp.

Byerly, D. W., 1966, Structural geology along a segment of the Pulaski Fault, Greene County, Tennessee: The University of Tennessee, Knoxville, Dept. of Geol. Sci. Ph. D. dissertation, 94 pp.

Calver, J. S., and Hobbs, C. R. B., Jr., eds., 1963, Geologic map of Virginia: Virginia Div. Mineral Res.

Conway, C. D., 1983, The development of slaty cleavage and its relationship to mesoscopic and macroscopic structure in the Pulaski thrust sheet near Bristol, Tennessee: The University of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 129 pp.

Cooper, B. N., 1961, Grand Appalachian field excursion: Virginia Polytech. Inst. Engineering Extension Series Geol. Guidebook 1, 187 pp.

Cooper, B. N., 1964, Relation of stratigraphy to structure in the southern Appalachians, in Tectonics of the southern Appalachians: Virginia Polytech. Inst., Dept. Geol. Studies Mem. 1, p. 81-114.

Cooper, B. N., 1968, Profile of the folded Appalachians of western Virginia, in A coast to coast tectonic study of the United States: UMR Jour., no. 1, p. 27-64.

Currie, D. B., Patnode, H. W., and Trump, R. P., 1962, Development of folds in sedimentary strata: Geol. Soc. America Bull., vol. 73, p. 655-724.

Eaton, H. N., 1936, Report on the Bachman Ford Dam site: Tenn. Valley Authority, Geologic Division, 7 pp.

Elder,J. A., Epley, I. B., Yates, E. K., Sams, W. C., Anderson, A. C., and Odom, L. E., 1958, Soil survey of Washington County, Tennessee: U. S. Dept. of Agriculture, Soil Conservation Ser., Series 1948, no. 5.

Geyer, R. A., Jackson, M., Jr., and Trostle, M. E., 1982a , Major geological sub-provinces in the Appalachian Overthrust Belt-1: Oil and Gas Jour., vol. 80, no. 42, p. 153-158.

Geyer, R. A., 1982b, Major geological sub-provinces in the Appalachian Overthrust Belt-2: Oil and Gas Jour., vol. 80, no. 43, p. 200-208.

Grant, L. F., and Benziger, C. P., 1949, Geology of the Spurgeon Island dam site: Tenn. Valley Authority Div. of Water Control Planning, Geologic Branch, 15 pp.

Hardeman, W. D., Swingle, G. D., Fullerton, D. S., Sykes, C. R., and Miller, R. A., 1966, Geologic map of Tennessee--East sheet: Nashville, Tennessee Div. Geology, scale 1;250,000.

Hasson, K. O., and Haase, C. S., (in press), Lithofacies and paleogeography of the Conasauga Group (Middle and Late Cambrian) in the Valley and Ridge province of East Tennessee: Geol. Soc. America Bull.

Hatcher, R. D., and Odom, A. L., 1980, Timing of thrusting in the southern Appalachians, USA: model for orogeny?: Jour. Geol. Soc. London, vol. 137, p. 321- 327.

Jackson, M., Jr., 1982, The Kingsport Lineament: cross-strike structural discontinuity in the southern Appalachian Overthrust Belt: Proceedings SEG 52nd Annual Meeting, Dallas.

Jacobeen, J., and Kanes, W. H., 1975, Structure of the Broadtop synclinorium, Wills Mountain anticlinorium and Allegheny frontal zone: Am. Assoc. Pet. Geol. Bull., v. 59, no. 7, p. 1136-1150.

Johnson, A. M., 1970, Physical processes in geology; a method for interpretation of natural phenomena: San Francisco, Freeman, Cooper, 577 pp.

Jones, P. B., 1971, Folded faults and sequences of thrusting in Alberta foothills: Bull. Amer. Assoc. Pet. Geol., vol. 55, p. 292-306.

Keith, Arthur, 1905, Description of the Greenville Quadrangle, Tennessee-North Carolina: U. S. Geol. Survey Geol. Atlas, Folio 118, 11 pp.

Keith, Arthur, 1907, Description of the Roan Mountain Quadrangle, Tennessee-North Carolina: U. S. Geol. Survey Geol. Atlas, Folio 151, 11 pp.

King, P. B., 1950, Tectonic framework of southeastern United States: Am. Assoc. Pet. Geol. Bull., vol. 34, p. 635-671.

