To the Graduate Council:

I am submitting herewith a thesis written by Robert A. Horton, Jr., entitled "Structural Analysis of the Jacksboro Fault, East Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

Dietrich H. Roeder, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

Thesis
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STRUCTURAL ANALYSIS OF THE JACKSBORO FAULT, EAST TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Robert A. Horton, Jr.

June 1977

135513

DEDICATION

This is dedicated to my parents.

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ABSTRACT

The Pine Mountain overthrust originates from a sole fault in the Rome Formation (Cambrian) and ramps into Silurian and Devonian shales beneath the Powell Valley anticline. It ramps to the surface northwest of Pine Mountain. The Chattanooga fault ramps from the Rome sole to the surfact in Dutch Valley. Another thrust extends from Dutch Valley beneath the Cumberland Plateau in the Pennington Shale (Mississippian). Drilling data indicate the presence of a fourth thrust (Bales fault) subcropping beneath Powell Valley; surface data indicate its presence beneath Dutch Valley. The Pine Mountain and Chattanooga fault systems are separated by the Jacksboro cross fault.

Fabric data indicate that folds on either side of the Jacksboro fault developed simultaneously prior to wrenching. The onset of strike-slip movement caused a local readjustment in the regional stress field.

Three phases of thrusting are recognized, each with associated folding. T-1 movement was initiated late in the Pennsylvanian or in the Permian and occurred on a single plane consisting of the present day Pine Mountain and Chattanooga faults. Ramping was not uniform along the entire length of the fault, but the stratigraphic position into which the fault ramped varied along strike. Transport zone fabrics indicate that thrusting may have occurred below 3 kilometers of overburden. T-2 movement occurred on the Bales thrust, warping the earlier fault. T-3 resulted in renewed movement on the T-1 thrust

surface. Northeast of the Jacksboro fault movement occurred on the Pine Mountain fault. The Chattanooga fault ramped through the Dutch Valley anticline to Pennsylvanian shales. These two levels of thrusting were connected by the Jacksboro fault, resulting in wrenching between the Pine Mountain block and the Cumberland Plateau. Folding accompanied all three phases.

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CHAPTER I

INTRODUCTION

A. General Statement

The Pine Mountain overthrust block, located along the boundary of the Valley and Ridge and Cumberland Plateau provinces in southwestern Virginia, southeastern Kentucky, and adjoining Tennessee (Figure 1), measures approximately 40 kilometers by 200 kilometers. This block is bounded by faults on three sides (Figure 1), the Russell Fork fault on the northeast, the Pine Mountain fault on the northwest, and the Jacksboro fault on the southwest. Butts (1927) discovered the existence of fensters in the Powell Valley anticline on the southeast side of the overthrust indicating that the entire block is underlain by the Pine Mountain fault. This fact proved crucial to the development of the thin-skinned hypothesis of Appalachian development (Rich, 1934; Rodgers, 1949).

Movement along these faults occurred during the Alleghanian orogeny in late Paleozoic time. The structural style is typical of that developed in forelend regions, i. e., low-angle sledrunner thrusts which occassionally ramp upwards to higher stratigraphic levels or the surface, accompanied by asymmetric folding in the thrust plate (Coney, 1973, Hobbs, Means, Williams, 1976). Recent investigations (Harris, 1967, 1970, 1976; Rodgers, 1970) have shown that the nature of deformation is much more complicated than was supposed by previous authors (King, 1951; Harris and Zietz, 1962).

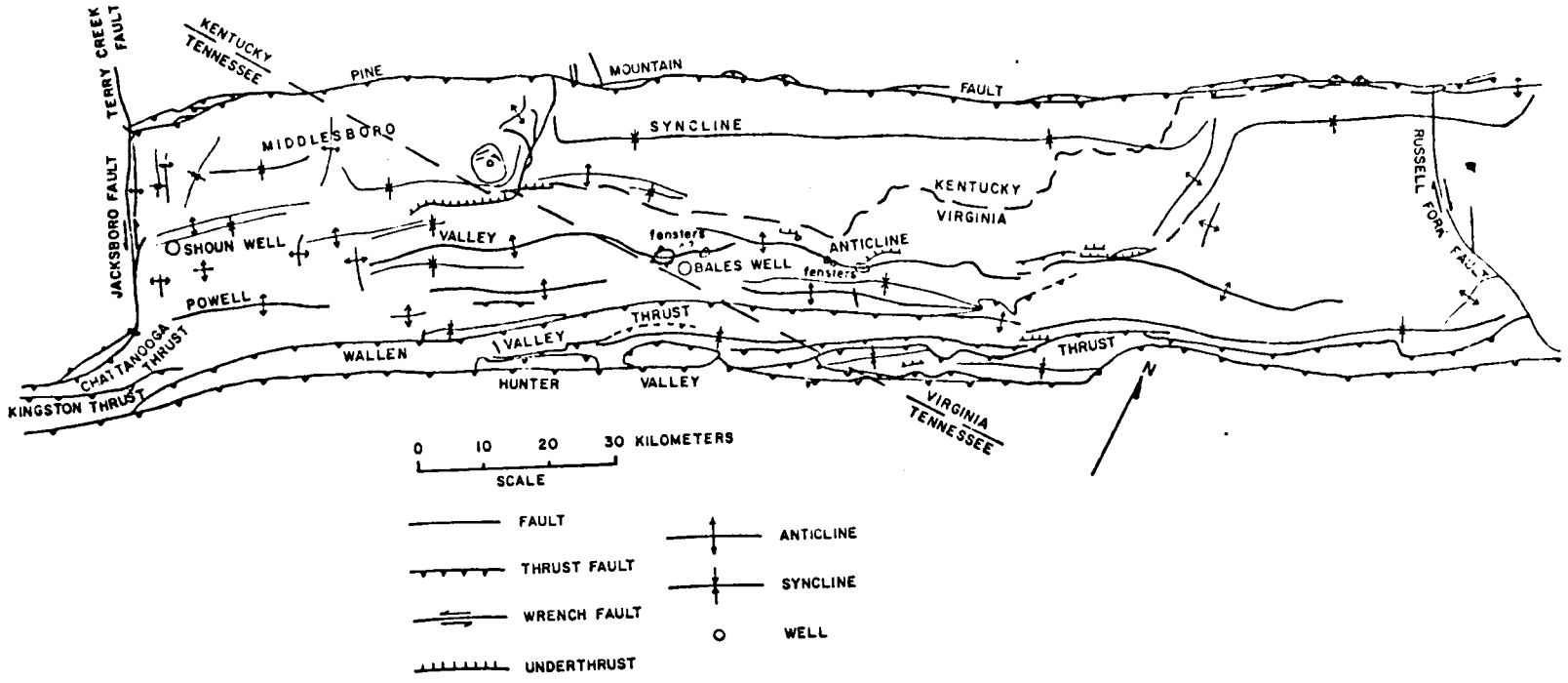


Figure 1. Structural map of the Pine Mountain overthrust (modified from Harris, 1970).

B. Purpose

The objective of the present investigation is to examine the relationships of mesoscopic structures associated with the Jacksboro fault and the southwestern edge of the Pine Mountain system. By examining geometric and kinematic relationships of one mesoscopic structure to another it should be possible to correlate these structures macroscopically. Such a correlation will allow a detailed study of the deformational history on a regional scale and should permit development of a detailed model for the evolution of the Pine Mountain overthrust block. Ultimately this could be utilized in plate tectonic models of the Appalachian orogeny.

C. Previous Investigations

The first author to recognize the Pine Mountain and Jacksboro faults was Safford (1869), who also realized that the deformation in the Valley and Ridge was the result of compression from the southeast. Keith (1896) made the first detailed geologic maps of the area, but failed to recognize the relationship which exists between the Pine Mountain and Jacksboro faults. Instead he considered the Jacksboro fault to be a thrust fault related to a northeast-southwest component of compression.

Wentworth (1921) recognized that the Jacksboro fault was actually a strike-slip system and postulated an offset of 16.1 kilometers. He also developed the first model for the structural evolution of the Pine Mountain overthrust system, and showed that horizontal

displacement on opposite ends of the overthrust block was not the same, but that a pivoting of the overthrust block was also involved. Glenn (1925) recognized the presence of the Terry Creek fault (Figure 1), a zone of slight disturbance extending northwestward into the Plateau from the end of the Jacksboro fault. However, he regarded the horizontal displacement along the Jacksboro fault to be 3.2 kilometers maximum.

The discovery of fensters in Powell Valley by Butts (1927) revealed that the Pine Mountain fault soles out as a bedding plane thrust. Rich (1934) extended this concept to the entire Valley and Ridge, providing fuel for the debate which soon developed between proponents of the thin-skinned and thick-skinned schools of thought (Rodgers, 1949).

Miller and Fuller (1954) and Miller and Brosge (1954) noticed that the folding of the Pine Mountain fault in the Powell Valley anticline was greater than could be adequately explained by Rich's (1934) model. Instead, they postulated that development of the Powell Valley anticline was contemporaneous with thrusting. In their models a gentle warp is the cause of ramping. Later development of the fold eventually caused motion along the thrust to cease, with further deformation taken up on a new imbrication to the southeast.

Studies of the Cumberland Plateau overthrust by Stearns (1954, 1955) and Wilson and Stearns (1958) revealed that wrenching is an integral part of the thrust system. Wrench faults connect thrust faults at different stratigraphic levels at the base of the overthrust block.

The authors noted the similarities which exist between the Pine Mountain and Cumberland Plateau overthrusts and suggested that their model could be applied to the Pine Mountain system.

Regional mapping by Rodgers (1953) was followed by detailed mapping of 7.5 minute quadrangles by Byerly (1957), McCallum (1958), Englund (1957, 1958), Swingle (1960 a,b) and Luther (1967). Utilizing this information Englund (1968) made a detailed analysis of the deformation at the southwestern end of the Pine Mountain overthrust. He concluded that convergent wrenching along the Jacksboro fault produced the folds and faults which parallel the main fault plane and that the Jacksboro fault extended downward only as deep as the Pine Mountain fault. He also studied the thickness of stratigraphic intervals on either side of the Jacksboro fault and showed that displacement was approximately 17.7 kilometers.

Meanwhile, Harris and Zietz (1962) concluded from magnetic data that the Powell Valley anticline is rooted in the basement. However, analysis of Shell Oil Company's L. S. Bales number one well in Lee County, Virginia, revealed the presence of another, formerly unknown, thrust fault (the Bales fault) subcropping beneath Powell Valley (Harris, 1967). Harris (1970) combined this data with the concepts developed by Wilson and Stearns (1958) and developed a detailed model for the Pine Mountain overthrust. He concluded that the Chattanooga thrust at the southeast end of the Jacksboro fault and the Pine Mountain thrust originated from a single sole fault in the Rome formation and ramped to different stratigraphic levels. These were connected by the Jacksboro fault. He suggested that wrench faults in the subsurface are

the cause of structures which die out abruptly or trend perpendicular to the regional strike (Figure 1). The Bales fault developed later and warped the Pine Mountain fault, resulting in the formation of the Powell Valley anticline. Miller (1973) proposed a similar model for the evolution of the Pine Mountain overthrust and suggested that gravity sliding was the cause of movement.

D. Present Investigation

The use of fabric analysis has recently seen widespread use in structural studies. Sander (1948) is largely responsible for the development of these techniques. The techniques have been used primarily in metamorphic terrains, but they have been successfully applied in non-metamorphic rocks in the French Jura (Lindstrom, 1962) and Canadian Rockies (Price, 1964, 1967; Roeder, 1967). More recently Yust (1975), Roper (1977), and Roeder, Yust and Little (in preparation) have demonstrated that the techniques can be quite useful in the Valley and Ridge of east Tennessee. No studies of this type are known for the Pine Mountain system.

The present study area includes the Jacksboro fault and associated structures along the southwestern end of the Pine Mountain overthrust block (Figure 2). Portions of six 7.5 minute quadrangles were investigated: Lake City, Jacksboro, Clinton, Pioneer, Ivydell, and Block.

Field work was carried out over a period of approximately one year, starting in February, 1976. Data were collected from individual outcrops, primarily in the areas near Lake City and Caryville (Figure 2)

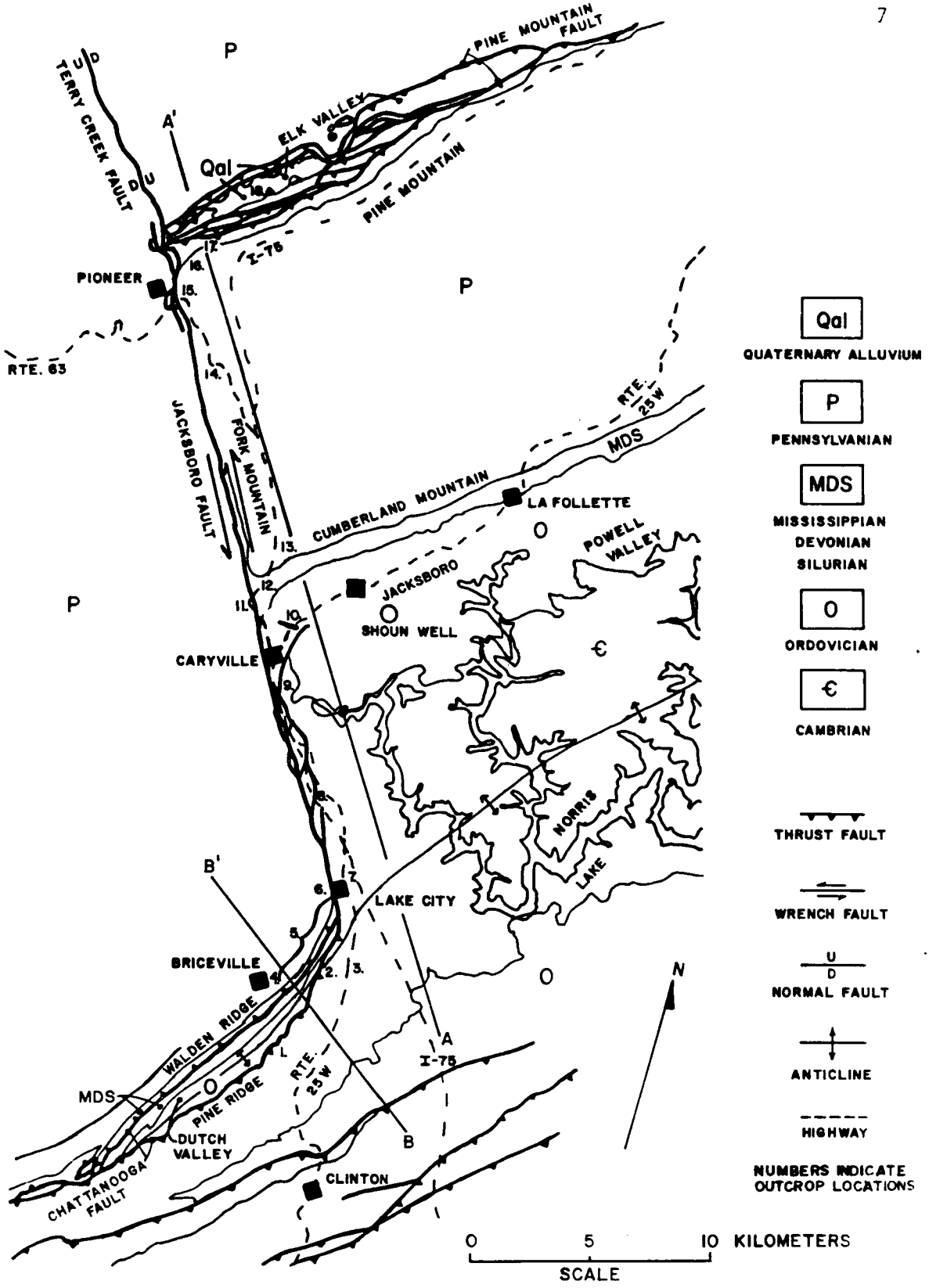


Figure 2. Generalized geologic map of the area studied (modified from Swingle et al., 1966). Lines A-A' and B-B' indicate positions of structure sections, plates I and II (in pocket).

where outcrops containing mesoscopic structures are most abundant. Fabric data were plotted on lower hemisphere equal area (Schmidt) projections. Finally regional cross sections were constructed by utilizing data both collected in the field and available from existing maps and literature.

Each outcrop was approached in a similar manner. First, the structural style was described. Next, mechanical and sequential relationships as seen in the outcrop were interpreted for the various structural elements. Finally, orientation data were used to estimate the kinematic axes of deformation and, as far as possible, to infer the mechanical or sequential relationships.

In this paper data are compared and contrasted in an attempt to relate the mesoscopic structures to the major macroscopic structural features. Ultimately a regional deformational model is formulated.

CHAPTER II

GEOLOGIC SETTING

A. General Statement

The area studied in this report lies along the northwestern margin of the Valley and Ridge province and adjacent parts of the Cumberland Plateau province in Tennessee. Rocks in this portion of the Valley and Ridge are predominantly sedimentary and are cut by numerous thrust faults which are accompanied by asymmetric folds parallel to the thrusts. Dips are predominantly to the southeast, however, the northwest limbs of folds often contain beds dipping steeply towards the northwest. Rocks of the Cumberland Plateau are also sedimentary and are generally flat lying, however, along the front with the Valley and Ridge they are upturned homoclinally and have vertical dips. Further south the Plateau is gently warped, forming the Sequatchie Valley anticline.

