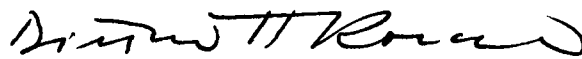


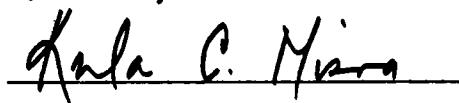
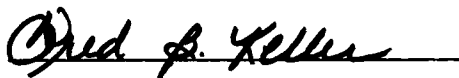
To the Graduate Council:

I am submitting herewith a thesis written by Edward J. Ossi III
"Mesoscopic Structures and Fabric Within the Thrust Sheets Between the
Cumberland Escarpment and Saltville Fault." 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
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Thesis
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MESOSCOPIC STRUCTURES AND FABRIC WITHIN THE THRUST SHEETS
BETWEEN THE CUMBERLAND ESCARPMENT
AND SALTVILLE FAULT

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Edward J. Ossi III

December 1979

1405009

DEDICATION

This thesis is dedicated to my parents.

ACKNOWLEDGMENT

I would like to extend my appreciation to Dr. Dietrich H. Roeder for his encouragement and help during the course of this investigation. His timely encouragement was a constant source of inspiration. I would also like to thank Drs. Fred B. Keller and Kula C. Misra who served on my committee and who provided unparalleled guidance during the writing of the manuscript.

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Finally, special thanks go to Kathy who drafted my cross-sections, and who kept me sane during the hectic hours.

ABSTRACT

Mesoscopic structures and fabrics within the thrust sheets between the Cumberland Escarpment and the Saltville fault are analyzed and evaluated to determine the chronological history of shortening and extensional episodes of rocks involved in late Paleozoic thrusting and folding. The fabric relationships provide an accurate movement picture of the deformation in the study area that can be correlated with specific stages of thrust transport and subsequent folding of the thrust sheets.

Fabrics in the Rome Formation and Conasauga shales in the hanging walls of the Copper Creek, Beaver Valley and Southern Branch of the Saltville fault reveal the existence of an early deformational event that cannot be correlated with NW directed thrusting. Compressional fabrics consist of low-angle thrust faults that are associated with N-S trending kink folds. Extensional fabrics consist of a conjugate system of (hk0) faults that record an oblique to regional strike extension subsequent to folding and low-angle thrusting. The age of this fabric is unknown.

Fabric within the Chattanooga and Kingston thrust sheets is suggestive of deformation that postdates arrival of these thrust sheets at the surface. The tectonic fabric consists of concentric buckle folds with subhorizontal fold axes and subvertical axial planes. The folds are not rotated into the thrust transport direction. This suggests folding in a regime of pure shear, rather than simple shear that is correlative with active thrust transport.

Mesosopic structures and fabric were examined in two separate subthrust synclines in the footwall of the Whiteoak Mountain fault. Mesoscopic structural fabrics within the southwesternmost syncline suggest that a complex interplay of compressional and extensional deformation took place during growth of the syncline. At least two folding events that are separated by an extensional event are recorded in the rocks within this syncline. The first is documented by the development of the syncline itself. Folding was followed by an extension subparallel to regional strike. Fabric indicative of this extension consists of (hk0) faults at the SW end of the syncline. The second folding phase is represented by concentric folds with E-W trending axes at its SW end. This event is correlative with a late wave of horizontal compression that caused rethrusting on the Whiteoak Mountain fault.

Mesosopic structural fabric relationships within another subthrust syncline to the NE of the first, suggest that initial folding of the footwall rocks occurred before development of the Chattanooga thrust fault. Within this syncline, mesoscopic kink folds on its SE dipping limb are crosscut by a conjugate system of dip-slip faults that have been tilted into their present attitude. These structural fabrics developed when bedding was subhorizontal and were subsequently tilted to the SE by ramping of the Chattanooga fault over subhorizontal bedding. Initial folding of the footwall rocks probably occurred during ramping of the Whiteoak Mountain fault over undetached subhorizontal bedding in the subsurface.

Fabric within the Copper Creek thrust sheet that is correlative with a NW-SE trending stress is present in the Rome Formation in the hanging wall of the thrust sheet. It consists of left-lateral kink folds with steeply SE dipping axial planes and high angle reverse faults that are subparallel to the kink fold axial planes. The faults are not low angle thrusts that can be correlated with initial transport of the thrust sheet so that it is likely that folding and faulting postdate arrival of the leading edge at the surface.