Little, R. L., 1969, Lithostratigraphy and structural geology of a portion of the Dunham Ridge thrust block, Greene and Washington Counties, Tennessee: The University of Tennessee, Knoxville, Dept of Geol. Sci. Ph. D. dissertation, 130 pp.

Matzek, B. L., et al, 1953, Soil survey of Sullivan County, Tennessee: U. S. Dept. of Agriculture, Series 1944, no. 2.

Milici, R. C., 1975, Structural patterns in the southern Appalachians: Evidence for a gravity slide mechanism for Alleghenian deformation: Bull. Geol. Soc. Am., vol. 86, no. 9, p. 1316-1320.

Oder, C. R. L., 1934, Preliminary subdivision of the Knox dolomite in East Tennessee: Jour. Geol., vol. 42, p. 469-497.

Prouty, C. E., 1944, Bachman Ford Project: Tenn. Valley Authority Water Control Planning Dept., Geologic Branch, 10 pp.

Pugh, L. E., 1966, Geology along a portion of the Cross Mountain fault near Blountville, Sullivan County, Tennessee: The University of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 66 pp.

Ramsay, J. G., and Huber, M. I., 1983, The techniques of modern structural geology: New York, Academic Press, 307 pp.

Reks, I. J., and Gray, D. R., 1983, Strain patterns and shortening in a folded thrust sheet: an example from the Southern Appalachians: Tectonophysics, v. 93, p. 99-128.

Rich, J. L., 1934, Mechanics of low angle overthrust faulting as illustrated by Cumberland thrust block, Virginia, Kentucky, and Tennessee: Bull. Amer. Assoc. Pet. Geol., v. 18, p. 1584-1596.

Rodgers, John, 1949, Evolution of thought on structure of middle and southern Appalachians: Am. Assoc. Pet. Geol. Bull., vol. 33, p. 1643-1654.

Rodgers, John, 1953, Geologic map of East Tennessee with explanatory text: Tenn. Div. Geol. Bull. 58, pt. 2, 168 pp.

Rodgers, John, 1964, Basement and no-basement hypotheses in the Jura and the Appalachian Valley and Ridge, in Lowry, W. D., ed., Tectonics of the Southern Appalachians: Virginia Polytech. Inst., Dept. of Geol. Sci., Mem. 1, p. 71-80.

Rodgers, John, 1968, The eastern edge of the North American Continent during the Cambrian and Early Ordovician, Chap. 10 in Studies of Appalachian geology, northern and maritime (Zen, E-an, et al., eds.): New York and London, Interscience Publishers, p. 141-149.

Roeder, D., Gilbert, O. E., Jr., and Witherspoon, W. D., 1978, Evolution and macroscopic structure of Valley and Ridge thrust belt, Tennessee and Virginia: Univ. of Tenn. Dept. of Geol. Sci. Studies in Geology 2, 25 pp.

Roper, D. C., 1977, Mesoscopic fabric of Babbs Knob area (Pulaski thrust, East Tennessee): The University of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 83 pp.

Safford, J. M., 1869, Geology of Tennessee: State of Tennessee, Nashville, 550 pp.

Tegland, E. R., 1978, Seismic investigations in eastern Tennessee: Tenn. Div. of Geol. Bull. 78, 68 pp.

Woodward, N. B., (ed.), 1985, Valley and Ridge thrust belt: balanced structural sections, Pennsylvania to Alabama: Univ. of Tenn. Dept. of Geol. Sci. Studies in Geology 12, 64 pp.

Woodward, N. B., and Beets, J. W., (in press), Critical evidence for southern Appalachian valley and ridge thrust sequence, Geol. Soc. Am. Special Paper.

Woodward, N. B., Gray, D. R., and Spears, D. B., 1986, Including strain data in balanced cross-sections: Jour. Structural Geology, v. 8, p. 313-334

Woodward, N. B., Walker, K. R., and Lutz, C. T., (in press), Relationships between lower Paleozoic facies patterns and structural trends in the southern Appalachians.

Wilson, S. M., 1979, Geology of the Fall Branch, Tennessee area: The University of Tennesse, Knoxville, Dept. of Geol. Sci. Master's thesis, 80 pp.