B. Stratigraphy

Rocks in the study area range from the lower Cambrian Rome Formation to the Pennsylvanian Cross Mountain Group. A complete stratigraphic sequence about 3700 meters thick is present (Figure 3).

The rocks are quite varied and consist of shales, sandstones, conglomerates, and carbonates (Figure 3). Fabric data presented is not restricted to any formation or lithology but represents all the

SYSTEM	FORMATION			DOMINANT LITHOLOGY
PENNSYLVANIAN	CROSS MOUNTAIN GROUP	Pcgm		SANDSTONE SHALE (COAL)
	VOWELL MOUNTAIN GROUP	Pvm		
	REDOAK MOUNTAIN GP.	Prm	ANDERSON SANDSTONE	
	GRAVES GAP GP.	Pgg	SCOTT SHALE	
	INDIAN BLUFF GP.	Pib	JELLICO FORMATION	
	SLATESTONE GP.	Ps	BRICEVILLE FORMATION	
	CROOKED FORK GP.	Pcf		
	CRAB ORCHARD MOUNTAINS AND GIZZARD GROUPS	Pcg	LEE FORMATION	CONGLOMERATE SANDSTONE SHALE (COAL)
MISSISSIPPIAN	PENNINGTON FORMATION	Mp		SHALE
	NEWMAN FORMATION	Mn		LIMESTONE
	FORT PAYNE CHERT	Mfp		CHERTY LIMESTONE
DEVONIAN	CHATTANOOGA SHALE	MDc		SHALE
SILURIAN	ROCKWOOD FORMATION	Sr		SHALE, SILTSTONE
ORDOVICIAN	SEQUATCHIE FORMATION	Os		SHALY LIMESTONE
	CHICKAMAUGA LIMESTONE	Och	REEDSVILLE SHALE Or	CALCAREOUS SHALE
			UPPER CHICKAMAUGA LIMESTONE Ouc	LIMESTONE
			LOWER AND MIDDLE CHICKAMAUGA LIMESTONE Olmc	SHALY LIMESTONE
	CHEPULTEPEC, LONGVIEW AND NEWALA FORMATIONS	Ocn		SILICEOUS DOLOMITE
CAMBRIAN	COPPER RIDGE DOLOMITE	€cr		SILICEOUS DOLOMITE
	CONASAUGA SHALE	€c		SHALE LIMESTONE
	ROME FORMATION	€r		SHALE

Figure 3. Stratigraphic column showing lithologies. Formation name symbols are those used in structure sections (Plates I and II, in pocket).

lithologic types present in the area. The main factors controlling outcrop distribution are apparently the location of Interstate 75 and local structural setting. Indeed, most of the data were gathered along roadcuts on the Interstate.

Detailed descriptions of the formations present in the area have been given elsewhere (Rodgers, 1953; Byerly, 1957; Englund, 1957, 1958, 1968; McCallum, 1958; Swingle, 1960 a,b; Luther, 1967). Therefore only brief descriptions are given here. Nomenclature is that of Swingle (1960 a,b).

Cambrian System

The Rome Formation is approximately 300 meters thick (this and all of the following thickness estimates are from Swingle, 1960a, b, unless otherwise noted). It consists of reddish brown to maroon shale interbedded with siltstone, sandstone, and occassionally carbonate. The Conasauga Shale consists of thin bedded gray to black shale interbedded with limestone and is approximately 300 meters thick. The Copper Ridge Dolomite consists of dark gray, fine grained, massive dolostone and black cryptozoan chert and is estimated to be 300 meters thick.

Ordovician System

The upper Knox Group, containing the Chepultepec, Longview, and Newala Formations, is estimated to be 600 meters thick and consists of interbedded massive dolostone and limestone. The Chickamauga Limestone consists of massive, fossiliferous, blue gray limestone with abundant shaly partings and is approximately 550 meters thick. The

Reedsville Shale consists of 60 to 90 meters of olive green, calcareous shale. The Sequatchie Formation consists of thin bedded, reddish brown, calcareous shale and argillaceous limestone and is about 335 meters thick.

Silurian System

The Silurian is represented by the Rockwood Formation, an interbedded sequence of brown gray to reddish brown, thin bedded shale and siltstone 90 to 150 meters thick.

Devonian and Mississippian Systems

The Chattanooga Shale (Devonian-lower Mississippian) consists of thin bedded black, shale and is between 6 and 18 meters thick. The Fort Payne Chert (Mississippian) consists of siliceous dolostone and limestone containing abundant light gray chert and is about 60 meters thick. The Newman Formation (Mississippian) ranges between 120 meters (Luther, 1967) and 215 meters in thickness and consists of light gray fossiliferous limestone with occassional shale beds. The Pennington Formation (Mississippian) is an argillaceous shale, with interbedded carbonate and sandstone, ranging from 30 to 215 meters thick (Luther, 1967; Swingle, 1960a, b).

Pennsylvanian System

Rocks of the Pennsylvanian System are 1500 meters thick and contain the following groups: Crab Orchard Mountains and Gizzard Groups (undifferentiated), Crooked Fork Group, Slatestone Group, Indian Bluff Group, Graves Gap Group, Redoak Mountain Group, Vowell Mountain Group,

and Cross Mountain Group. These consist primarily of sandstone and shale with conglomerate beds in the lower groups and minor (although economically important) coal seams.

C. Structure

Pine Mountain Mountain Overthrust

Underlying the Pine Mountain overthrust sheet is the Pine Mountain fault (Plate 1). This is essentially a bedding plane thrust (Butts, 1927). At its southwestern end it lies in the Rockwood Formation near the contact with the Sequatchie Formation, although further north it lies in the Chattanooga Shale. The fault ramps upward to the surface along the base of Pine Mountain where it splits into several imbricate slices.

The fault originates in the Rome Formation but ramps upward to younger rocks beneath Powell Valley. Movement on the fault is estimated at 17.7 kilometers (Englund, 1968) at its southwestern end, but this diminishes to the northeast until displacement at its terminus along the Russel Fork fault is only about 3.2 kilometers (Wentworth, 1921). Associated structures include homoclinal folds on either side of Elk Valley and several smaller folds located there.

Powell Valley Anticline

The Powell Valley anticline is located southeast of Cumberland Mountain. This broad topped anticline apparently dies out to the northeast (Harris, 1970), but is well developed in the Jacksboro area. Butts (1921) and Rich (1934) demonstrated that the Pine Mountain fault is

involved in this structure and that the fault plane ramps from the Rome Formation to the Chattanooga shale beneath it. Evidence of ramping of the fault along the Powell Valley anticline was further substantiated by the drilling of the N. A. Shoun number one test well one kilometer east of Jacksboro (Milhous, 1959) in which Cambrian dolomite lies on top of beds belonging to the Sequatchie Formation at a depth of about 600 meters (Milhous, 1959; Englund, 1968).

Middlesboro Syncline

This broad syncline which lies between Cumberland Mountain and Pine Mountain, is 12 kilometers wide. To the northwest it is bounded by beds dipping approximately 30° southeast which were folded as the Pine Mountain fault ramped upwards. To the southeast the syncline is bounded by the vertical beds of the Cumberland Mountain monocline (Miller and Fuller, 1954) which represents the extreme edge of the northwestern limb of the Powell Valley anticline. Between these two bounding folds beds are flat lying and relatively undisturbed.

Jacksboro Fault

The most unusual structural feature in the area studied is the Jacksboro cross fault. The fault plane is vertical at the surface but Englund (1968) and Swingle (1960a, b) considered it to flatten and merge with the Pine Mountain overthrust at depth. Movement was not restricted to a single plane but was taken up along several subparallel, interconnecting surfaces.

Total length of the fault is approximately 32 kilometers. It originates near Lake City, Tennessee, where the Chattanooga thrust makes

an abrupt right angle turn toward the northwest (Figure 1, page 2; Figure 2, page 7). This bend is topographically expressed by Walden and Pine Ridges. The fault continues northwest to Elk Valley where the Pine Mountain fault terminates against it. Beyond this point the zone of disturbance continues to the northwest along the Terry Creek fault, a hinged normal fault on which the sense of displacement reverses (Figure 2, page 7) due to folding of the strata directly in front of the Pine Mountain block.

Rocks on either side of the Jacksboro fault are folded with orientations typical of folds formed as a result of wrenching (Wilcox, et al., 1973). Large folds occur along Walden Ridge, Fork Mountain, and Chestnut Ridge. Smaller folds are scattered throughout the areas around Caryville and Lake City and presumably elsewhere along the fault.

Chattanooga Fault

At its southeastern end the Jacksboro Fault merges with the Chattanooga thrust (Figure 1, page 2; Figure 2, page 7). This fault continues to the southwest along the base of Walden Ridge. The fault brings Cambrian rocks of the Rome Formation into contact with Mississippian and Pennsylvanian rocks. However, at several places along its length the fault splits, exposing Ordovician rocks between the two spurs. Rodgers (1953) hypothesized that these are windows through a folded thrust which extends beneath the Cumberland Plateau, but recent authors, including Rodgers (1970), have interpreted

them as slices from the main thrust. One of these features occurs in the thesis area in Dutch Valley, southeast of Lake City (Figure 2, page 7).

To the southeast Dutch Valley is bounded by Pine Ridge. This is formed by the Rome Formation which has been thrust upon the Chickamauga Formation. Dips in the Rome Formation average about 45° to the southeast, but small folds are present within the thrust sheet. To the northwest the valley is bounded by Walden Ridge, on which rocks of the Pennington Formation are in fault contact with the Fort Payne and Newman Formations. These rocks have been upwarped and overturned by folding which accompanied faulting. Along the crest of Walden Ridge beds are nearly vertical, but overturned Pennsylvanian strata dip as much as 50° to the southeast at various places along the Ridge. In Dutch Valley rocks of Ordovician through Mississippian age are exposed between the aforementioned faults. The Chickamauga Limestone and the Chattanooga fault are folded into an asymmetric anticline, the Dutch Valley anticline, with its axial surface dipping to the southeast. Younger rocks are exposed on the northwest limb of the anticline.

CHAPTER III

INTERPRETATION OF STRUCTURE

A. Introduction

The fabric (Sander, 1948) of a geological body records the deformational history of that body. Therefore, at least theoretically, it should be possible to infer the deformational history of a given body by studying the geometrical relationships of the various elements, or structures, which make up the fabric (Turner and Weiss, 1963).

The orientation of fabric elements can be defined by their relationships to a triaxial coordinate system whose orientation is determined by the overall stress field controlling deformation. These coordinate axes are referred to as the strain axes and are denoted a, b, and c. The a-axis is defined as being parallel to the direction of maximum lengthening, the c-axis is parrallel to the direction of maximum shortening, and the b-axis is perpendicular to the plane containing the a- and c-axes (termed the ac-plane). The orientation of the stress field may change with time. Therefore, the orientation of the strain axes may also vary for structures produced during separate phases of deformation. It is this relationship which is employed in geometric analysis.

B. Macroscopic Structure

Relationships between macroscopic structures are shown in Plates I and II. Plate I is a cross-section along line A-A' of Figure 2,

page 7. This cross-section is based on surface data available from existing geologic maps, field observations made by the author, and subsurface data obtained from drilling (Milhous, 1959; Harris, 1967). The Pine Mountain fault ramps from a bedding plane sole in the Rome Formation (Cambrian) to a bedding plane at the base of the Rockwood Formation (Silurian) beneath the Powell Valley anticline, exposing rocks of the Rome Formation near Lake City and causing Cambrian dolomite to be thrust upon the Sequatchie Formation (upper Ordovician) near Jacksboro (Milhous, 1959). The fault ramps to the surface in Elk Valley, northwest of Pine Mountain (Figure 2, page 7), where rocks belonging to the lower Rockwood and upper Sequatchie Formations lie on top of Pennsylvanian strata. Evidence obtained from the Bales well in Lee County, Virginia (Harris, 1967), and by extrapolating strata thicknesses downward from the surface indicates that the Bales fault also ramps from basal Rome beneath Powell Valley, joining the Pine Mountain fault as a bedding thrust in the base of the Rockwood Formation. The Pine Mountain fault has been folded to accomodate the duplication of beds caused by movement on the Bales fault (Harris, 1967), indicating that the Bales thrust is the younger fault.

Plate II is a cross-section across Dutch Valley along line B-B' of Figure 2, page 7. This section is based entirely on surface data. It shows that the structure of the Chattanooga fault is similar to that of the Pine Mountain fault. The Chattanooga fault originates as a bedding thrust in the Rome Formation and ramps upward along the southeast limb of the Dutch Valley anticline. Rocks of the Rome Formation

lie above the Chickamauga Formation (Ordovician) along the northwestern slope of Pine Ridge (Figure 2, page 7) and along Walden Ridge (Figure 2, page 7) the Pennington Formation lies directly on top of the Fort Payne chert or, in some places, the lower Newman limestone indicating that the fault has flattened out. This suggests that the fault ramps into the base of the Pennington Shale. Downward extrapolation of bed thicknesses also suggests that this is the location of the fault beneath the Cumberland Plateau and that the fault plane has been folded by a lower fault subcropping beneath Dutch Valley. The trace of the Dutch Valley anticline lies approximately in line with the trace of the Powell Valley anticline. Therefore, it is concluded that this lower fault is an extension of the Bales fault. Rodgers (1953) proposed a similar origin for fault structures along the base of the Cumberland Escarpment to the southwest and more recently Roeder (1975) proposed a similar mechanism for the formation of the Nittany Arch along the Allegheny front, of which the Cumberland Escarpment is a part (Milici, 1970), in Pennsylvania. Other workers in the Dutch Valley area (Swingle, 1960b, 1964) and along the Cumberland Escarpment elsewhere in Tennessee (Wilson and Stearns, 1958; Milici, 1970, 1975) have interpreted these structures to be imbricate thrusts. Such an interpretation is not consistant with the surface orientation of the rocks. Swingle's (1960b, 1964) cross-sections show thrust faults cutting bedding at right angles. This relationship is not generally seen elsewhere in the Valley and Ridge. In addition, it does not adequately account for the occurrence of Ordovician rocks in Dutch Valley.

C. Tectonic Style

Tectonic style (Appendix A) is commonly used in structural investigations of deformed rocks. Folds belonging to different generations commonly show different tectonic styles (Hobbs, et al., 1976). However, Williams (1970), working in New South Wales, Australia, pointed out that this technique should be used with caution as the style within a generation of folds may vary with lithological differences and several generations of folding may have overlapping styles. In the area covered by this report it was found that style is controlled by the lithologic character of the rocks as shown in Figure 4. Figure 4A shows rocks of the Conasauga Group at location 3 (location map, Figure 2, page 7). The rocks consist of alternating limestone and shale beds, generally one meter or less in thickness. The folds are close flexural flow folds (Appendix A). Figure 4B shows an open flexural slip fold in sandstone of the Conasauga Group at location 7. Figure 4C shows a close flexural slip fold in the Newman Limestone at location 12. Close folds in which both flexural slip and flexural flow have occurred are shown in Figure 4D. This outcrop is a shale in the Newman Formation at location 12. These styles are typical of folds developed in the aforementioned rock types, regardless of the age of the rocks or the generation of folding. Thus, style is not a criterion which can be used to unravel the deformational history of this area.



A



B

Figure 4. Fold styles. A. Close flexural flow folds at location 3. B. Open flexural slip fold at location 7. C. Close flexural slip fold at location 12. D. Close folds in which both flexural slip and flexural flow have occurred at location 12.



C



D

Figure 4. (Continued)

D. Orientation

Throughout the Valley and Ridge province in Tennessee there is a consistent orientation to the structural fabric. Figure 5 shows data collected by the author and others under the direction of D. H. Roeder during 1975 from folds associated with the Saltville thrust at Sharp's Gap in Knoxville. The data indicate a vertical ac-plane and a nearly horizontal b-axis trending at roughly 45 degrees. Similar orientations have been found for folding associated with the Pulaski fault (Roper, 1977), the Great Smoky fault (Livingston, 1977), and in the Tellico-Sevier belt (Yust, 1976). It can be reasonably expected that a structure which cuts across regional strike in the manner and on the scale of the Jacksboro fault should cause a reorientation of the local stress field. This should in turn be reflected in the orientation of strain found in the deformed rocks.

During the present investigation, mesoscopic folds with three distinct orientations were found. One group was associated with the Pine Mountain and Chattanooga faults, another with the Bales fault, and the third with the Jacksboro fault. In addition, overprinting relationships indicate that all three thrust faults are older than the Jacksboro fault. A detailed discussion of these relationships follows.

Figure 6 shows data collected during the present investigation at locations 1 and 4 near Dutch Valley, 13 along Cumberland Mountain near Caryville, and 17 in Elk Valley (location map, Figure 2, page 7). The orientations of these folds are similar to those located in other

Figure 5. Orientation of fabric elements at Sharp's Gap, Knoxville, Tennessee (228 ss contoured at .25%, .5%, 1%, 2%, and 4% per 1% area). The following legend refers to this and all other orientation diagrams in this text. All of the symbols shown are not necessarily used in each diagram.

- • ss
- ○ h0l
- ▫ hk0
- △ 0kl
- ■ hkl
- ⊙ Axial surface
- ● cleavage (s_1)
- • cleavage (s_2)
- ▲ cleavage (s_3)
- × fold axis
- ⊕ b-axis
- - - - ac-plane
- ↗ slickenside (arrow points in direction of movement where determinable)
- —·—· small circle of rotation



Figure 5.