Fabric in the Beaver Valley thrust sheet that is correlative with a NW-SE trending stress consists of right-lateral kink folds that are interpreted to be conjugate to the basal shear plane of the thrust sheet. On a regional scale, the footwall rocks of the underlying Copper Creek thrust sheet are folded into a subthrust syncline. On a mesoscopic scale the fabric in the footwall consists of tectonic breccia.

Fabric in the hanging wall of the northern branch of the Saltville fault that is correlative with a NW-SE trending stress consists of low-angle thrust faults that are associated with kink folds. This fabric is correlative with initial transport of the thrust sheet. Fabric in the footwall consists of tectonic breccia. On a regional scale, the footwall rocks of the underlying Beaver Valley thrust sheet are folded into a subthrust syncline.

Fabric in the hanging wall of the southern branch that is correlative with a NW-SE trending stress consists of upright and overturned buckle folds. Buckle folds are related to folding of the Saltville fault in the subsurface and overturning is associated with subsequent rethrusting on the Saltville faults.

Based upon the mesoscopic structural fabric relationships within the thrust sheets of the study area, the following inferences are made regarding the nature of the deformation in this part of the thrust belt:

1. NW directed thrusting was preceded by an E-W trending layer parallel compression that resulted in low-angle E to W directed thrusting and kink folding.
2. Layer parallel shortening above the basal shear planes of the thrust sheets was minimal during initial NW directed thrusting. Most of the shortening took place either during ramping or after emplacement of the thrust sheets.
3. Macroscopic folding of bedding in the footwall of the Whiteoak Mountain fault took place during early NW directed thrusting. Macroscopic folding was accompanied by an extension parallel to the regional strike.

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CHAPTER I

INTRODUCTION

The Valley and Ridge Province of East Tennessee consists of a 3 to 5 km thick eastward facing wedge of Paleozoic miogeosynclinal strata that has been complexly imbricated by regional-scale thrust faulting. The imbrication does not involve basement and consists of northwesterly-directed sledrunner thrust faults above a basal detachment zone in the lower Cambrian Rome Formation (Rodgers, 1953; Gwinn, 1964; Harris, 1976; Harris and Milici, 1977; Roeder, Gilbert and Witherspoon, 1978).

The structural styles and kinematic sequence of the mesoscopic deformation within the shear zones of the major thrust faults have not been described for the majority of thrusts in East Tennessee. An understanding of the mesoscopic tectonic fabric relationships within the shear zones can provide a basis for distinguishing fabrics developed during active transport of a thrust sheet from fabrics that can be correlated with subsequent deformation of a static thrust sheet. In addition, the mesoscopic fabric relationships may reveal deformational phases that are only discernible at the mesoscopic scale and that are not apparent at the macroscopic level.

The present investigation characterizes the structural styles and establishes the kinematic sequence of the mesoscopic deformation in the shear zones and within the thrust sheets between the Cumberland Escarpment and Saltville fault (Figure 1). The structural styles and kinematic sequence of the mesoscopic deformation have not been