APPENDIXES

APPENDIX A

STRUCTURAL THIN-SECTION DESCRIPTIONS

CONASAUGA GROUP
Honaker Formation

Slide Number	
1-Chk	Compositionally layered wackestone with numerous bedding-perpendicular calcite veins, minor en-echelon vein fillings, and occassional bedding-parallel stylolites.
2-Chk	Fine grained dolostone with numerous calcite-filled fractures in various orientations, and minor stylolites.
3-Chk	Compositionally layered wackestone with minor calcite-filled fractures.

Nolichucky Formation

Slide Number	
1-Cn	Numerous fractures; thick (2.2 cm) accumulation of bedding - parallel growth fibers, with rare inclusion trails asymptotic to fiber edges.
2-Cn	Closely spaced stylolitic cleavage; crescent-shaped extension fractures containing antitaxial fibers; minor stylolites and occassional pressure shadows associated with isolated carbonate grains.

Maynardville Limestone

Slide Number	
1-Cmn	Calcite - filled fractures oriented sub-normal to bedding; occassional roughly sigmoidal en-echelon veins that kink bedding laminations.

KNOX GROUP

Slide Number	
1-OCk	Crush breccia with abundant micro-fracture fabric; minor stylolites offset by fractures; relict peloidal texture.
2-OCk	Pebble conglomerate with minor bedding parallel stylolites that are cut by high angle calcite veins; paleokarsts.
3-OCk	Wavy laminated dolostone.
4-Ock	Large amplitude bedding - parallel stylolites that are cut by calcite-filled fractures oriented sub-normal to bedding.
5-OCk	Finely laminated, compositionally layered wackestone; minor bedding-parallel stylolites, and occassional vertical veins.
6-OCk	Numerous cross-cutting fractures and several bedding-parallel stylolites.
7-OCk	Minor bedding-parallel stylolites.
8-OCk	Peloidal wackestone with bedding-parallel stylolites that are cut by large, bedding-normal veins, filled with twinned polygonal calcite.
9-OCk	Anastomosing, widely-spaced, stylolitic cleavage; bedding-normal veins that exhibit a dendritic habit.
10-OCk	Incipient spaced stylolitic cleavage fabric oriented at a high angle to bedding; occassional calcite veins that are truncated by selvage seams.
11-OCk	Two generations of cross - cutting veins; numerous bedding - parallel stylolites.

12-OCk	Weak cleavage fabric at a high angle to bedding; anastomosing, brittle fractures normal to bedding.
13-OCk	Flat pebble conglomerate with minor bedding-normal, calcite veins.
14-OCk	Wavy laminated dolostone.
15-OCk	Occassional bedding-normal, calcite veins; bedding-parallel stylolites.

APPENDIX B

ROAD LOG AND DESCRIPTION OF STOPS

MILEAGE		DESCRIPTION
Cumulative	Interval	
0.0	0.0	Depart from Geology building on "The Hill". Turn right on Cumberland/W. Main. Keep straight onto I-40E entrance ramp. Take I-40E to Ashville.
33.6	33.6	I-40E separates from I-81N. Stay on I-81N toward Johnson City.
88.5	54.9	Take exit 57A to I-181S. Take I-181S toward Johnson City.
88.9	0.4	Cross the Colonial Heights thrust. Ridge to the left is underlain by strata of the Nolichucky Formation.
89.8	0.9	Cross the Dunham Ridge thrust.
90.2	0.4	Exposure of Knox Group soils on the right.
93.4	3.2	Pull off on right shoulder just past exit ramp from highway overpass. Roadcut exposures present on either side of highway. Stop 1.

Relatively undeformed Knox strata in the body of the Dunham Ridge fault block. This is one of the few exposures of Knox Group strata in the area. Bedding is oriented N61°E with a gentle 12° dip to the northwest. The dominant lithology consists of medium grained wackestone-packstone, with occassional two inch intraclastic layers. The fabric of the rocks consists primarily of numerous anastomosing, bedding-parallel, stylolites. A general absence of tectonic fabric here is probably a result of both the gentle nature of the folding, and the strata being located within the body of the thrust sheet.

94.4	1.0	Cross the Spurgeon thrust.
94.6	0.2	Pull off on right shoulder just past bridge. Stop 2.