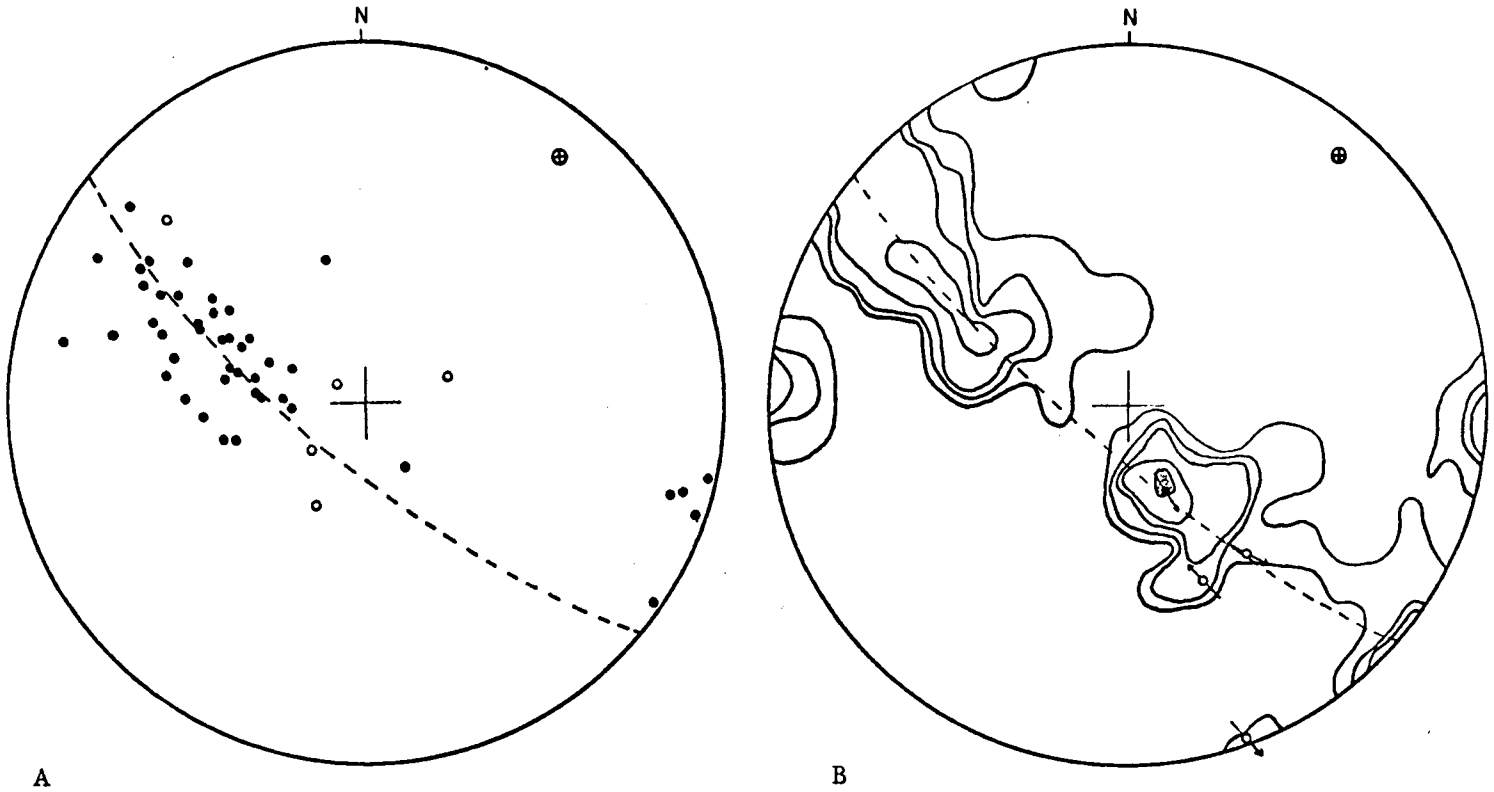


Figure 6. Orientation of fabric elements at locations 1, 4, 13, and 17. A. Location 1. B. Location 4 (64 ss contoured at 1%, 2%, 4%, 8%, and 16% per 1% area). C. Location 13 (72 ss contoured at 1%, 2%, 4%, 8%, and 16% per 1% area). D. Location 17.

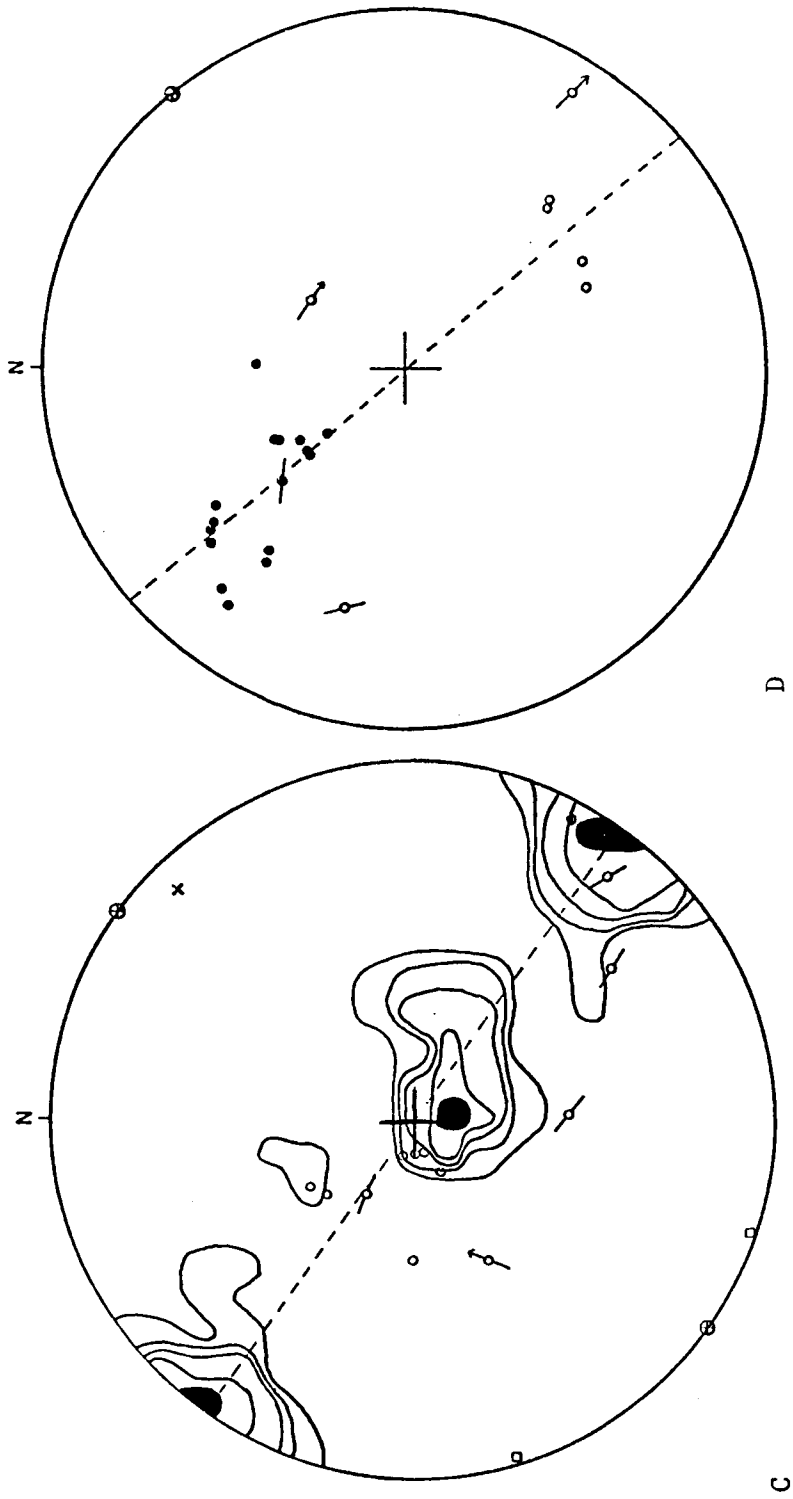


Figure 6. (Continued).

parts of the Valley and Ridge in Tennessee. Figure 7 shows data collected at location 10 (Figure 2, page 7). The orientation of the b-axis has changed slightly, but it is still close to that of the regional fabric. Therefore, the folding depicted in Figures 6 and 7 is believed to predate the Jacksboro fault. The locations and orientations of these structures indicate that they formed as a result of thrusting on the Pine Mountain and Chattanooga faults. The slight variation from the regional fabric depicted in Figure 7 may be the result of later modification caused by wrenching.

Figure 8 shows data collected along the crest of Walden Ridge (location 5, Figure 2, page 7). The data reflect steeply dipping beds folded about a vertical b-axis. Such an orientation is inconsistent with deformation accompanying thrusting. However, it could be consistent with wrenching provided the beds has already been folded into a vertical position. This indicates that the folding along Walden Ridge (Figure 6B) formed as a result of thrusting on the Chattanooga fault and was modified by wrenching.

Data collected at locations 3, 7, 8, and 9 near Lake City and Caryville (Figure 2, page 7) are shown in Figure 9. The b-axes trend between 5 degrees and 25 degrees. This is similar to the strike of the Dutch Valley anticline (Figure 2, page 7). This anticline formed as a result of movement on the Bales fault. Since the orientation of the b-axis of the Dutch Valley anticline is the same as the b-axes shown in Figure 9, they are concluded to belong to the same phase of deformation. The variations in b-axis orientations, especially at

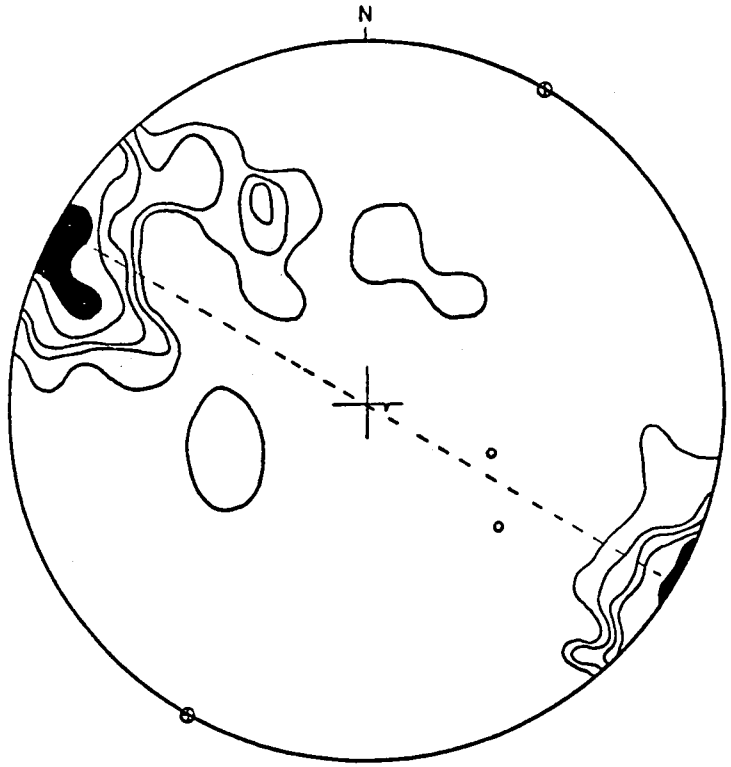


Figure 7. Orientation of fabric elements at location 10 (51 ss contoured at 1%, 2%, 4%, 8%, and 16% per 1% area).

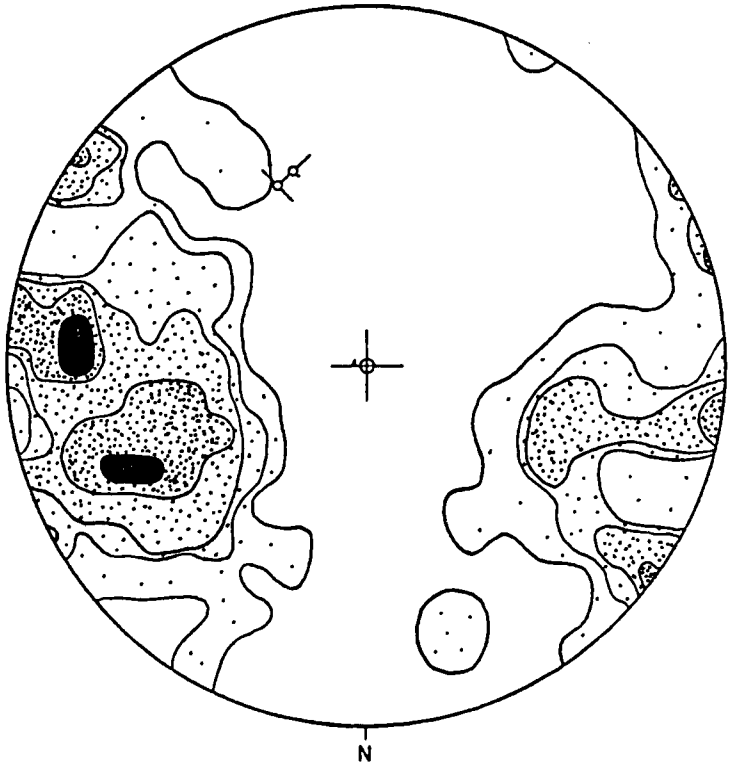


Figure 8. Orientation of fabric elements at location 5 (210 ss contoured at .25%, 1%, 4%, and 8% per 1% area).

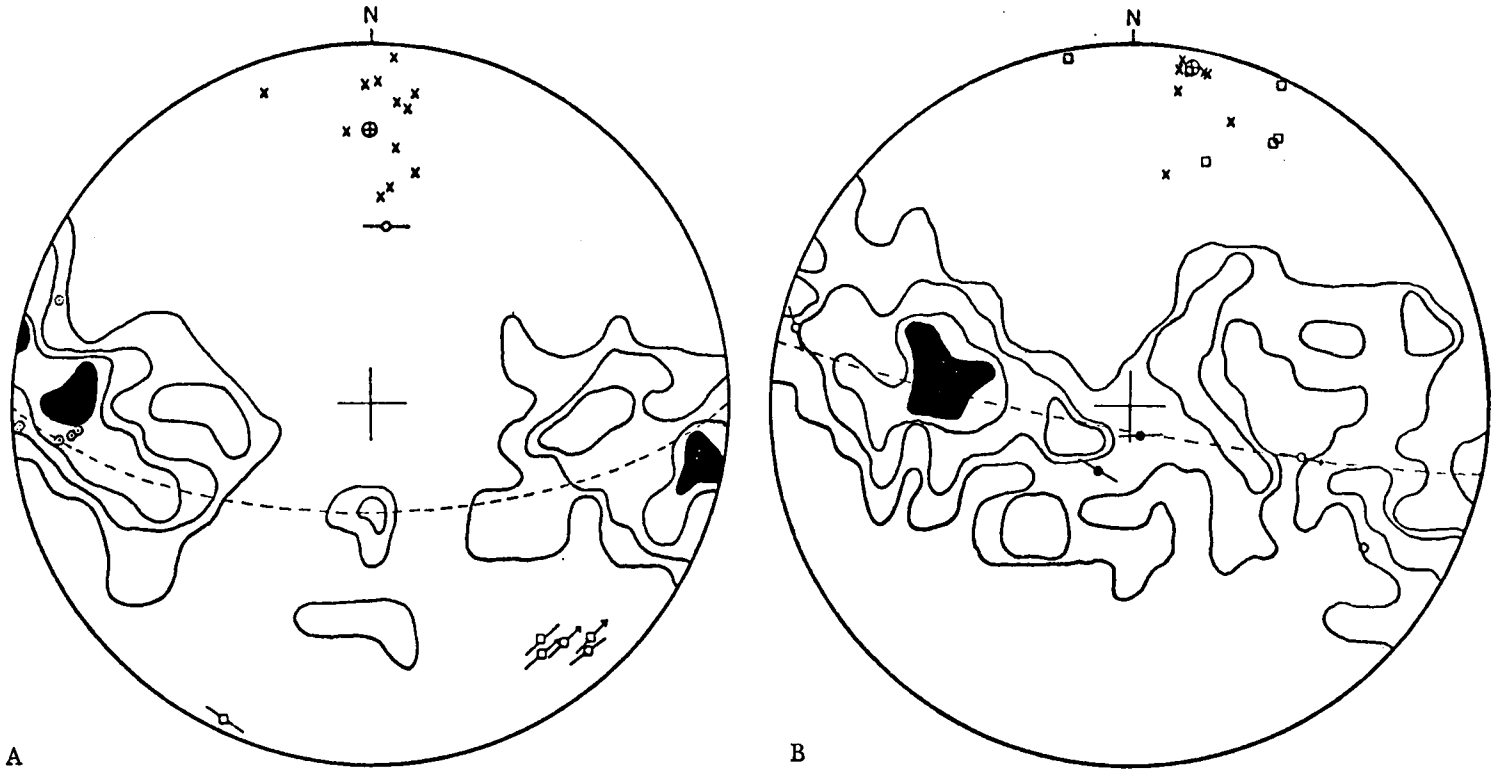


Figure 9. Orientation of fabric elements at locations 3, 7, 8, and 9. A. Location 3 (61 ss contoured at 1%, 2%, 4%, and 8% per 1% area). B. Location 7 (86 ss contoured at 1%, 2%, 4%, and 8% per 1% area). C. Location 8 (208 ss contoured at .25%, 1%, 2%, 4% and 8% per 1% area). D. Location 9 (139 ss contoured at .5%, 1%, 2%, 4%, and 8% per 1% area).