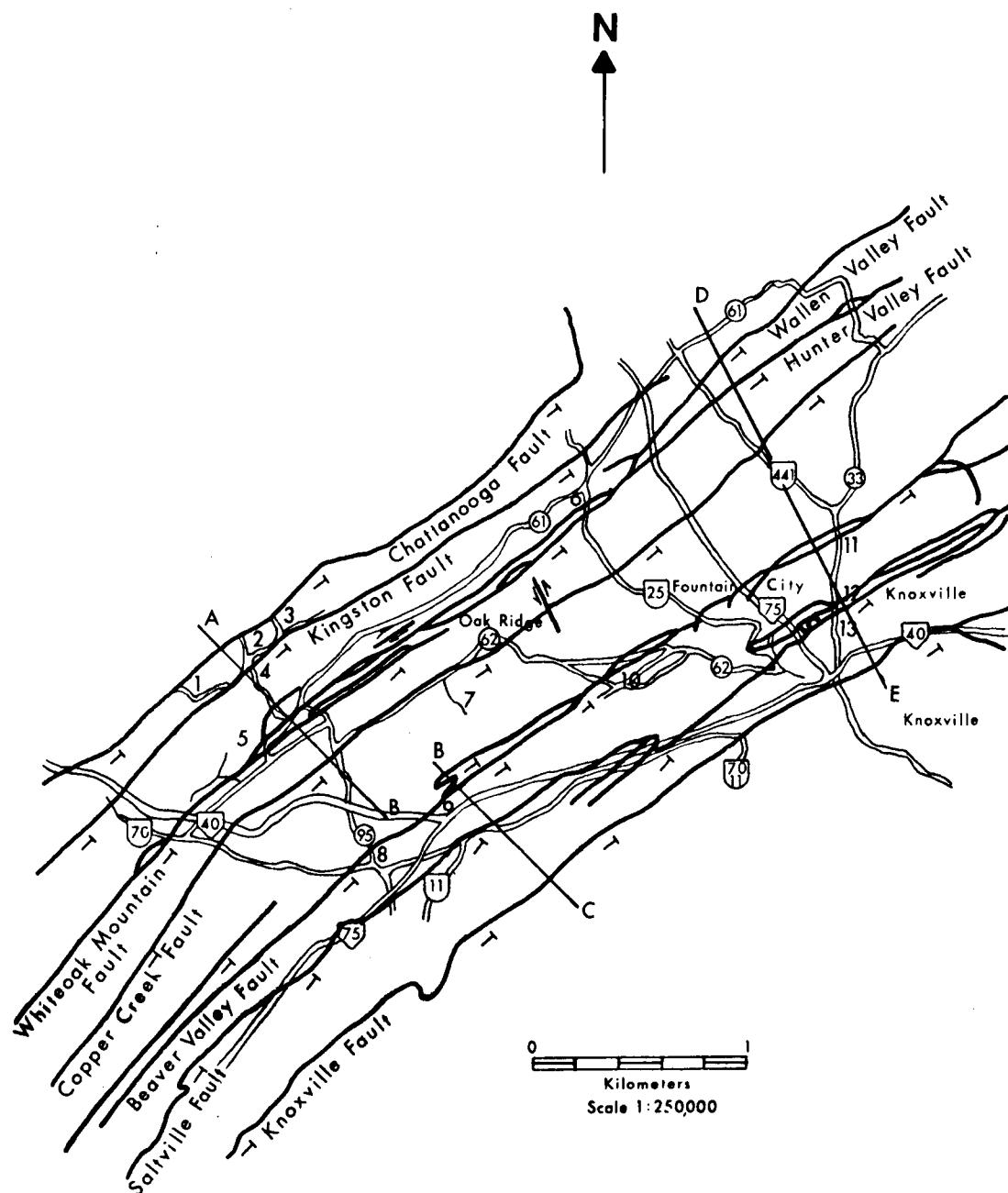


Figure 1. Sketch map of the study area showing the location of the major thrust faults (after Hardeman, 1966). Upper plate is denoted by a T. Numbers 1-13 specify outcrop locations from which mesoscopic fabric datum were collected. Lines A-B, B-C and D-E are lines of cross section.

previously reported for the thrust sheets in this area. As such, the fabric data presented in this report provides new structural information which is used in developing a regional synthesis of the structural evolution of this area.

The macroscopic structure and regional stratigraphy of the region have been compiled by Rodgers (1953) and revised by Hardeman (1966). Within the study area, mapping on a quadrangle scale has been done by Cattermole (1958, 1960, 1966), McMaster (1963) and Swingle (1964). Additional unpublished geologic maps by Elder (ms., 1956), McMaster (1957), Nalewaik (ms., 1961), Jones (ms., 1963), Davis (ms., 1970) and Penley (1973) provided guides to the stratigraphy and structure of the study area.

The framework of macroscopic thrusting and folding established by Roeder, Gilbert and Witherspoon (1978) was used as a basic reference in studying the structural geometry of the thrust sheets in the subsurface. The seismic reflection data in Harris (1976), Harris and Milici (1977), and Tegland (1978) provided additional subsurface information.

Fabric analyses were conducted by using the techniques developed by Sander (1948), Turner and Weiss (1963) and Ramsay (1967).