Deformed Nolichucky strata just southeast and above the Spurgeon thrust. In contrast to the previous stop this exposure exhibits numerous deformation fabrics. It is located on the northwest limb of the chevron-folded Spurgeon sheet, approximately 400 meters above the Spurgeon thrust. The Nolichucky strata here consist of siltstone "ribbon rock", with occassional 30-45 centimeters limestone interbeds.

Mesoscopic deformation is represented by high angle conjugate faults that extend bedding and offset some limestone interbeds up to four meters. Enechelon vein arrays are developed in the siltstone lithologies and are also oriented at a high angle to bedding. Close examination of the limestones reveals numerous bedding-perpendicular, calcite-filled, extension veins. The fine grained siltstone layers consist of both micritic areas and slightly coarser microsparous areas, thereby giving the rocks a "ribboned appearance. Some bedding surfaces are coated with thick (> 1 cm) calcite accumulations. These calcite accumulations are comprised of a series of overlapping growth fibers separated by thin, shale partings.

95.0	0.4	Knobby hill to the south is underlain by strata of the Nolichucky Formation and marks the nose of the steeply northeast-plunging, chevron-folded Spurgeon sheet.
95.3	0.3	Cross Clinchfield Railway.
96.4	1.1	Take exit for route 354. Follow sign for 354W. Take left at the end of exit ramp onto 354W.
97.5	1.1	Turn left onto Old Gray Station Road.
99.8	2.3	Cross Clinchfield Railway. Pull off onto right shoulder just past bridge. Walk back to bridge and proceed down bank to railroad tracks, continue northwest along tracks for about 500 meters to Free Hill Tunnel. Stop 3.

Exposure of Honaker Formation southeast of and immediately above the Spurgeon thrust. Outcrop of the lower, shaly member of the Honaker is present beside the north side of the tracks near the tunnel entrance. The strata are intensely folded due to their proximity to the Spurgeon thrust. Axial planes for these folds are oriented N40-50°E, and dip steeply to the southeast. The trace of the Spurgeon fault lies near the west end of the tunnel. (Return to van). Proceed on Old Gray Station Road.

100.4	0.6	Cross the Spurgeon fault.
101.4	1.0	Turn left onto Wickway.
101.7	0.3	Turn right onto I-181N.
104.6	2.9	Take exit 45 towards Eastern Star Road. Pull to right shoulder of exit ramp. Roadcut exposure located next to exit ramp. Stop 4.

Exposure of the Honaker Formation southeast of and above the Dunham Ridge thrust. Bedding strikes north 80° east and dips 57° to the southeast. Imbrication of the strata is observed near the western limit of the exposure. These are minor hanging wall imbricates immediately above the large Dunham Ridge fault. Intense veining occurs within a thick carbonate bed, which is repeated by the minor imbricates. Minor antithetic thrusts with approximately one foot of displacement are present near the east end of the exposure.

104.9	0.3	End of exit ramp. Yield sign. Turn right onto Eastern Star Road.
105.1	0.2	Turn right onto Mitchell Road.
105.3	0.2	Cross the Dunham Ridge fault. Ridge to the left is underlain by rocks of the Nolichucky Formation.
106.4	1.1	Stop sign. Right onto Lebanon Drive.
106.7	0.3	Cross Sproll's Hollow fault.
106.8	0.1	Left into driveway of the Newsome residence. Park here (ASK!). Walk back down road to curve and down bank to railroad tracks. Stop 5.

Looking northeast, the ridge to the left is underlain by strata of the Nolichucky and Maynardville Formations, whereas the ridge to the right is underlain by the rocks of the Honaker Formation. The saddle between these two ridges is the approximate location of the Sproll's Hollow fault.

Walk southeast along the tracks. Intensely folded dolomitic shales of the lower member of the Honaker are observed. This highly crumpled appearance is due to their proximity to the fault. Above these shales occur the remainder of the Honaker, consisting of medium-to-thick bedded, limestones and dolostones. A number of bedding wedges are observed in these rocks. At the southeast limit of the exposure the shales of the Nolichucky Formation are observed. Return to van. Turn around in drive and turn right back onto Lebanon Drive.