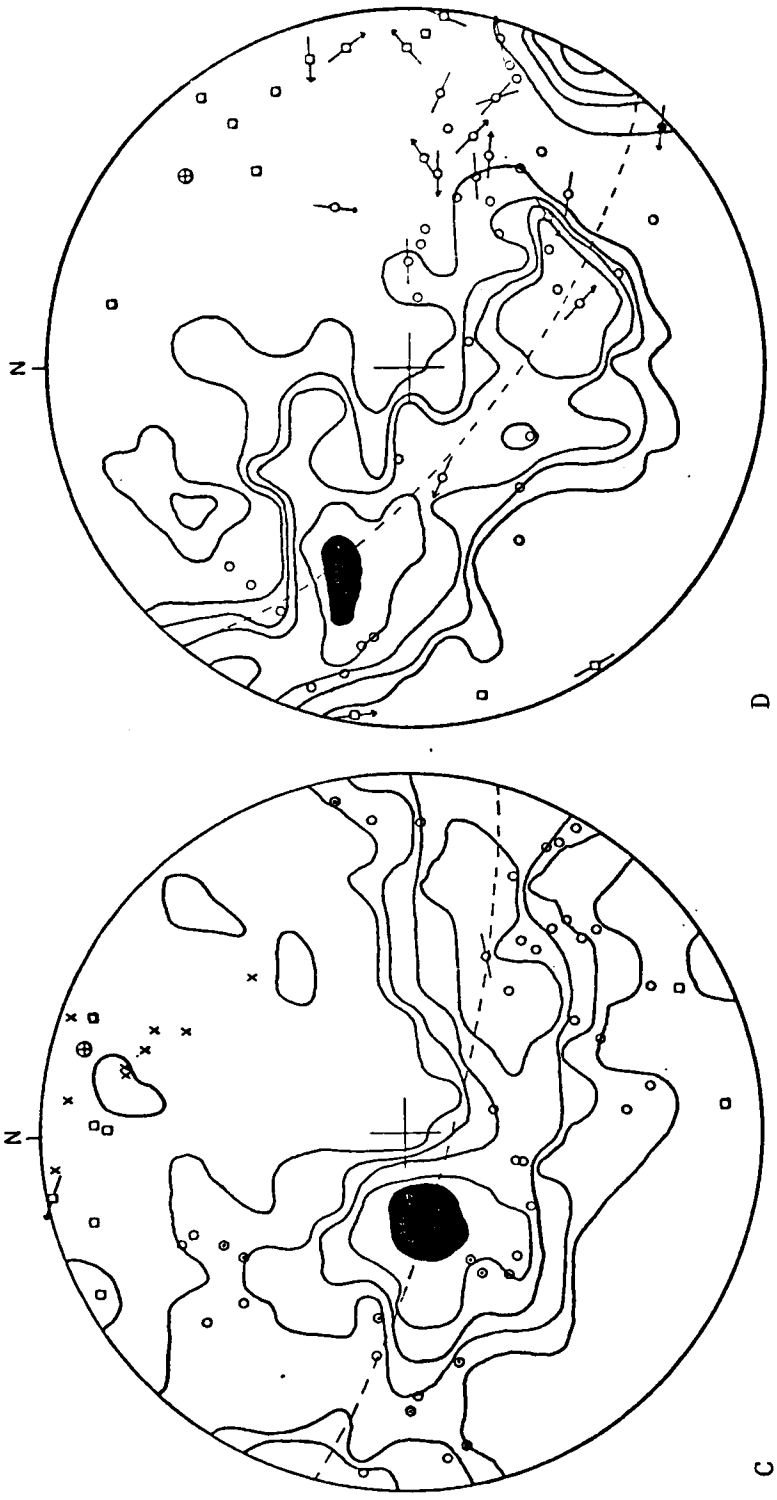


Figure 9. (Continued).

location 3, may be the result of either overprinting on deformation accompanying earlier motion on the Pine Mountain and Chattanooga faults or modification by a later phase of deformation.

Figure 10 shows data collected at location 2 near Lake City (Figure 2, page 7). Figure 10A depicts folds with their b-axis trending approximately 20 degrees and dipping 30 degrees northeast, while Figure 10B depicts folds with their b-axis trending roughly 130 degrees and dipping 25 degrees northwest. These two fold sets are less than 20 meters apart and indicate the superposition of one fold generation upon another (Weiss, 1959; Turner and Weiss, 1963; Ramsay, 1967). Axial surfaces for both of these fold sets dip steeply. Figure 10C shows the fold axes and axial surfaces from Figures 10A and 10B plotted on one diagram. Fold axes plot on a small circle about an axis trending 115 degrees and plunging 54 degrees. This orientation is compatible with wrenching on the Jacksboro fault. Axes of the folds depicted in Figure 9 also lie on this small circle. Therefore, it is likely that the folds depicted in Figures 10A and 10B belong to the same generation as those of Figure 9, but were later modified by wrenching. This indicates that thrusting on the Bales fault preceded wrenching on the Jacksboro fault.

Data collected from folds in outcrops at locations 6 (near Lake City), 11 and 14 (near Caryville), 15 (near Fork Mountain) and 16 (in Elk Valley, see location map, Figure 2, page 7) are shown in Figure 11. Their orientations are significantly different from those previously mentioned and it is unlikely that they had the same origin.

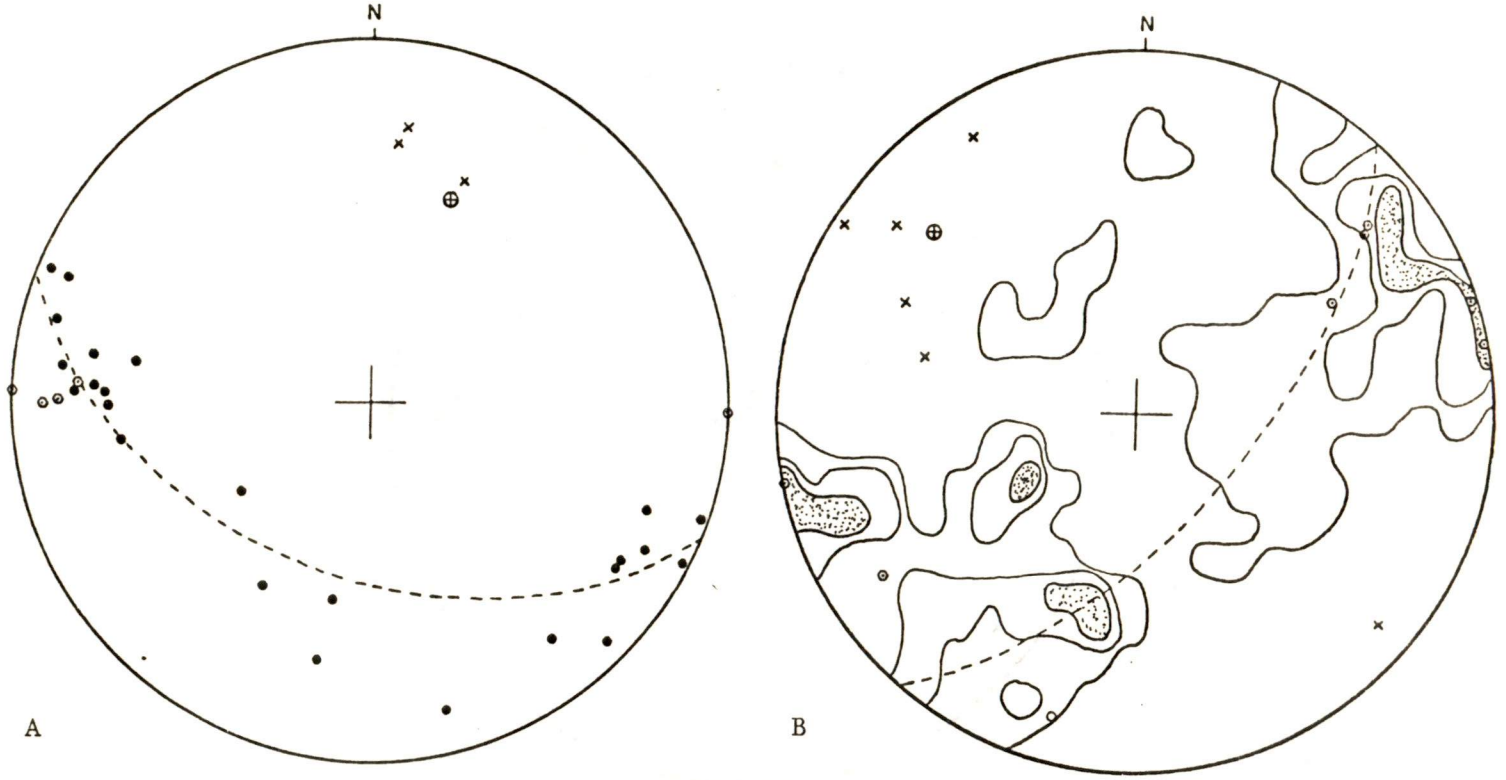


Figure 10. Orientation of fabric elements at location 2. A. East end of outcrop. B. West end of outcrop (54 ss contoured at 1%, 2%, 4%, 8%, and 16% per 1% area). C. Axial surfaces and fold axes from entire outcrop.

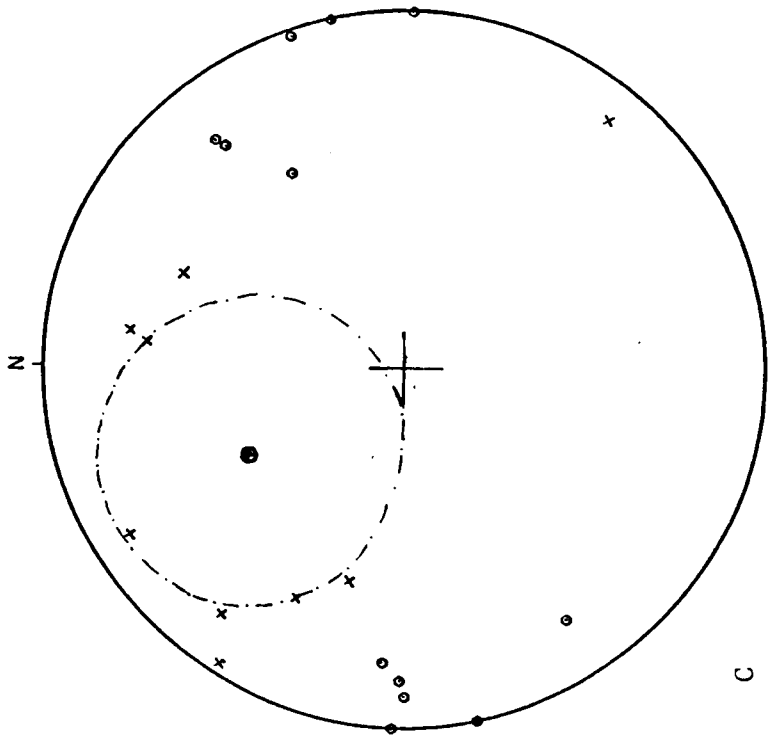


Figure 10. (Continued).

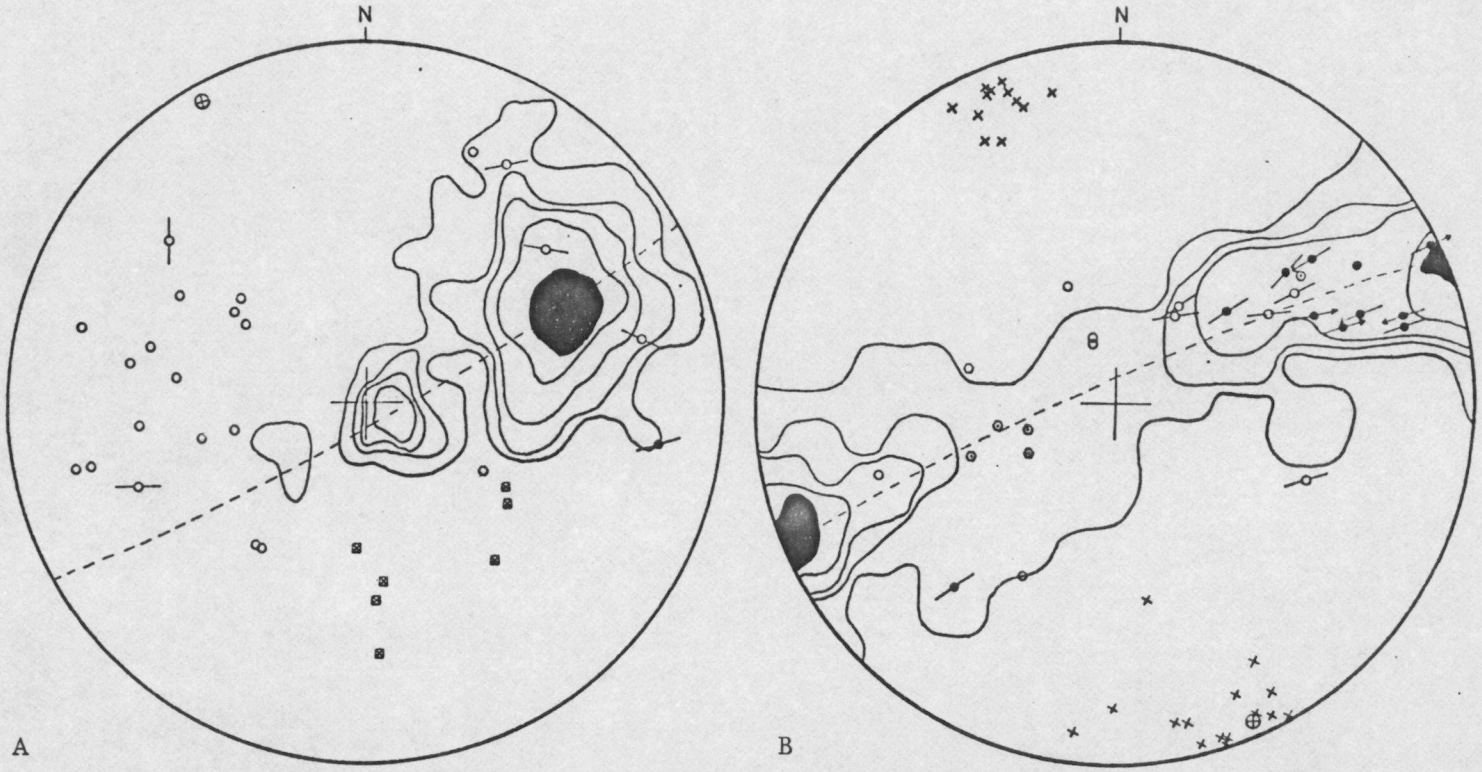
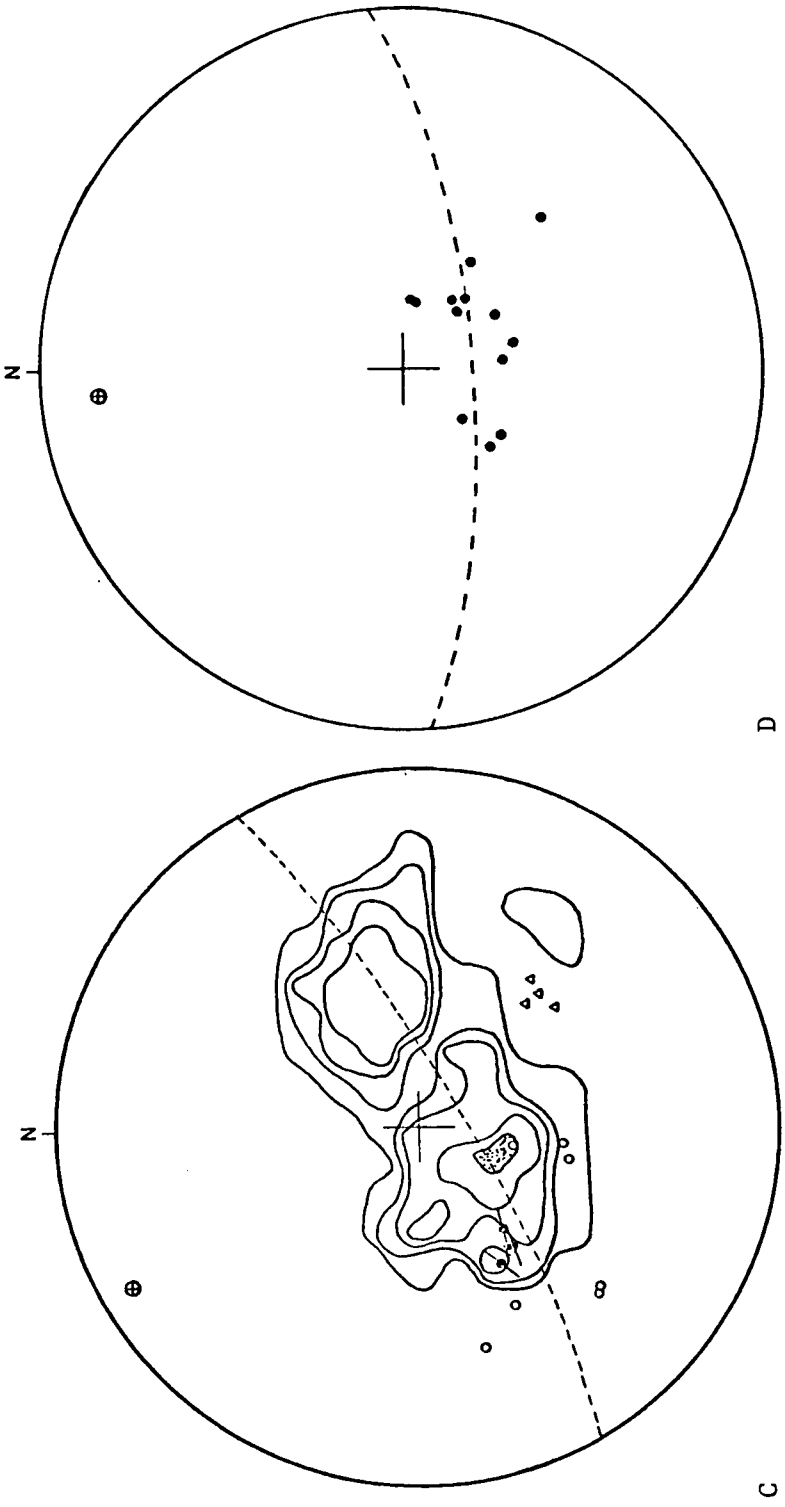


Figure 11. Orientation of fabric elements at locations 6, 11, 15, and 16. A. Location 6 (81 ss contoured at 1%, 2%, 4%, 8%, and 16% per 1% area). B. Location 11 (138 ss contoured at .5%, 2%, 4%, 8%, and 16% per 1% area). C. Location 14 (72 ss contoured at 1%, 2%, 4%, 8%, and 16% per 1% area). D. Location 15. E. Location 16.