CHAPTER II

REGIONAL GEOLOGIC SETTING

Stratigraphy

Stratigraphic units within the study area range in age from early Cambrian to early Mississippian (Figure 2). The oldest is the lower Cambrian Rome Formation and the youngest is the Mississippian Fort Payne Chert.

Mesoscopic fabric data was collected from the Rome and Rockwood Formations. Fabric data was also collected from the Conasauga and Chickamauga Groups.

Structural Geology

The major imbrications in the study area, proceeding from NW to SE are the Chattanooga, Kingston, Whiteoak Mountain, Copper Creek, Beaver Valley and Saltville faults (See Figure 1). A brief description of the faults is given below.

Chattanooga Fault

The trace of the Chattanooga fault extends from the Jacksboro fault southwestward to Chattanooga, Tennessee, and on into Georgia and Alabama (Rodgers, 1953). Within the study area, it brings lower Cambrian Rome over lower Mississippian units. The trace of the fault in the study area is parallel to the Cumberland Escarpment and dips 15-20° to the SE at the surface (Elder, ms., 1956).

SYSTEM	GROUP	FORMATION	THICKNESS
MISSISSIPPIAN		Fort Payne Chert	Eroded to 27 Meters
DEVONIAN		Chattanooga Shale	5-10
SILURIAN		Rockwood Formation	215
ORDOVICIAN			Sequatchie Formation
	Chickamauga	Reedsville Shale	85
		Martinsburg Shale	215+
		Moccasin Formation	280+
		Ottossee Shale	215-609
		Holston Limestone	40-120
		Lenoir Limestone	120-180
	Knox	Mascot Dolomite	150-240
		Kingsport Formation	100
		Chepultepec Dolomite	220-370
		Copper Ridge Dolomite	275-305
	CAMBRIAN	Conasauga	Maynardville Limestone
Nolichucky Shale			180-250+
Maryville Limestone			75-110
Rogersville Shale			90+
Rutledge Limestone			35-100
Pumpkin Valley Shale			250-305
		Rome Formation	250+

Figure 2. Stratigraphic column of units within the study area (from Rodgers, 1953; McMaster, 1963; Harris, 1969, 1976; Milici, 1973).

Kingston Fault

The Kingston fault (Rodgers, 1953) extends SW of the Jacksboro fault and continues into Georgia. Within the study area it brings lower Cambrian Rome over the middle Cambrian units of the Chattanooga thrust sheet. Further to the NE, it dies out in middle Cambrian shales. The fault plane was not exposed in the area, but its map trace strikes 045° .

Whiteoak Mountain Fault

The Whiteoak Mountain fault extends from NW Georgia through the study area and splits to form the Wallen Valley and Hunter Valley faults approximately 20 km NE of the study area (Rodgers, 1953; Murray, 1960; McMaster, 1956, 1963; Jones, 1963). Within the study area it brings lower Cambrian Rome over middle Ordovician Chickamauga limestones of the Kingston thrust sheet. Several klippen and a macroscopic syncline are in the footwall of the fault in the study area. The fault plane is not exposed, but because bedding in the hanging-wall dips steeply to the SE, it is assumed that the fault plane dips steeply to the SE. The strike of the fault ranges from $045-055^{\circ}$.

Copper Creek Fault

The trace of the Copper Creek fault extends from Virginia to Cleveland, Tennessee. Near Cleveland the fault merges with the Whiteoak Mountain fault. Another branch of the fault emerges on the SW side of the imbricated area as the Pine Hill fault (Rodgers, 1953). Within the study area, the trace of the Copper Creek fault is remarkably straight.

Fault planes measured along the strike of the fault had a uniform strike of 045-048° and dips of 45-50° SE. Within the study area the fault brings lower Cambrian Rome over middle Ordovician Chickamauga limestones of the Whiteoak Mountain thrust sheet.

Beaver Valley Fault

The trace of the Beaver Valley fault extends from a few kilometers NE of Knoxville to NW Georgia, where it merges with the Rome fault (Rodgers, 1953). Within the study area, numerous slices of lower and middle Ordovician age rocks are complexly interwoven with the Beaver Valley fault (Rodgers, 1953; Cattermole, 1960, 1966; Nalewaik, ms., 1961). In the SW part of the study area, near the I-40/I-75 interchange, a splay off the main fault has been folded. Within this area the Beaver Valley fault dips 50° to the SE. Approximately 25 km NE along strike the fault dips 25° to the SE.