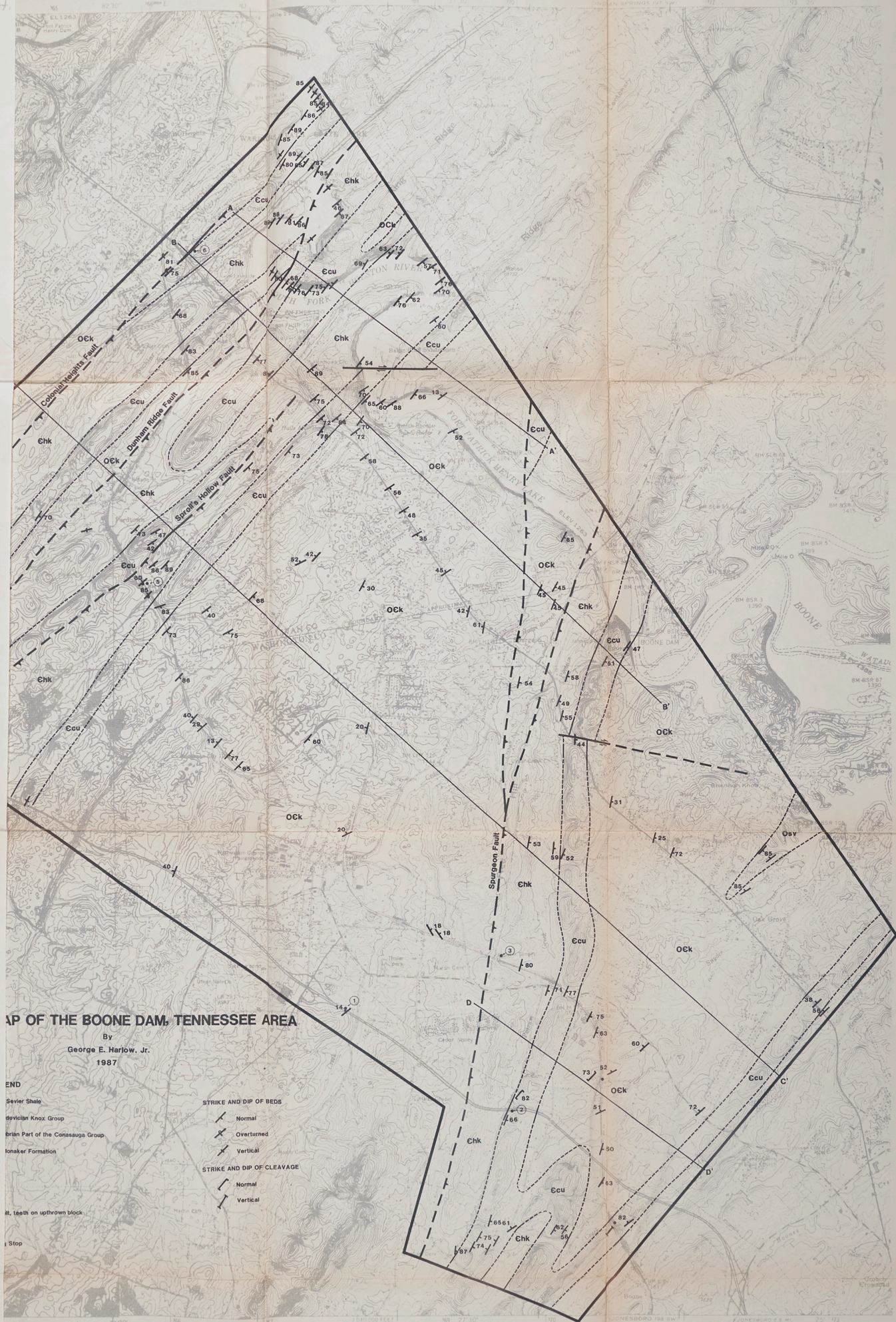
107.5	0.7	Four way intersection. Continue straight on Lebanon Drive.
107.7	0.2	Cross ridge underlain by Nolichucky Formation.
108.6	0.9	Cross the Colonial Heights fault.
108.7	0.1	Right onto Shipley Ferry Road.
109.1	0.4	Railroad overpass.
109.3	0.2	Intersection of Shipley Ferry Road and Tennessee route 36. Turn left onto 36N and get in right hand lane.
109.4	0.1	Pass under I-81.
109.5	0.1	Intersection of I-81S exit ramp and 36N. Pull off onto right shoulder just past intersection. Stop 6.