D

C

Figure 11. (Continued)

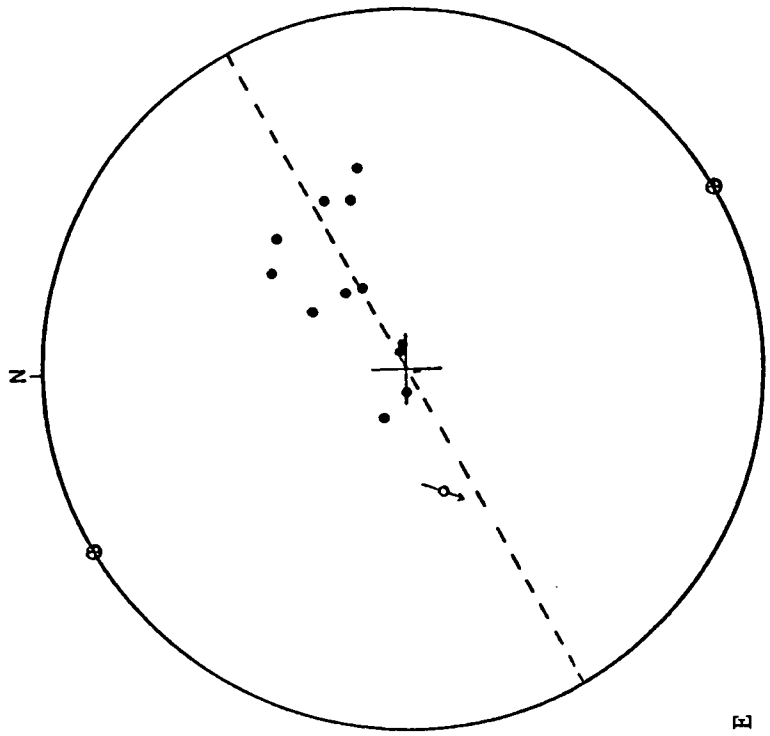


Figure 11. (Continued)

Wilcox et al. (1973) have demonstrated with both field and experimental evidence that folds form en echelon along wrench systems with b-axes diverging from the strike of wrenching at an angle of 30 degrees, plus or minus 15 degrees; this angle may be modified by convergent wrenching. This is approximately the orientation of the folds shown in Figure 11. In addition, Wilcox et al. (1973) showed that wrenching produces a system of conjugate strike-slip faults. In a left-handed wrench system (such as the Jacksboro fault) left-lateral faults are formed synthetic to wrenching while right-lateral faults are antithetic, showing small displacement and significant rotation. Conjugate faults of this nature were found at location 12 near Caryville accompanying folds whose orientation (Figure 12) is similar to that of the folds shown in Figure 11. Therefore, the deformation depicted by Figures 11 and 12 is concluded to have resulted from wrenching and to be younger than the folding which accompanied thrusting.

The homoclinal folding along the Cumberland Escarpment northwest of Dutch Valley is similar to that northwest of Powell Valley. The style is large, open flexural slip folding. The same formations are involved. The size of the folds is of the same order of magnitude, and their orientations are identical (Figure 6, page 26). The displacement between them is approximately equal to the displacement along the Jacksboro fault estimated by Englund (1968) using stratigraphic thicknesses; therefore, it is concluded that this was originally a single fold. Both of these locations are on the flanks of folds formed

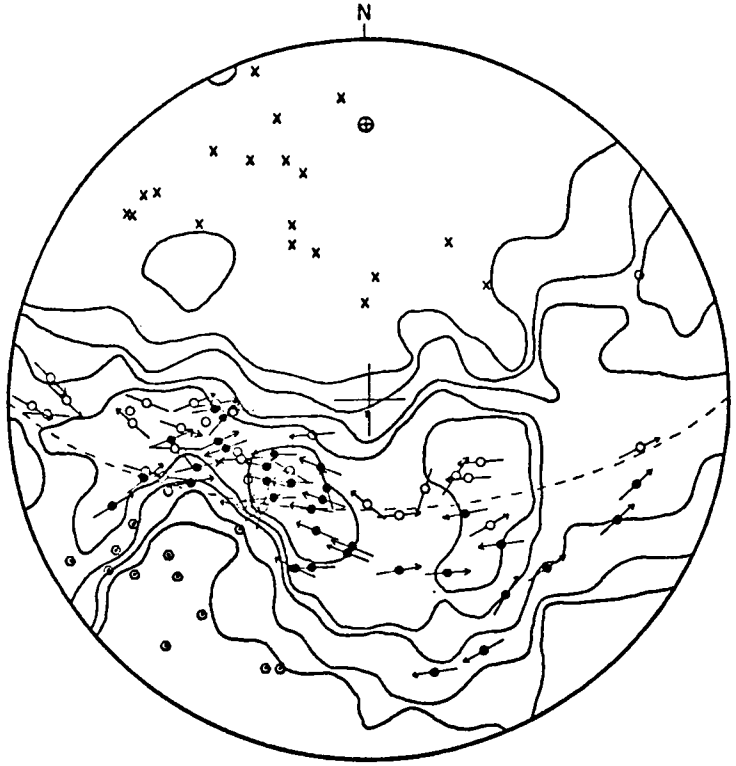


Figure 12. Orientation of fabric elements at location 12. A. Bedding (333 ss contoured at .25%, .5%, 1%, 2%, and 4% per 1% area), h01 axial surfaces, and foldaxes. B. Right-lateral strike-slip faults (260 hk0 contoured at .25%, .5%, 1%, 2%, and 4% per 1% area). C. Left-lateral strike-slip faults (167 hk0 contoured at .5%, 1%, 2%, 4%, and 8% per 1% area).

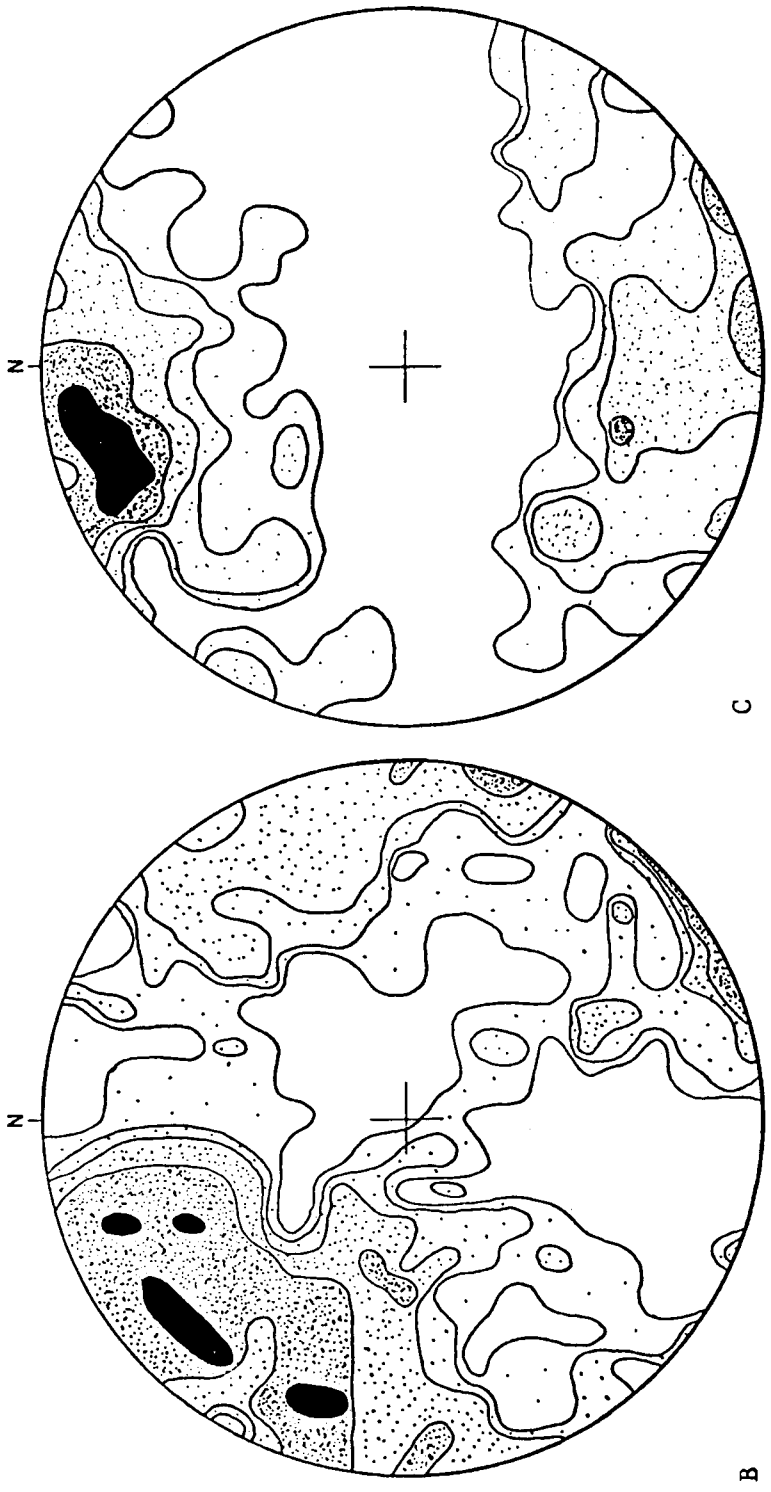


Figure 12. (Continued)

by the initial faulting along the Pine Mountain and Chattanooga thrusts and modified by the emplacement of the Bales fault, indicating that the Bales thrust also predates the Jacksboro fault.

E. Development of Deformation

Data presented thus far have shown that three separate episodes of deformation were involved in the formation of the Pine Mountain overthrust. An initial thrusting phase (T-1) on the Pine Mountain and Chattanooga faults (T-2) was followed by a second thrusting phase on the Bales fault. Renewed movement on the Pine Mountain and Chattanooga faults (T-3) accompanied by wrenching on the Jacksboro fault (Harris, 1970) constitute the last major phase of deformation. The development of these thrust sheets is summarized in Figure 13.

The earliest phase (T-1) involved movement along a sole fault in the Rome Formation and ramping beneath the general area now occupied by Powell and Dutch Valleys. Ramping was accompanied by a lateral change in the stratigraphic position of the fault. To the northeast the Pine Mountain fault flattened out in the base of the Rockwood Formation, while to the southwest the Chattanooga fault continued upwards into the Pennington Formation. These two levels of thrusting were connected by a wrench fault of the type described by Wilson and Stearns (1958). Total displacement along this fault cannot be accurately estimated from the data available at present. However, by calculating the approximate offset between beds exposed in the allochthonous block

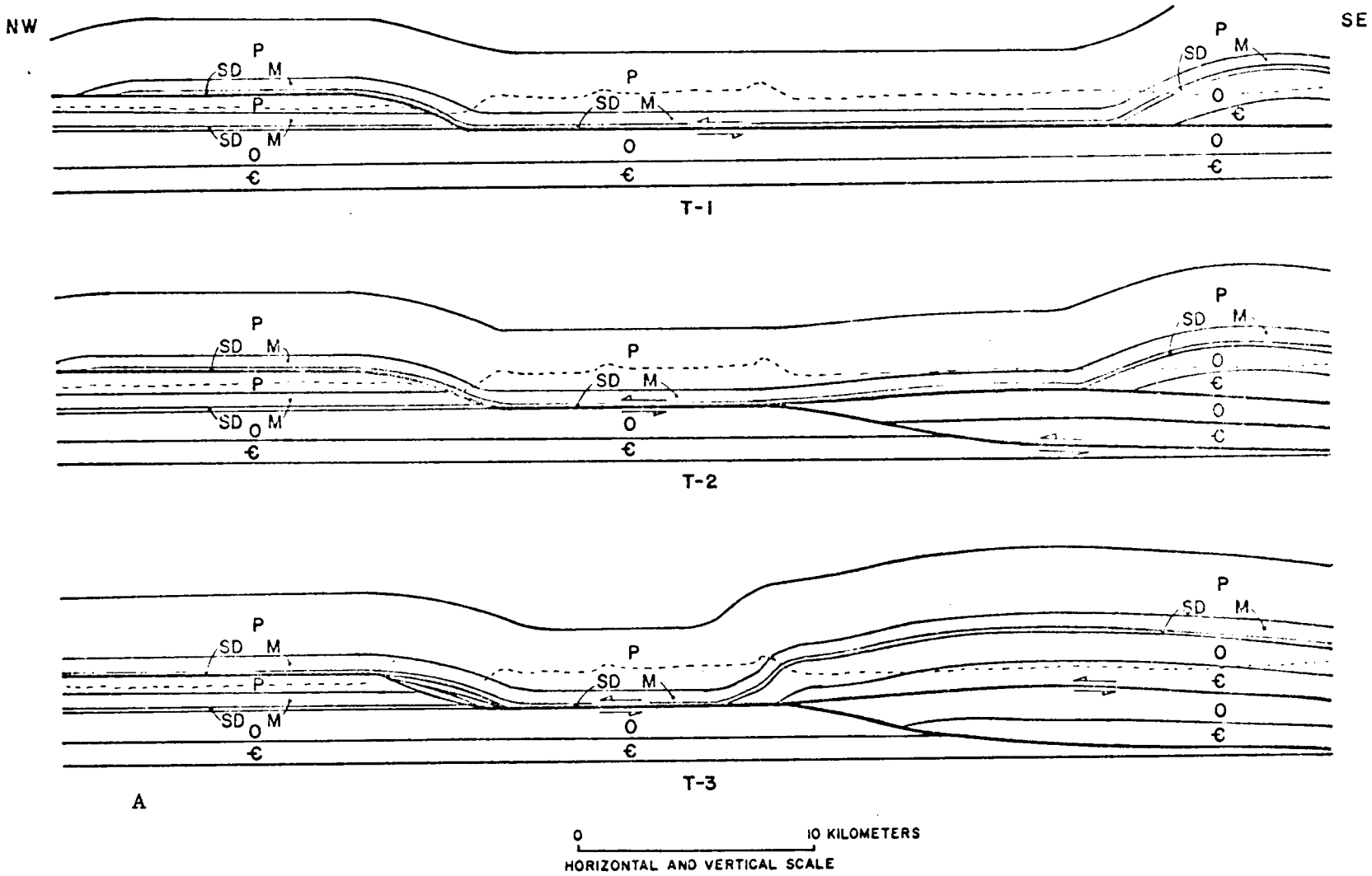


Figure 13. Sequential development of structure. A. Pine Mountain (line A-A', Figure 2). B. Dutch Valley (line B-B', Figure 2). Dashed lines indicate present surface.