Saltville Fault

The Saltville fault has been traced for about a distance of 700 km from Roanoke, Virginia, to Dalton, Georgia (Rodgers, 1953). At the SW end in Georgia, the Saltville fault merges with the Beaver Valley fault to form the Rome fault (Rodgers, 1953).

Near Knoxville, Tennessee, the main trace of the fault and a subsidiary splay has been folded (Roeder, Yust and Little, 1978). There the Saltville fault brings lower Cambrian Rome over lower Ordovician Knox. A back-limb thrust of the folded fault also places Rome over middle Cambrian Conasauga. Along strike, further to the SW the fault

brings middle Cambrian Conasauga over lower and middle Ordovician age rocks.

CHAPTER III

MESOSCOPIC FABRIC AND STRUCTURE

Concepts

The term fabric is defined as the "internal ordering of both geometric and physical spatial data in an aggregate" (Turner and Weiss, 1963, p. 19). It can be treated as a "three-dimensionally ordered array of structural discontinuities" within a geological body (Turner and Weiss, 1963, p. 21).

Kinematic fabric analyses are concerned with establishing the spatial orientation and sequential development of fabric within a geological body. Together they effectively define the movement picture of the deformation within the domain under consideration.

A key part of fabric analysis is the choice of a triaxial coordinate system to which the fabric orientation data must be related. In this regard the triaxial coordinate system consists of three kinematic axes that are perpendicular to each other. In the present report the kinematic axes are defined as follows: the a kinematic axis is the direction of gross lengthening, the c kinematic axis is the principal axis of shortening, and the b kinematic axis is normal to the plane of deformation defined by the a and c axes.

Fabric Elements Used in the Investigation

Bedding

Bedding is the only pre-existing or inherited fabric element used in this investigation. It is assumed to have been initially horizontal before it was deformed. Because it is a penetrative planar fabric (Sander, 1948), it is designated S_0 in this report.

Folds

The term fold is applied to any segment of a set of surfaces that are curvilinear (Turner and Weiss, 1963, p. 105). Folds can be geometrically described in terms of a fold axis and an axial plane. Two types of folds were observed in the study area: buckle and kink folds.

Buckle folds statistically have their axial planes oriented perpendicular to the principal shortening axis (Gnash, 1966). Their fold axes are parallel to the b kinematic axis. Buckle folds in the study area are characterized by rounded hinges and a concentric profile.

Kink folds are generically different from buckle folds because their axial planes are parallel to one of the principal shear planes. Kink fold axes are parallel to the b kinematic axis.

Kink folds are classified as right or left-lateral kinks depending upon the sense of middle limb rotation relative to the thrust transport direction. The middle limbs of right-lateral kinks rotate antithetically and the middle limbs of left-lateral kinks rotate synthetically relative to the direction of thrust transport.

Faults

A fault is a non-penetrative planar fabric element that cuts across bedding and displaces one volume of rock relative to another along the plane of rupture. If the displacement is along bedding, it is not considered as a fault and is referred to as bedding plane slip.

Faults are parallel to one of the principal shear planes associated with a compressive stress. Conjugate faults define both shear planes and can be utilized to determine the spatial orientation of the strain axes during faulting. In this regard, the intersection of the shear planes defines a line that is parallel to the intermediate strain axis.

Faults can be related to the kinematic axes by means of Miller indices. The letters h, k, and l refer to the reciprocals of intercepts of the fault plane on the a, b and c kinematic axes, respectively. A zero (0) intercept indicates parallelism with a kinematic axis.

Slickensides

Slickensides on bedding and fault surfaces are useful kinematic indicators because the normal to the fault surface and the slip linears on the fault surface define the ac plane of deformation. Slickensides are also used to discern the sense of displacement on a fault.

Organization of Fabric Data

The presentation of the fabric orientation data follows the sequential order of the macroscopic imbrication. In each case the outcrop location is specified and generally described. This is followed

by an analysis of the fabric orientation data and a discussion of the sequential and mechanical relationships between the various structural elements.

Outcrops 1 to 3

General Description. Outcrops 1 to 3 are located in the NE corner of the Elverton quadrangle (Figure 1, p. 2). A generalized geologic map of this area, showing the outcrop locations and representative bedding orientations is shown in Figure 3. All of the outcrops are in the Cambrian Rome Formation, which is in the hanging wall of the Chattanooga fault (Rodgers, 1953; Elder, 1956; Hardeman, 1966).