Approximate location of the Colonial Heights thrust. Strata of the Nolichucky, (observed in roadcut adjacent to exit ramp), are thrust over the carbonates of the Knox Group, (observed in roadcut adjacent to route 36N).

VITA

George Edward Harlow, Jr., was born in Waynesboro, Virginia on March 5, 1961. He attended Riverheads Elementary School in Greenville, and was graduated from Riverheads High School in June 1979. In September 1979 he entered Virginia Polytechnic Institute and State University, and received a Bachelor of Science degree in geology in July 1983. In the Spring of 1984 he entered the graduate program at the University of Tennessee, Knoxville, and began working toward a Master of Science degree in geology. He received this degree in December 1987.

Thesis
87
.H368
pocket pt
1 of 3



AP OF THE BOONE DAM, TENNESSEE AREA

By
George E. Harlow, Jr.
1987

END

Sevier Shale

dovician Knox Group

brian Part of the Conasauga Group

lonaker Formation

lt, teeth on upthrown block

Stop

STRIKE AND DIP OF BEDS

Normal

Overturned

Vertical

STRIKE AND DIP OF CLEAVAGE

Normal

Vertical

N

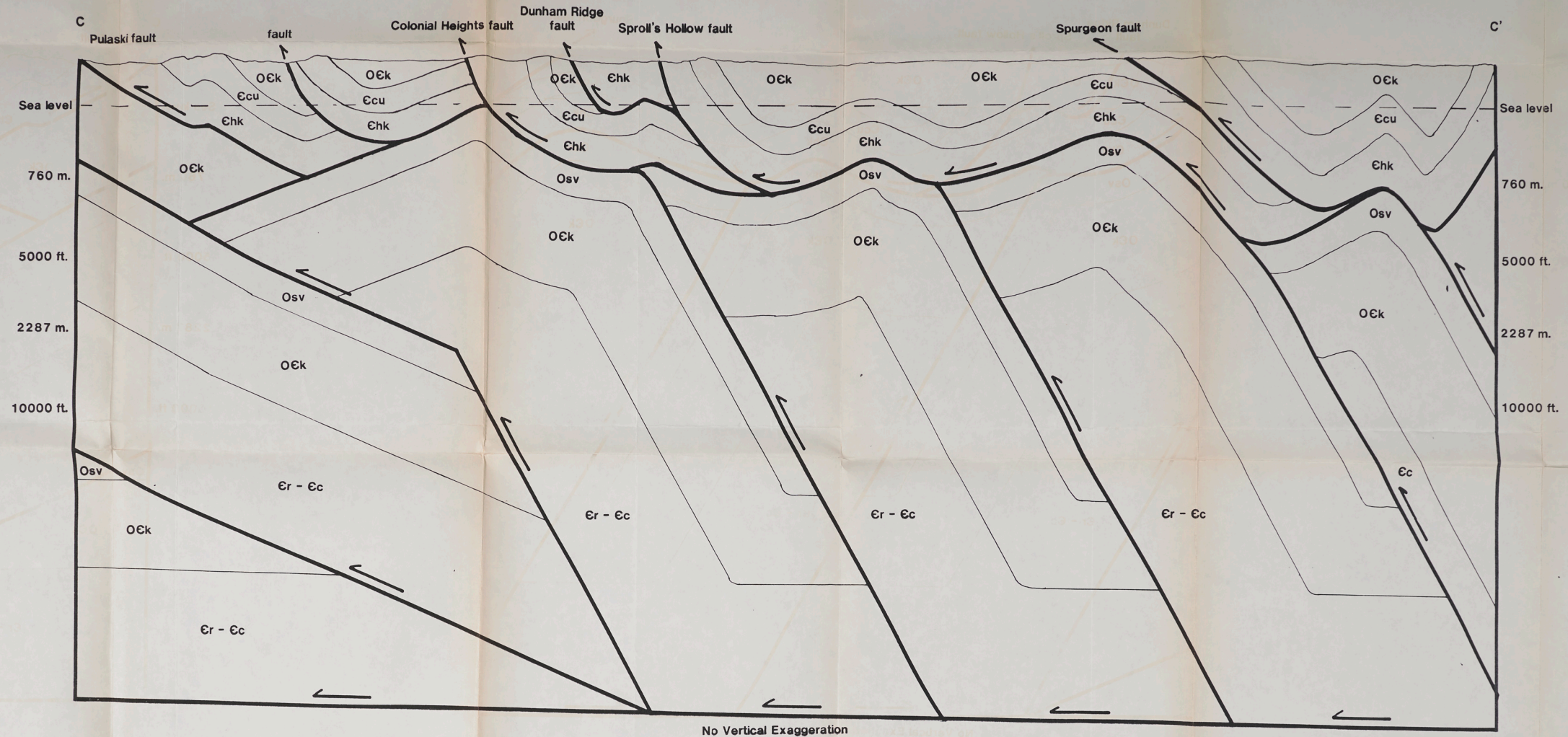
0 Mile

Feet (by thousand)