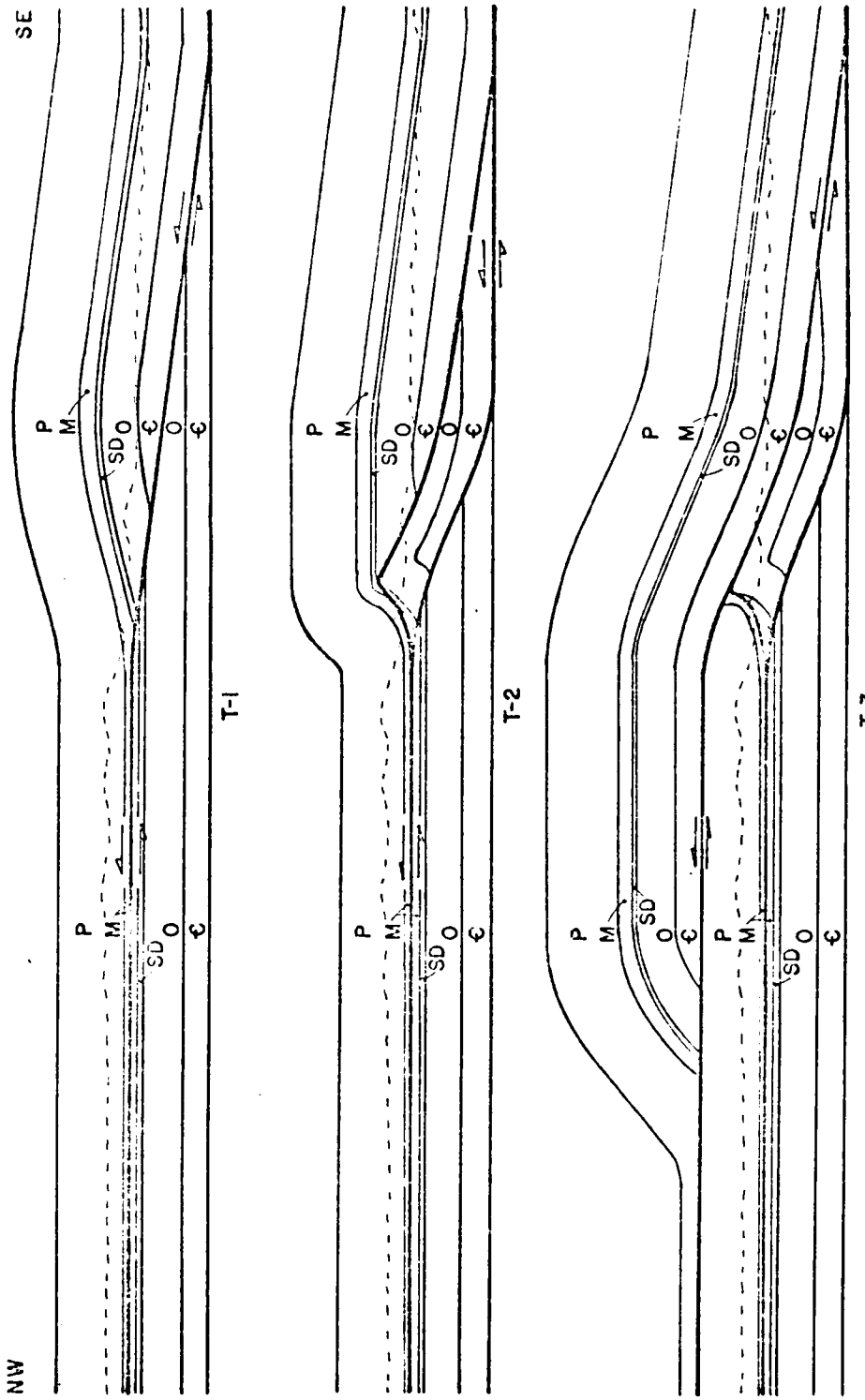


Figure 13. (Continued)

on the northwest limb of the Dutch Valley anticline and the estimated position of the same beds in the autochthonous block along a fault surface dipping 35 degrees (the approximate dip of beds in the allochthonous block) an estimate of 5 to 8 kilometers is obtained for displacement during this phase (Figure 13).

T-2 movement occurred along the Bales fault. This fault developed from the sole fault in the Rome Formation and ramped upward beneath the Powell Valley-Dutch Valley anticline to the northwest of the Pine Mountain-Chattanooga thrust (Figure 13). Ramping along the Bales fault was also accompanied by a lateral change in stratigraphic position; this fault rejoined the Pine Mountain-Chattanooga fault system in the Rockwood and Pennington Formations beneath the respective portions of the thrust sheet. The duplication of beds resulting from ramping warped the earlier (and stratigraphically higher) thrust sheet, thus enlarging the Powell Valley-Dutch Valley anticline. Based on the amount of duplication inferred from downward extrapolation of bed thicknesses (Chapter II), T-2 displacement along the Bales fault is estimated at 3.5 kilometers. Harris (1967) made a similar estimate for displacement on the Bales fault in Lee County, Virginia.

The last thrusting phase (T-3) involved renewed movement on the Pine Mountain-Chattanooga fault system (Figure 13). Thrusting on the Pine Mountain fault was not greatly influenced by the Powell Valley anticline. However, the increased stratigraphic thickness duplicated beneath the Dutch Valley anticline had resulted in a tighter fold being formed. This acted as an effective barrier against movement along the Chattanooga fault in the Pennington Formation, with the result

that the Chattanooga fault ramped upward to a higher stratigraphic level or to the surface. The Jacksboro fault formed as a connecting fault plane between these two levels of thrusting (Harris, 1970). Englund (1968) compared stratigraphic thicknesses on each side of the fault and found that displacement along the Jacksboro fault is 17.7 kilometers. The Jacksboro fault was active only during T-3. Therefore, this estimate applies to the displacement along the Pine Mountain and Chattanooga faults during T-3 as well.

Structures reflective of shortening due to T-1 and T-2 deformation should be present in the Cumberland Plateau northwest of the Chattanooga fault. This portion of the Plateau is largely unmapped. However, Avery and Luther (1970) noted the presence of local gentle folds and subtle changes in the regional dip. Statler and Sykes (1970) noted that this entire portion of the Plateau is underlain by the Wartburg basin, a gentle syncline bounded by the Cumberland Escarpment on the southeast and the Cincinnati Arch on the northwest.

F. Depth of Thrusting

Roeder (1967) suggested that deformation in thrust sheets occurs in two distinct depth dependent zones. The upper, or frontal, zone is characterized by folding, with decreasing transport along and steepening of the thrust surface (Roeder et al., in preparation), and lengthening along the b-axis. The lower, or transport, zone exists beneath 3 to 4 kilometers of overburden and is characterized by a lack of folding, subhorizontal lengthening along the thrust sheet in the

direction of transport, and shortening parallel to the b-axis (Roeder, 1967; Roeder et al., in preparation). The fabrics presented thus far indicate subhorizontal shortening and folding and are concluded to have formed under frontal conditions.

Data collected at location 18 in Elk Valley (Figure 2, page 7) are shown in Figure 14. Folds in bedding are oriented with their b-axis trending 85 degrees and plunging 20 degrees to the southeast (Figure 14A). Three distinct sets of cleavage, denoted s_1, s_2, and s_3 with no inference to genetic relationships, were also observed at this outcrop. S_2 and s_3 are located along a great circle which also contains a significant portion of the bedding poles. The orientation of this girdle is the same as that established for T-1 folds found elsewhere. Figure 14B shows bedding and s_1 rotated 20 degrees about the b-axis of the girdle formed by s_2, s_3, and bedding (Figure 14A) and combined. The result is a girdle parallel to the T-1 b-axis, indicating shortening parallel to this axis. This suggests transport zone deformation during T-1 and implies burial at a depth significantly greater than the 750 meters at which the Pine Mountain fault is presently buried. Alternately, some heretofore undescribed mechanism may have acted along the fault surface causing an increase in pore pressure, thereby bringing transport zone conditions nearer to the surface. This problem deserves further investigation. It is probable that rocks favorable to bedding plane thrusting (shales) would have existed in the sedimentary pile somewhere above the present level of the Pine Mountain fault and that ramping into these beds occurred.

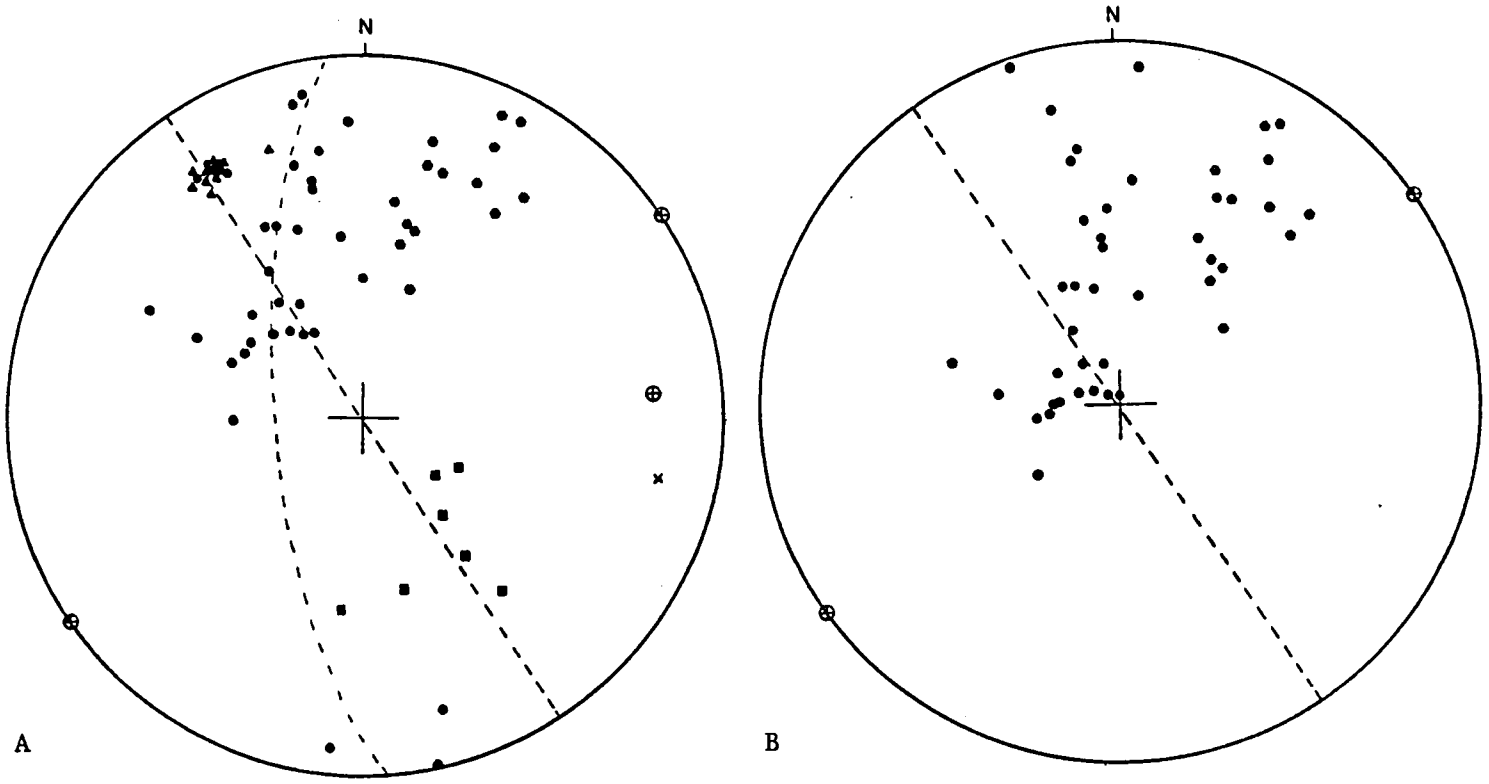


Figure 14. Orientation of fabric elements at location 18. A. Bedding and cleavage (s_1, s_2, s_3). B. Bedding and s_1 rotated 20 degrees about b-axis.

Beyond the northwest end of the Jacksboro fault the Terry Creek fault extends the zone of deformation for about 8 kilometers into the Cumberland Plateau. This fault probably reflects wrenching in the strata above it. It is therefore possible that the northwestern end of the Terry Creek fault indicates reuniting of the Pine Mountain and Chattanooga faults in the same stratigraphic unit.

G. Age of Deformation

Deformation along the Cumberland Escarpment is generally believed to be late Pennsylvanian or Permian (Rodgers, 1970). Lower Pennsylvanian rocks are deformed along the Cumberland Escarpment, Pine Mountain, and the Jacksboro fault. However, it has been suggested that thrusting began prior to this, perhaps as early as Devonian (Roeder, 1975). The earliest phase of deformation (T-1) observed during this investigation involved ramping into rocks of upper Mississippian (Pennington Formation). Therefore, T-1 could not have occured until very late in the Mississippian or in the Pennsylvanian. Miller and Fuller (1954) noted that the Cumberland Mountain monocline is more sharply folded than the Powell Valley anticline and is probably older. The model presented in this paper calls for the inception of both of these structures to have begun during the earliest phase of thrusting (T-1). The age of T-1 is concluded to be no older than Pennsylvanian, as Pennsylvanian rocks form the backbone of Cumberland Mountain and are conformable with older rocks below. No structures which

predate T-1 were found during the present investigation. This does not rule out deformation at an earlier time, but it implies that a major thrusting phase did not occur until the Pennsylvanian and that any earlier event had only a slight impact on the local structure.

CHAPTER IV

CONCLUSIONS

Data collected during this investigation indicate that three distinct phases of thrusting occurred during the development of the Pine Mountain overthrust. The first phase occurred along a fault comprising the present day Pine Mountain and Chattanooga faults. Ramping into different stratigraphic levels caused the fault to split into two separate bedding thrusts connected by a wrench fault. The orientation of structures formed during T-1 is similar to that of the regional fabric in the Valley and Ridge. Folding along the present day Cumberland Escarpment, Dutch Valley anticline, Powell Valley anticline, and in Elk Valley accompanied this phase. The Cumberland Mountain monocline and Walden Ridge formed one continuous structure. T-2 occurred on the Bales fault, warping the Chattanooga and Pine Mountain faults. This caused further development of the Powell Valley and Dutch Valley anticlines. T-2 was followed by renewed activity on the T-1 thrust surface (T-3). The Pine Mountain fault continued to act as a slip surface, but the Chattanooga fault broke through the crest of the Dutch Valley anticline and ramped to a higher stratigraphic level. This caused the development of the Jacksboro fault, which acted as a connecting surface between the two levels of faulting. Minor structures were created during each phase of thrusting. Most of the folding occurred in the frontal zone of thrusting. However, data collected in Elk Valley indicate that in the earliest stages of

T-1 movement burial was sufficient to create transport zone conditions. This implies that a significant stratigraphic thickness has been removed by erosion.

Deformation associated with all three thrust phases involve Pennsylvanian rocks, indicating that thrusting was initiated late in the Pennsylvanian Period.

LIST OF REFERENCES

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Avery, G. G., and Luther, E. T., 1970, Geologic map and mineral resources summary of the Norma quadrangle, Tennessee: Tenn. Div. Geol. mineral resources summary MRS 128-sw, 18 p., and geologic map GM 128-sw, scale 1:24,000.

Badgley, P. C., 1965, Structural and tectonic principles: Harper and Row, New York, 521 p.

Butts, C., 1927, Fensters in the Cumberland over-thrust block in southwestern Virginia: Virginia Geol. Sur., Bull. 28, 12 p.

Byerly, D. W., 1957, The geology of the northern portion of Dutch Valley, Anderson County, Tennessee: Unpublished master's thesis, University of Tennessee, Knoxville, 43 p.

Clark, R. H., and McIntyre, D. B., 1951, The use of the terms pitch and plunge: Am. J. Sci., v. 249, p. 591-599.

Coney, P. J., 1973, Plate tectonics of marginal foreland thrust-fold belts: Geology, v. 1, no. 3, p. 131-134.

de Sitter, L. U., 1964, Structural geology: McGraw-Hill, New York, 551 p.

Donath, F. A., and Parker, R. B., 1964, Folds and Folding: Geol. Soc. Am. Bull., v. 75, p. 45-62.

Englund, K. J., 1957, Geology and coal resources of the Pioneer quadrangle, Scott and Campbell Counties, Tennessee: U. S. Geol. Sur. coal investigations map C-39, scale 1:24,000.

Englund, K. J., 1958, Geology and coal resources of the Ivydell quadrangle, Campbell, Tennessee: U. S. Geol. Sur. coal investigations map C-40, scale 1:24,000.

Englund, K. J., 1968, Geology and coal resources of the Elk Valley area, Tennessee and Kentucky: U. S. Geol. Sur. Prof. Pap., no. 572, 59 p.

Fleuty, M. J., 1964, The description of folds: Geol. Assoc. Proc., v. 75, p. 461-492.

Gay, N. C., 1970, The formation of step structures on slickensided shear surfaces: J. Geol., v. 78, p. 523-532.

Glenn, L. C., 1925, The northern Tennessee coal field: Tenn. Div. Geol. Bull. 33-B, p. 36-42, and p. 136-141.

Harris, L. D., 1967, Geology of the L. S. Bales well, Lee County, Virginia--a Cambrian and Ordovician test: Kentucky Geol. Sur. spec. pub. 14, ser. 10, p. 50-55.

Harris, L. D., 1970, Details of thin-skinned tectonics in parts of Valley and Ridge and Cumberland Plateau provinces of the southern Appalachians in Fisher, G. W., Pettijohn, F. J., Reed, J. C., Jr., and Weaver, K. N., eds., Studies of Appalachian geology: central and southern (Cloos vol.) John Wiley and sons, New York, p. 161-173.

Harris, L. D., 1976, Thin-skinned tectonics and potential hydrocarbon traps--illustrated by a seismic profile in the Valley and Ridge province of Tennessee: J. Res. U. S. Geol. Sur., v. 4, p. 379-386.

Harris, L. D., and Zietz, I., 1962, Development of Cumberland Overthrust block in vicinity of Chestnut Ridge fenster in southwest Virginia: Am. Assoc. Pet. Geol. Bull., v. 46, no 12, p. 2148-2160.

Hobbs, B. E., Means, W. D., and Williams, P. F., 1976, An outline of structural geology: John Wiley and Sons, New York, 571 p.

Keith, A. L., 1896, Briceville folio: U. S. Geol. Sur., Geol. Atlas, no. 33.

King, P. B., 1951, The tectonics of middle North America: Middle North America east of the Cordilleran system: Hafner, New York, p. 125-131.

Livingston, J., 1977, Structural analysis in the Great Smoky thrust sheet, Tennessee: Unpublished master's thesis, University of Tennessee, Knoxville, in preparation.

Luther, E. T., 1967, Geologic map and mineral resources of the Block quadrangle, Tennessee: Tenn. Div. Geol., geologic map GM 128-SE, scale 1:24,000.