In general, deformation of the Rome has been moderate. Large open concentric folds and megascopic kink and chevron folds are the predominant structural discontinuities at Outcrops 1 to 3.

Fabric Analysis. Figure 4 is a plot of linear and planar fabric elements at Outcrop 1. Poles to bedding (S_0) can be fitted to a northwesterly-trending pi circle, which defines a subvertical ac plane of folding for buckle folds in the Rome. Buckle fold axes (b_{Buckle}) are subnormal to this plane. Buckle fold axial planes are subvertical and poles to buckle fold axial planes (ap_{Buckle}) plot on the ac plane of folding.

Figure 5 is a plot of linear and planar fabric elements at Outcrop 2 (Blair Road). Poles to bedding can be loosely fitted to a northwesterly trending pi circle, which defines the ac plane of folding for buckle

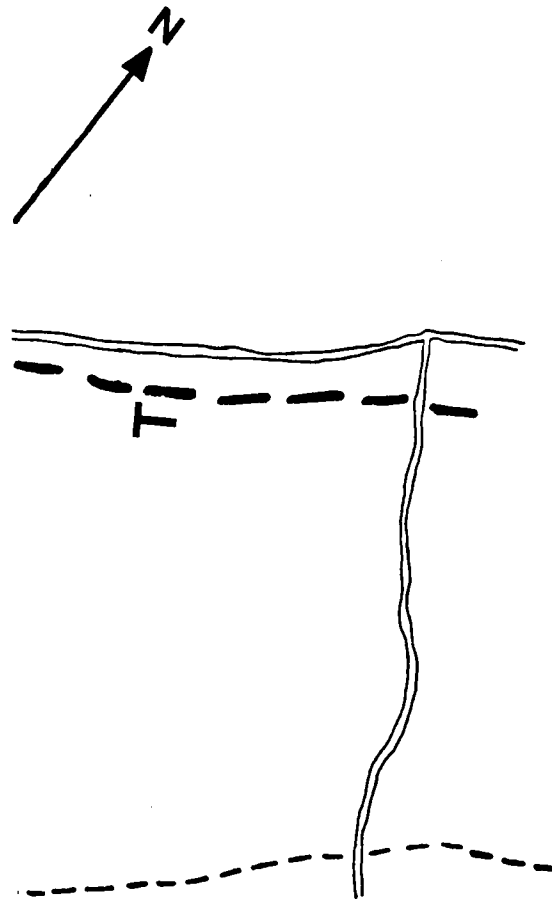


Figure 3. Geologic map of the area within the hanging wall of the Chattanooga fault. Outcrop localities are indicated by bold numbers. Lines A-A' and B-B' are lines of section.

Figure 4. Fabric orientation data from Outcrop 1. $N_{so} = 39$, $N_b = 10$, $N_{ap} = 7$.

This and all other stereograms are equal-area lower hemisphere projections. The following legend applies to all symbols used in the stereograms.

●	Poles to bedding
○	Pole to overturned bedding
←●→	Poles to bedding, with direction and sense of slip on the bedding surface indicated by Hoeppner arrow
□	Pole to kink fold axial plane
⬡	Pole to buckle fold axial plane
⊗	Kink fold axis
⊗	Buckle fold axis
←◁→	Pole to reverse fault with, direction and sense of slip on the fault surface indicated by Hoeppner arrow
←◇→	Pole to (hk0) fault surface with direction and sense of slip on the fault surface indicated by Hoeppner arrow
----	ac plane of deformation
⊙	Pole to ac plane
_____	Trace of fault surface