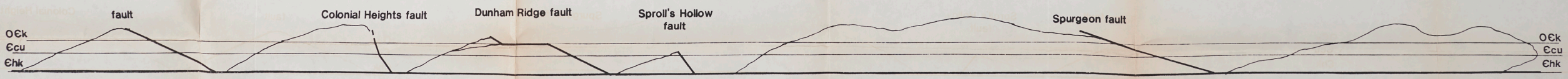
0 5 0 Kilometer

CONTOUR INTERVAL 20 FEET

PLATE 2



No Vertical Exaggeration
Scale 1:24000



No Vertical Exaggeration
Scale 1:37800

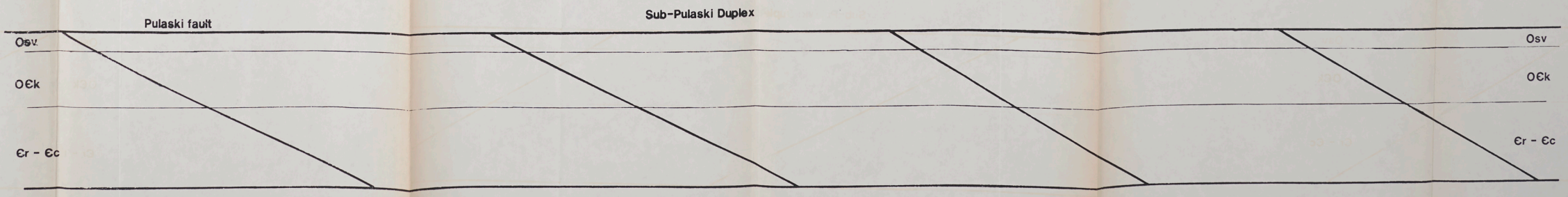