McCallum, M. E., 1958, The geology of the western half of the Jacksboro quadrangle, Campbell County, Tennessee: Unpublished master's thesis, University of Tennessee, Knoxville, 72 p.

Milhous, H. C., 1959, Well logs in Tennessee: Tenn. Div. Geol., Bull. 62, p. 13-18.

Milici, R. C., 1970, The Alleghany structural front in Tennessee and its regional tectonic implications: Am. J. Sci., v. 268, p. 127-141.

Milici, R. C., 1975, Structural patterns in the southern Appalachians: evidence for a gravity slide mechanism for Alleghanian deformation: Geol. Soc. Am. Bull., v. 86, p. 1316-1320.

Miller, R. L., 1973, Structural setting of hydrocarbon accumulations in folded southern Appalachians: Am. Assoc. Petroleum Geologists Bull., v. 57, p. 2419-2427.

Miller, R. L. and Brosge, W. P., 1954, Geology and oil resources of the Jonesville district, Lee County, Virginia: U. S. Geol. Sur. Bull., v. 990, p. 169-205.

Miller, R. L., and Fuller, J. O., 1954, Geology and oil resources of the Rose Hill District--the fenster area of the Cumberland overthrust block--Lee County, Virginia: Vir. Geol. Sur. Bull., no. 71, p. 256-265.

Paterson, M. S., 1958, Experimental deformation and faulting in Wombeyun marble: Geol. Soc. Am. Bull., v. 69, p. 465-476.

Price, R. A., 1964, Flexural-slip folds in the Rocky Mountains, southern Alberta and British Columbia: Seminars in tectonics - IV, Dept. Geol. Sci., Queen's Univ., Kingston, Ont., p. 6-21.

Price, R. A., 1967, The tectonic significance of mesoscopic subfabrics in the southern Rocky Mountains of Alberta and British Columbia: Can. Jour. Ea. Sci., v. 4, p. 39-70.

Ramsay, J. G., 1967, Folding and fracturing of rocks: McGraw-Hill, New York, 568 p.

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

Rodgers, J., 1949, Evolution of thought on structure of middle and southern Appalachians: Am. Assoc. Petroleum Geologists Bull., v. 33, p. 1643-1654.

Rodgers, J., 1953, Geologic map of east Tennessee with explanatory text: Tenn. Div. Geol., Bull. 58, part II, 168 p.

Rodgers, J., 1970, The tectonics of the Appalachians: John Wiley and Sons, New York, p. 20-28.

Roeder, D. H., 1967, Rocky Mountains: Berntraeger, Berlin-Nikolasse p. 226-243.

Roeder, D. H., 1975, Polyphase thrusting in the Valley and Ridge: Geol. Soc. Am. Abs. w. Prog., v. 7, p. 527-528.

Roeder, D. H., Yust, W. W., and Little, R. L., 1978, Folding in the Valley and Ridge province of Tennessee: Am. J. Sci., in preparation.

Roper, D., 1977, Mesoscopic fabric analysis of the Babb's Knobs area (Pulaski thrust, east Tennessee): Unpublished master's thesis University of Tennessee, Knoxville, in preparation.

Safford, J. M., 1869, Geology of Tennessee: Nashville, Tennessee, p. 141-143.

Saman, N. F., 1976, Sedimentation and stratigraphy of the Rome Formation in east Tennessee: Unpublished doctoral dissertation, University of Tennessee, Knoxville, 337 p.

Sander, B., 1948, An introduction to the study of fabrics of geological bodies, part I, translated by F. C. Phillips and G. Windsor: Pergamon Press, Braunschweig, Germany, 186 p.

Statler, A. T., and Sykes, C. R., 1970, Geologic map and mineral resources summary of the Duncan Flats guadrangle, Tennessee: Tenn. Div. Geol. Geologic map GM 129-NE, scale 1:24,000, and mineral resources summary MRS 129-NE, 26 p.

Stearns, R. G., 1954, The Cumberland Plateau overthrust and geology of the Crab Orchard Mountains area, Tennessee: Tenn. Div. Geol., Bull. 60, 47 p.

Stearns, R. G., 1955, Low-angle overthrusting in the central Cumberland Plateau, Tennessee: Geol. Soc. Am. Bull., v. 66, p. 615-628.

Swingle, G. D., 1960a, Geologic map of the Jacksboro quadrangle, Tennessee: Tenn. Div. Geol., Geologic map 136-SW, scale 1:31,680.

Swingle, G. D., 1960b, Geologic map of the Lake City quadrangle, Tennessee: Tenn. Div. Geol., Geologic Map 137-NW, scale 1:31,680.

Swingle, G. D., 1964, Geologic map and mineral resources summary of the Clinton quadrangle, Tennessee: Tenn. Div. Geol., Geologic Map GM 137-SW, scale 1:24,000.

Swingle, G. D., Miller, R. A., Luther, E. T., Hardeman, W. D., Fullerton, D. S., Sykes, C. R., and Garman, R. K., 1966, Geologic map of Tennessee, East-Central sheet: Tenn. Div. Geol., scale 1:250,000.

Tjia, H. D., 1964, Slickensides and fault movements: Geol. Soc. Am. Bull., v. 75, p. 683-686.

Turner, F. J. and Weiss, L. E., 1963, Structural analysis of metamorphic tectonites: McGraw-Hill, New York, 545 p.

Weiss, L. E., 1959, Geometry of superposed folding: Geol. Soc. Am. Bull., v. 70, p. 91-106.

Wentworth, C. K., 1921, Russell Fork fault in the geology and coal resources of Dickenson County, Virginia: Vir. Geol. Sur. Bull., no. 21, p. 53-67.

Wilcox, R. E., Harding, T. P., and Seely, D. R., 1973, Basic wrench tectonics: Am. Assoc. Petroleum Geologists Bull., v. 57, p. 74-96.

Wilson, C. W., Jr., and Stearns, R. G., 1958, Structure of the Cumberland Plateau: Geol. Soc. Am. Bull., v. 69, p. 1283-1296.

Yust, W. W., A mesoscopic fabric analysis of a portion of the Tellico-Sevier belt of east Tennessee: Unpublished master's thesis, University of Tennessee, Knoxville, 106 p.

APPENDICES

APPENDIX A

DESCRIPTION OF FABRIC ELEMENTS

DESCRIPTION OF FABRIC ELEMENTS

Bedding

Bedding, denoted ss in this study, is the most common planar element examined. It is assumed to have originally been nearly horizontal. Bedding imparts an anisotropy to the rocks which may play an active or passive role in subsequent deformation (Donath and Parker, 1964).

Folds

Folds are important in structural analysis because they record a significant portion of any deformation which affected the rocks containing them. They are commonly classified according to morphology, orientation of their axial surfaces with respect to the strain axes, and the dominant mechanism of their formation. Collectively these properties constitute their tectonic style. Commonly folds of a similar generation belong to the same style group. Thus the description of style is an important part of mesofabric analysis. In describing style the following terms are used:

Morphology. In describing the morphology of folds, the terminology of Fleuty (1964) is adhered to in this report. The term fold axis is used synonomously with hinge, that is the line connecting points of greatest curvature along the folded surface. Initially this line is parallel to the b-strain axis, but its shape and orientation may be modified by later deformation. To avoid confusion the term b-axis is applied only to axes constructed from pi-diagrams.

The axial surface has been defined by Clark and McIntyre (1951, Page 595) as "the locus of the hinges of all beds forming the fold."

Folds may be described according to the interlimb angle (Fleuty, 1964), that is "the minimum angle between the limbs as measured in the profile plane" (Fleuty, 1964, page 469). Gentle folds have interlimb angles from 180 to 120 degrees. Open folds range from 120 to 70 degrees. Close folds range from 70 to 30 degrees. Tight folds have interlimb angles from 30 to 0 degrees and folds with parallel limbs are termed isoclinal.

Axial orientation. Folds which develop with their axial surfaces essentially normal to the c-strain axis or direction of compression are called buckle folds. The a-strain axis statistically lies in their axial surfaces. These are by far the most abundant folds found in this investigation, and all folds described may be assumed to be buckle folds unless specifically designated otherwise.

Kink bands are folds whose axial surfaces develop along one or both directions of a conjugate shear pair oblique to the c-axis but parallel to the b-axis. Commonly the ac-plane bisects the shear planes, so it may still be possible to determine the orientations of all three strain axes from these folds.

Folding mechanism. Donath and Parker (1964) described a fold classification based on the mechanism of deformation and implied rheologic and tectonic conditions. Three of their fold types were recognized in this study: flexural slip, flexural flow, and passive slip. Flexural slip refers to folds in which the dominant mechanism

of deformation was slip between layers. This is often, but not always, accompanied by the formation of slickensides on bedding surfaces. Flexural flow results from flow within individual layers, but not across their boundaries. Generally this results in thickening of the hinge zones and thinning on the limbs (Donath and Parker, 1964; Ramsay, 1967). Most flexural folds result from a combination of these two processes, and as deformation proceeds the dominant mechanism commonly changes from flexural slip to flexural flow (de Sitter, 1964; Donath and Parker, 1964; Ramsay, 1967). Folds in which inherited layering does not play a significant role in fold development are termed passive (Donath and Parker, 1964). If slip occurs along discrete surfaces they are termed passive slip folds. If no slip occurs the term passive flow is applied. Passive folds are rare in the area studied.

Fractures

Two types of fractures were studied. Those on which slippage is known to have occurred are called faults, except where slippage occurred parallel to bedding surfaces. If no displacement occurred parallel to their surfaces the fractures are referred to as joints. Particular attention was given to recording joints whose surfaces have been mineralized, as these are indicators of extention.

The orientation of fractures with respect to the kinematic axes can be described using Miller indices. The leters h, k, and l, are used to denote intercepts of a fracture surface on the a-, b-, and c-axes respectively. Where the surface is parallel to one of the axes the number 0 is used.

Lineations

Aside from fold axes, slickensides were the only type of lineation examined in this investigation. Traditionally it has been believed that the direction of movement on a fault surfact could be inferred from the steps on the slickensided surface. These steps were believed to face in the direction of movement of the opposing face. However, recent experiments (Patterson, 1958; Gay, 1970) and field studies (Tjia, 1964) have indicated that this interpretation is not always correct. Yet field studies by Durney and Ramsay (1973, page 86) "have consistently confirmed the traditional interpretation of the 'roughness-smoothness' technique." Price (1967) has also used this technique with success. During the present investigation it was found that the traditional roughness-smoothness method indicated the correct direction of movement in all cases in which the sense of displacement could be verified or predicted by some other means. Therefore, this method was applied to cases in which the sense of displacement could not be corroborated by other means.

Cleavage

Cleavage was not widespread in the area studied, therefore extensive investigations were not carried out. It was present at one small outcrop in Elk Valley. Several measurements were made, but thawing of frost resulted in a slide which all but eliminated this outcrop. For this reason a detailed analysis of the cleavage relationships was not possible.

APPENDIX B

DESCRIPTION OF OUTCROPS

DESCRIPTION OF OUTCROPS

Location 1

This outcrop is located on Pine Ridge along the first road crossing the ridge southwest of Beets Road (southeast of Pine Ridge these roads merge) at latitude 36°09'30", longitude 84°09'30". The rocks belong to the Rome Formation and generally consist of red brown sandstone and shale. There is a massive dolomitic limestone unit which underlies a valley near the western side of the ridge. This appears somewhat anomalous in that it does not resemble any Rome carbonates exposed elsewhere in the area studied. However, Saman (1976) described similar rocks in the Rome Formation on Pine Ridge South (there are two separate Pine Ridges) near the base of the formation.

The rocks dip towards the southeast and strike approximately 40 degrees. Dips vary somewhat but are generally between 20 and 60 degrees. In addition, several small open folds (Fleuty, 1964) are present. Several surfaces in h01 are present. Folding is presumed to be the result of flexural slip, although no direct evidence of this was found. No flow structures were observed.

Orientation data (Figure 6A, p. 36) show a partial girdle of ss about a nearly horizontal b-axis trending 30 degrees. h01 surfaces are generally subhorizontal. No evidence of displacement on h01 surfaces was observed.

Location 2

Location 2 is situated in the gap through Pine Ridge on Dutch Valley Road behind an auto junk yard (latitude 36°12'10", longitude 84°09'00"). Rocks belong to the Rome Formation and consist of thin bedded red brown shale and siltstone. Open folds with vertical axial planes were observed. One joint in h01 was found.

Orientation data (Figure 10, p. 34) indicate the presence of two fold sets. Data collected from the eastern end of the outcrop are plotted in Figure 10A. Folds have a b-axis trending 20 degrees and dipping 40 degrees northeast. Axial surfaces strike north and are nearly vertical. Folds from the western end of the outcrop are depicted in Figure 10B. They have a b-axis trending 130 degrees and dipping 25 degrees northwest. Axial surfaces are spread out, striking between 140 and 170 degrees. Fold axes for both fold sets are spread out but plot in the general areas of their respective b-axes.

Figure 10C shows axial surfaces and fold axes from Figures 10A and 10B plotted on one diagram. The fold axes plot on a small circle about an axis trending 115 degrees and plunging 54 degrees northwest. Axial surfaces are widely scattered. It has been shown (Weiss, 1959; Turner and Weiss, 1963; and Ramsay, 1967) that patterns of this type are the result of superposed folding. Apparently the small folds observed in the outcrop and depicted graphically in Figures 10A and 10B have been refolded about a b-axis trending 115 degrees and plunging 54 degrees. The second generation folds are reflected by a change in the general attitudes of bedding along the length of the outcrop but are obscured by the earlier generation folds.

Location 3

Location 3 is located on route 25W south of Lake City in the parking lot of David's Motel (latitude 36°12'30", longitude 84°09'00"). The rocks are part of the Conasauga Formation. They consist of alternating beds of limestone and shale which are generally less than one meter thick.

The rocks are folded into tight folds which plunge gently north. Folding resulted from flexural flow accompanied by hinge collapse. Faults occur in hk0 with slickensides indicating right-lateral movement. Axial surfaces are nearly vertical.

Orientation data (Figure 9A, p. 31) show a girdle of ss about b-axis trending north and plunging 25 degrees in that direction. Fold axes generally agree with this orientation. Right-lateral hk0 surfaces strike 50 degrees and dip 75 degrees northwest. One fault in hk0 strikes 115 degrees and is nearly vertical; this is probably conjugate to the right-lateral set. Axial surfaces strike north-south and are almost vertical. The orientations of axial and hk0 surfaces indicate a vertical c-axis and a horizontal, east-west trending a-axis.

Location 4

Location 4, along Summit Road, originates in Briceville and traverses Walden Ridge, terminating in Dutch Valley (latitude 36°11' 00", longitude 84°10'15"). The rocks exposed belong to the Crooked Fork, Crab Orchard Mountains, and Gizzard Groups. They consist of sandstone with some conglomeratic units. The sandstones are often

cross bedded, and occasionally graded beds may be observed. Exposure is not continous but outcrops are frequent, rarely more than 100 meters apart.

Northwest of Walden Ridge are the flat lying rocks of the Cumberland Plateau. These have been upturned along the length of Walden Ridge and are overturned along the southeastern flank of the ridge, and locally along the crest and northwestern flank as well. Vertical beds are common and overturned beds with dips as low as 20 degrees occur also. Several surfaces in h01 containing slickensides were found. Slickensides on ss surfaces were also found indicating folding by flexural slip.

The data plot a tight partial girdle with a b-axis trending 40 degrees and plunging 10 degrees northeast (Figure 6B, p. 26). Very few data were obtained on beds dipping steeply northwest. However, this believed to result from lack of exposure; indeed such beds are common at other points along Walden Ridge (Figure 14, p. 48).

Location 5

Walden Ridge is a major feature both structurally and topographically in the area studied. This ridge sits in front of the Cumberland Plateau and extends southwest for a considerable distance. At Lake City the ridge makes a sharp, almost right angle turn (Figure 2, p. 7), trending northwest-woutheast to Indian Gap, near Caryville, where it breaks up and dies out.

Walden Ridge is formed by rocks of the Crooked Fork, Crab Orchard Mountains, and Gizzard Groups. These have been upturned from the flat lying rocks of the Cumberland Plateau and are vertical and

overturned along the ridge crest. The ridge is bounded on its southwest flank by the Chattanooga thrust. At Lake City this fault merges with the Jacksboro fault, which follows the northeastern flank of the ridge for the rest of the ridge's length.

Data was collected along the crest of the ridge from the Coal Creek gap (latitude 36°13'00", longitude 84°10'00") to Summit Road south of Briceville (latitude 36°11"00", longitude 84°10'15"). The ridge was traversed at Coal Creek and Summit Road; the traverses are discussed separately.

The strike of beds along the ridge crest changes from 155 degrees at Coal Creek to 40 degrees at Summit Road. Orientation data (Fig. 8, p. 30) show a partial girdle of ss about a vertical b-axis. Beds are generally steep dipping although there is considerable variation. This is partially due to cross bedding. Two surfaces with slickensides in h01 were observed, one associated with folding similar to that discussed for location 4, and one formed as the beds were folded about the vertical axis. The slip directions indicate that flexural slip was the mechanism of fold development in both cases. This implies that folding occured in two stages. The first resulted in vertical or steeply dipping beds striking northeast. These were then refolded about a vertical axis resulting in the present configuration.

Location 6

This outcrop is located along route 116 west of Lake City. The main outcrop from which data were collected along Coal Creek in the gap through Walden Ridge (latitude 36°13'00", longitude 84°10'00"). Data was also collected from flat lying beds one kilometer south on route

116. The rocks consist of sandstone and conglomerate beds belonging to the Crooked Fork, Crab Orchard Mountains, and Gizzard Groups. Cross bedding is common.

The beds are folded into one large structure. To the west they are horizontal, but they are upturned and vertical on Walden Ridge. Several faults in h0l and some joints perpendicular to ss in hkl were found. A third set of fractures in hkl is poorly developed.

Orientation data (Figure 11A, p. 36) show a partial girdle of ss with a b-axis trending 150 degrees and dipping gently northwest. The wide dispersion of the girdle is probably due to cross bedding. The hkl joints form a wide girdle whose orientation is perpendicular to the ss girdle and may reflect a separate phase of deformation. Slickenside orientations indicate flexural slip folding.

Location 7

Outcrop 7 is located along U. S. 441 west of the I-75 interchange in Lake City at the Freeway Stop and Shop market (latitude 36°13'45", longitude 84°09'20"). The rocks belong to the Conasauga Shale. Folds are asymmetric with axial planes dipping steeply towards the east. Calcite filled tension joints parallel to the ac-plane indicate lengthening along the b-axis. Faults were observed in h0l. Slickensides indicate flexural slip.

Orientation data (Fig. 9B, p. 31) show a girdle of ss about a north trending horizontal b-axis which is reflected by fold axes. Steeply dipping axial planes indicate a nearly vertical c-axis and subhorizontal a-axis.

Location 8

Location 8 is a roadcut on Interstate 75 just north of the northbound entrance ramp at Lake City (latitude 36°14'20", longitude 84°10'15"). Thin bedded reddish brown shales, siltstones and sandstones of the Rome Formation form asymmetric open folds with axial planes dipping to the southeast. Faults in h01 commonly have small folds in ss adjacent to them. These appear to have formed from drag along the fault surfaces.

Poles to bedding plot a girdle about a b-axis which trends 15 degrees and plunges 10 degrees northeast (Figure 9C, p. 32). Fold axes reflect this orientation. Axial surfaces and h01 surfaces are spread out along the ss girdle indicating that they were rotated as deformation progressed. This might indicate that more than one episode of deformation occurred.

Location 9

Outcrop 9 lies on route 25W south of Caryville (latitude 36° 17'00", longitude 84°12'30") Rocks belong to the Copper Ridge dolomite and consist of light gray massive dolostone. The bedding is folded into an asymmetric anticline which plunges to the northeast. The central axial region of the anticline is cut by a large fault lying in h01. Several other faults lie in h01 and hk0. There is also a small fold located on the southeast limb of the anticline. As this fold developed it was cut by joints in h01 which were folded as deformation progressed.

Orientation data (Figure 9D, p. 32) show that bedding plots a girdle about a b-axis which trends 40 degrees and plunges 20 degrees northeast. Slickensides on ss indicate that flexural slip was the

mechanism of fold development. hk0 surfaces indicate a c-axis which is almost vertical, an orientation which is consistant with that of the axial plane.

Location 10

Location 10 consists of scattered outcrops in the vicinity of Cove Lake (latitude 36°18'20", longitude 84°12'40"). Most of the data come from the motorcycle trail, lake shore, and along 25W; several measurements were also made in the picnic ground. The rocks belong to the upper part of the Knox Group and the lower part of the Chickamauga Limestone. They consist of fine grained dolomite and fossiliferous limestone.

The beds are generally steeply dipping with no other apparent structure except for a gentle fold outcropping in the picnic ground. Two surfaces in h01 were found.

Orientation data (Fig. 7, p. 29) yield a spread out partial girdle with a b-axis trending 30 degrees.

Location 11

Location 11 is situated along the northbound lane of I-75 adjacent to and north of Cove Creek (latitude 36°18'30", longitude 84°14'00"). It lies approximately 100 meters southwest of the Jacksboro fault. The rocks exposed in this outcrop belong to the Slatestone Group. They consist of thin to medium bedded sandstone and shale with a coal seam exposed at the northwestern end of the outcrop. The shales are dark gray while the sandstones tend to be lighter in color. Beds generally strike 160 degrees and dip steeply to the southwest. Across the highway (southwest) beds are horizontal. Folds are generally small.

Slickensides on ss indicate that flexural slip occurred. Although the form of the folds is characteristic of buckle folds, the existance of axial planes inclined to each other indicates that they may actually be kink bands.

Poles to bedding plot a girdle about a nearly horizontal b-axis striking 155 degrees (Figure 11B, p. 36). Fold axes plot in this general vicinity. Poles to bedding measured across the highway in flat lying rocks also plot on the same girdle indicating that the kink bands formed on the limb of a larger fold.

Location 12

This outcrop lies on I-75 about one kilometer north of location 11 (latitude 35°18'50", longitude 84°14'00"). Crinoidal limestone beds about one meter thick and two shales between 6 and 10 meters thick of the Newman Formation are present. Folds are of two general types. Large, open, flexural slip folds in the limestone are accompanied by flowage of the shale in the hinge areas. Smaller folds are present in the shale. These have steeply dipping axial surfaces. In addition several passive slip folds were found with slickensided surfaces cutting bedding at a small angle. Faults are numerous and are generally slickensided. They fall into two general types. Low angle reverse faults and vertical faults conjugate to each other lie in h01 and conjugate strike-slip faults lie in hk0. The latter have been rotated about a vertical axis and some have been rotated about the b-axis of the folds. Others show little or no rotation about the b-axis indicating that movement on these faults occurred simultaneously with folding. Faults

in h0l show displacement up to ½ meter. The low angle faults cut bedding at angles ranging from 10 to 30 degrees.

Orientation data (Fig. 12, p. 40) indicate that folding occurred about a b-axis trending 0 degrees and plunging 25 degrees north (Figure 12A). Right-lateral hk0 surfaces are more numerous and more dispersed than left-lateral (Figures 12B and 12C) indicating that right lateral faults are antithetic to the sense of external rotation while left-lateral faults are synthetic to it. Fold axes measured in the shale are scattered; this is probably the result of a combination of rotation and flow. However, Ramsay (1967) has shown that dispersion of fold axes occurs when folds develop in strata obliquely inclined to the kinematic axes. The presence of passive folds in the shale also indicate that bedding was inclined at a small angle to the kinematic axes. This may reflect an earlier folding phase in which bedding developed a northwesterly dip similar to that seen elsewhere along Cumberland Mountain.

Location 13

Location 13 includes the spectacular beds standing vertical along the east side of I-75 where it passes through Bryce Gap north of Caryville (latitude 36°19'40", longitude 84°13'30"). Rocks of the Crab Orchard Mountains and Gizzard Groups are folded from Flat lying beds along the Interstate to the northwest to the vertical position at the gap. This structure is sometimes called the Cumberland Mountain Monocline. Although few slickensided surfaces were measurable, all but one indicated flexural slip folding. In addition several large

blocks were observed in the float with slickensides on bedding surfaces. Fractures were generally restricted to h0l, but three faults were found parallel to the ac-plane.

Orientation data (Figure 6C, p. 27) show an incomplete girdle, this is due lack of suitable outcrops. The fold has a horizontal b-axis striking 35 degrees.

Location 14

This outcrop is located just off old route 63 at Sharp Gap, northwest of Royal Blue (latitude 36°23'30", longitude 84°16'30"). Sandstone and conglomerate of the Crab Orchard Mountains and Gizzard Groups are present. The rocks form an open anticline. Slickensided ss and h0l surfaces indicate that flexural slip was the folding mechanism. In addition several joints in 0kl were observed.

Orientation data (Figure 11C, p. 37) yields a partial girdle about a b-axis trending 150 degrees and plunging 10 degrees to the northwest. 0kl surfaces indicate a subhorizontal a-axis and a nearly vertical c-axis.

Location 15

This small outcrop is located on the Howard Baker Highway (route 63) at the bridge across Cove Creek southeast of Pioneer (latitude 36°24'50", longitude 84°18'10"). The rocks belong to Briceville shale (equivalent to the Crooked Fork and Slatestone Groups). These are folded into a gentle anticline. Orientation data (Figure 11D) plot a partial girdle with a b-axis plunging north at 15 degrees.

Location 16

Location 16 lies along the tracks of the Southern Railway at the northwestern entrance of the tunnel in Elk Gap (latitude 36° 25'40", longitude 84°19'00"). The rocks are sandstones and conglomerates of the Crab Orchard Mountains and Gizzard Groups. At the mouth of the tunnel the rocks are nearly horizontal but the attitude changes towards Elk Valley to a strike of 150 degrees and a dip of 40 degrees southwest. Flexural slip is the presumed mechanism of folding although no direct evidence for this was found. Orientation data (Figure 11E, p. 38) show a partial girdle about a horizontal b-axis trending 150 degrees.

Location 17

Location 17 is a quarry in Elk Valley (latitude 36°26'20", longitude 84°18'30"). It is easily seen from the main valley road and is reached by turning southeast at the New Canan Church. The rocks belong to the Newman Formation and consist of fossiliferous limestone. They dip towards the southeast with variations in dip ranging from 30 to 60 degrees. Several faults in h01 were found. Slickensides were present on both ss and h01 surfaces. These indicate flexural slip folding. Orientation data (Fig. 6D, p. 27) show a partial pi girdle formed by ss and h01 surfaces about a horizontal b-axis trending 50 degrees.

Location 18

Location 18 is about 100 meters southwest of the Pioneer Atlantic Richfield station in Elk Valley (latitude 36° 27'10", longitude 84°17' 53"). Sliding which accompanied the spring thaw (1977) caused all

but the top portion of this outcrop to be buried. The rocks are red brown shales of the Rockwood Formation. Several small folds are observable; these are open folds with steeply dipping axial surfaces. Three distinct cleavage sets were observed, denoted s_1, s_2, and s_3.

Orientation data is plotted in Figure 14A, p. 48. Bedding forms a girdle about a b-axis trending 85 degrees and plunging 20 degrees northeast. s_2, s_3, and ss lie along a great circle girdle whose pi axis is horizontal and strikes 55 degrees. s_1 is also spread out along a great circle. Figure 14B shows ss and s_1 rotated about the axis of the pi circle formed by s_2, s_3, and ss. The result is a girdle which is parallel to the axis of rotation. This indicates that the main plane of deformation (ac-plane) is the girdle formed by s_2, s_3, and ss, and that the folds in bedding were formed with s_1 as an axial plane cleavage in an accessory plane of deformation by shortening along the b-axis. These folds were then rotated about the b-axis as folds formed about this axis in the main plane of deformation.

VITA

Robert A. Horton, Jr., was born on August 18, 1951, in Hackensack, New Jersey. He grew up in New York City and outside of Cleveland, Ohio. During this time he developed an interest in the outdoors which eventually led to his interest in geology. He graduated from West Geauga High School in Chesterland, Ohio, in 1968 and received a Bachelor of Science degree in Geology from the State University of New York at Binghamton in 1973. After graduation he worked as a stockboy in a paint store and traveled until enrolling in the graduate program of the University of Tennessee at Knoxville in 1974. He is currently employed by Getty Oil Company in Knoxville, Tennessee, as a consulting geologist in their zinc exploration program.

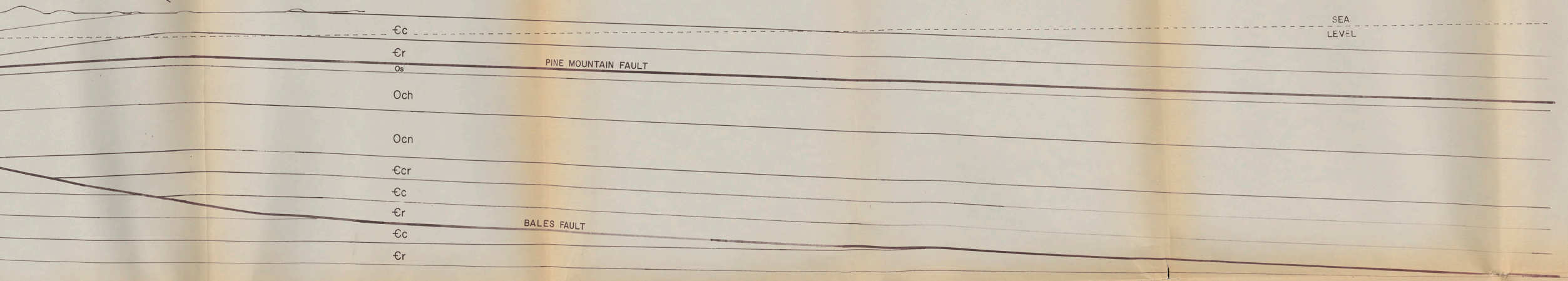
PLATE I

STRUCTURE SECTION ACROSS
PINE MOUNTAIN OVERTHRUST BLOCK
(LINE A-A', FIGURE 2, Chapter II)

0 1000 METERS
SCALE 1:24000
HORIZONTAL AND VERTICAL SCALE

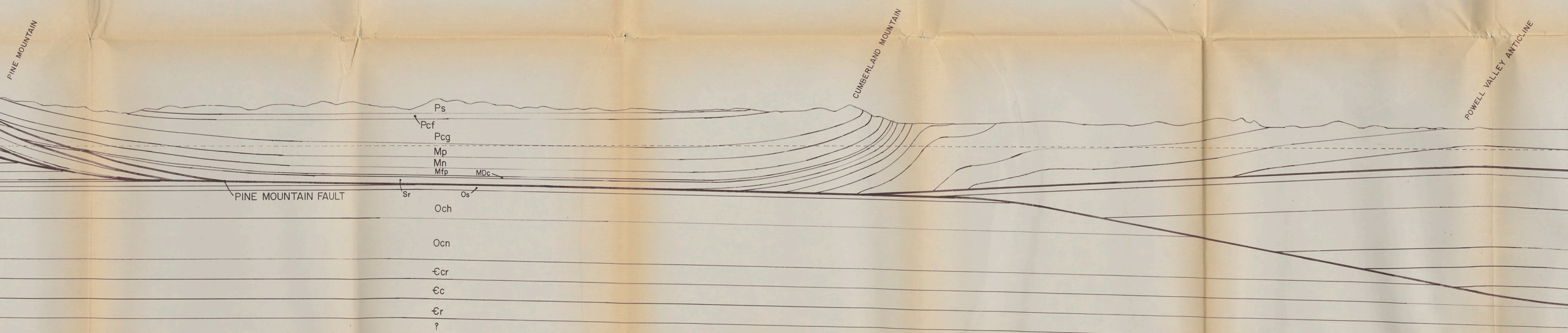
NW

A



SE

A'


PINE MOUNTAIN
CUMBERLAND MOUNTAIN
POWELL VALLEY ANTICLINE
Ps
Pcf
Pcg
Mp
Mn
Mfp
MDc
PINE MOUNTAIN FAULT
Sr
Os
Och
Ocn
Ccr
Cc
Cr
?

NW

A'

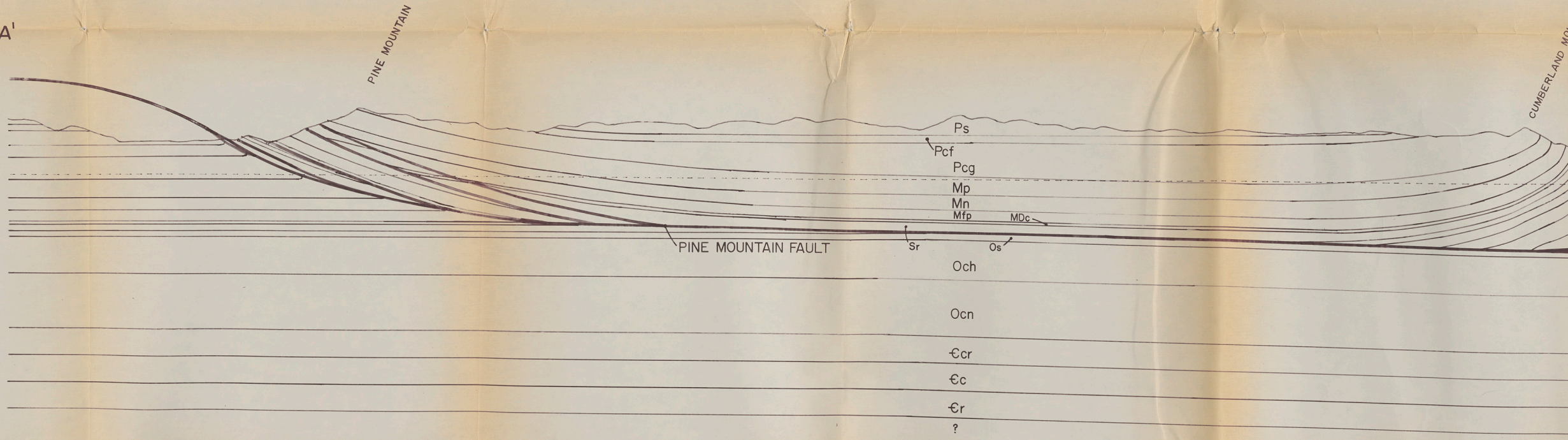

PINE MOUNTAIN
CUMBERLAND MO
Ps
Pcf
Pcg
Mp
Mn
Mfp
MDc
PINE MOUNTAIN FAULT
Sr
Os
Och
Ocn
€cr
€c
€r
?

PLATE II

STRUCTURE SECTION ACROSS
DUTCH VALLEY
(LINE B-B', FIGURE 2, Chapter II)

0 1000 METERS
SCALE 1:24000
HORIZONTAL AND VERTICAL SCALE