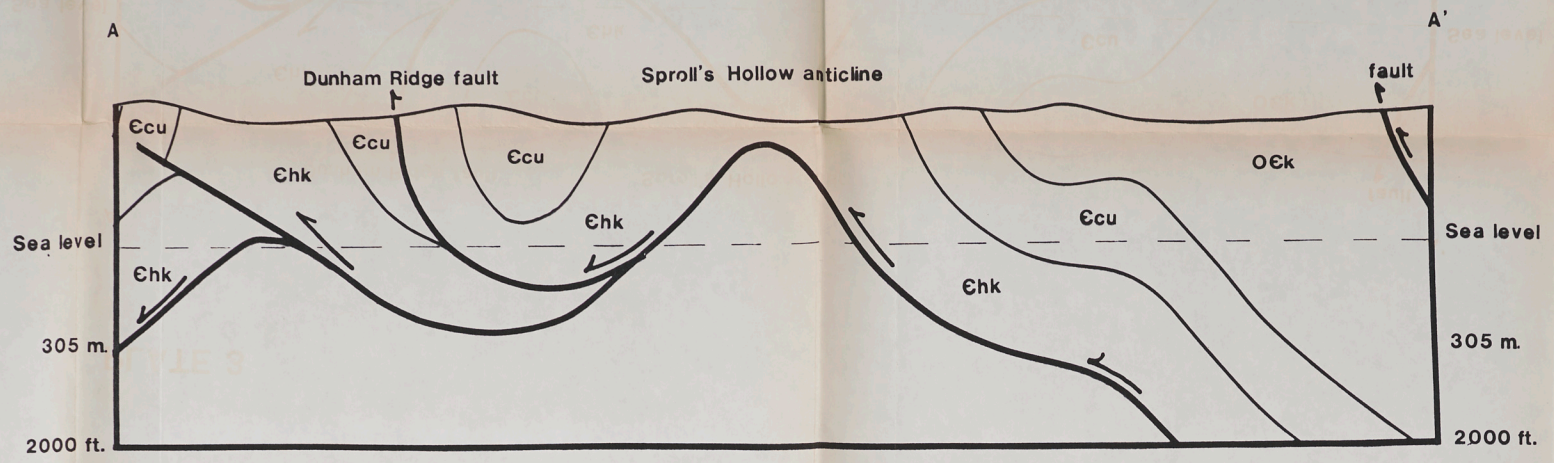
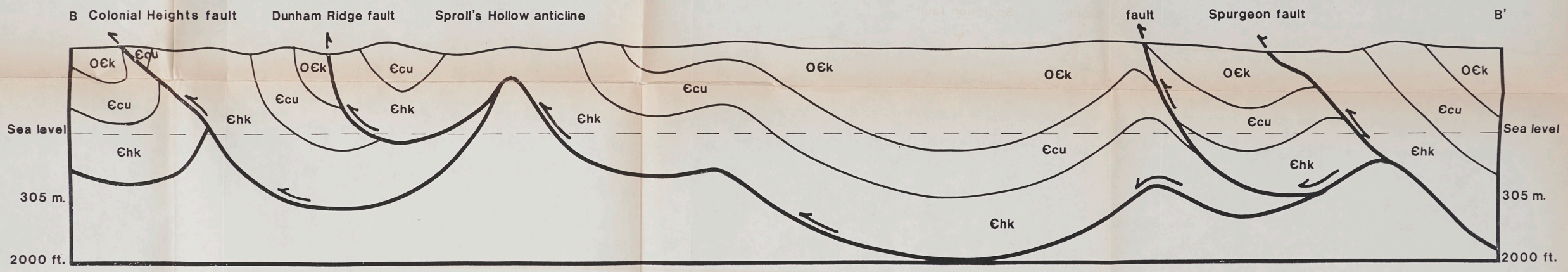
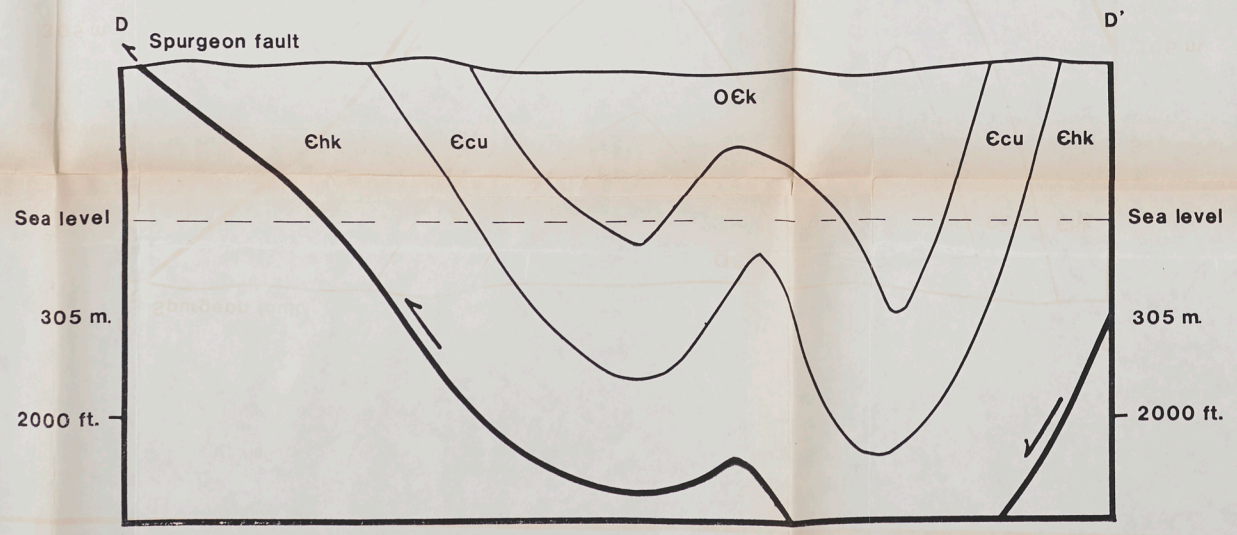


PLATE 3







No Vertical Exaggeration

Scale

1:12000