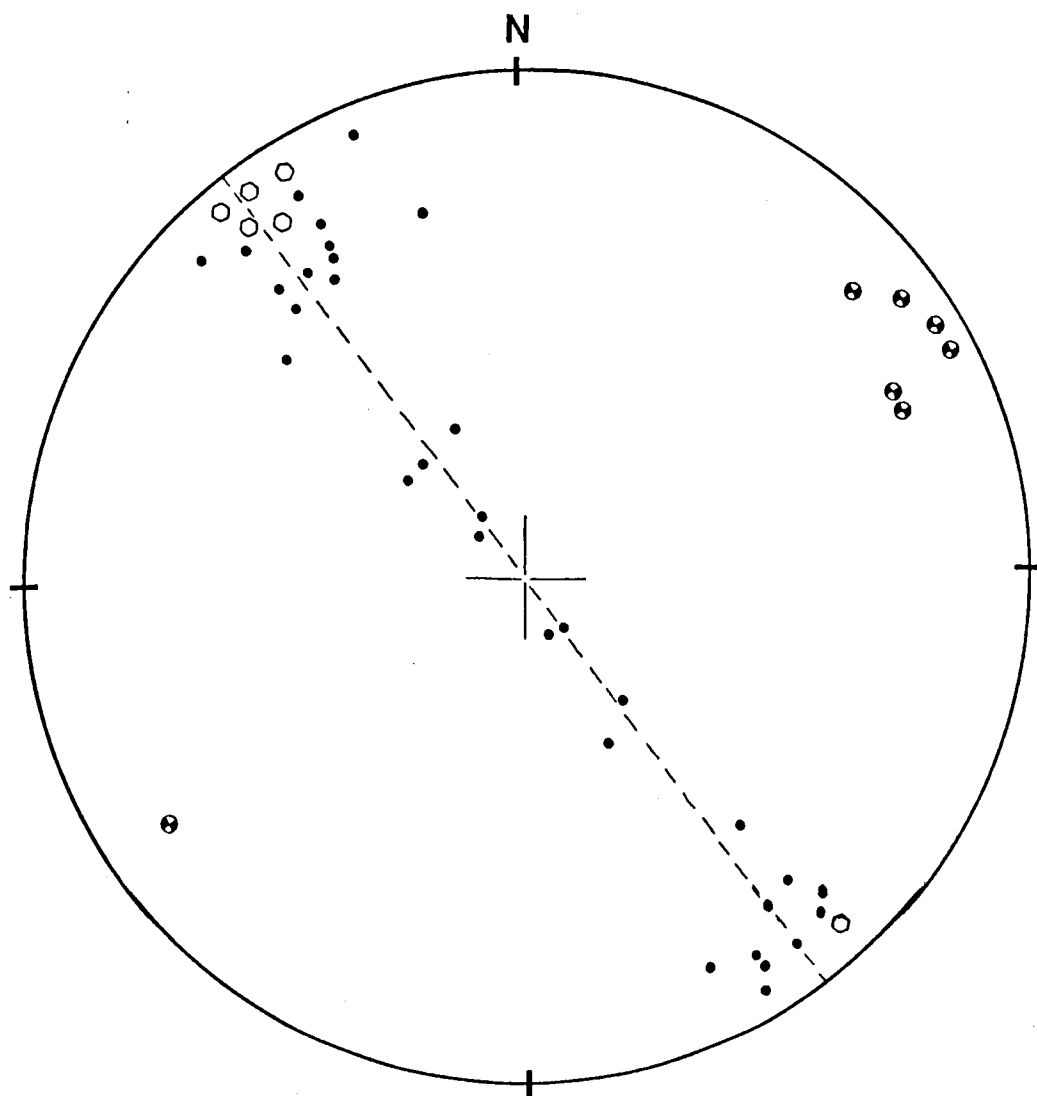


Figure 4

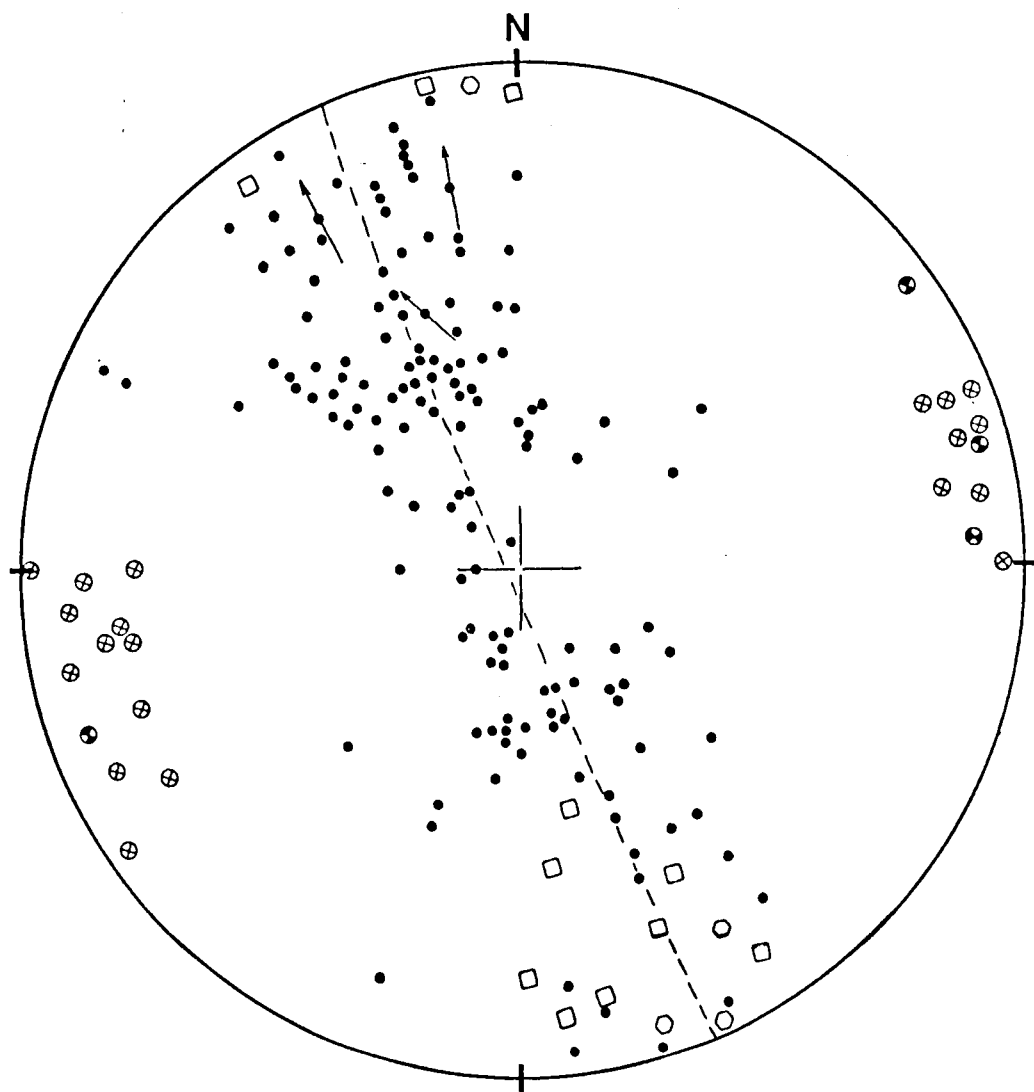


Figure 5. Fabric orientation data from Outcrop 2. $N_{So} = 134$, $N_{b(kink)} = 20$, $N_{ap(kink)} = 11$, $N_{b(buckle)} = 4$, $N_{ap(buckle)} = 4$.

folds at this outcrop. The scatter of bedding poles in Figure 5 is attributed to subsequent development of right-lateral kink folds on the SE dipping limbs of large concentric buckle folds. The ac plane of folding for the kink folds is subparallel to the ac plane of folding of the buckle folds. Buckle and kink fold axes are subnormal to the ac plane.

Figure 6 is a plot of planar fabric data at Outcrop 3 (Massergill Road). Poles to bedding can be fitted to a northwesterly-trending pi circle, which defines the ac plane of folding of a large anticline at this outcrop.

Discussion. At Outcrop 1 the mesoscopic folds are characterized by subhorizontal fold axes and rounded to angular hinges. The folded beds consist of alternating 5-10 cm thick siltstone beds and interlayered shale. The folds do not appear to be kink folds, and are interpreted to be megascopic concentric folds that are transitional into chevron folds. This interpretation is based on experimental folding results reported by Johnson (1978, ^{2, 1977} p. 169). In his experiments, alternating stiff and soft layers that were subjected to layer parallel shortening were observed to evolve from sinusoidal to concentric and finally chevron folds with increasing strain. The folded siltstone and shale beds at this outcrop are presumed to have evolved in a similar fashion.

At Outcrop 2, two styles of folding are present. The larger folds consist of concentric folds with long wavelengths (15-100 m). Axial planes are predominantly subvertical. The smaller folds consist of

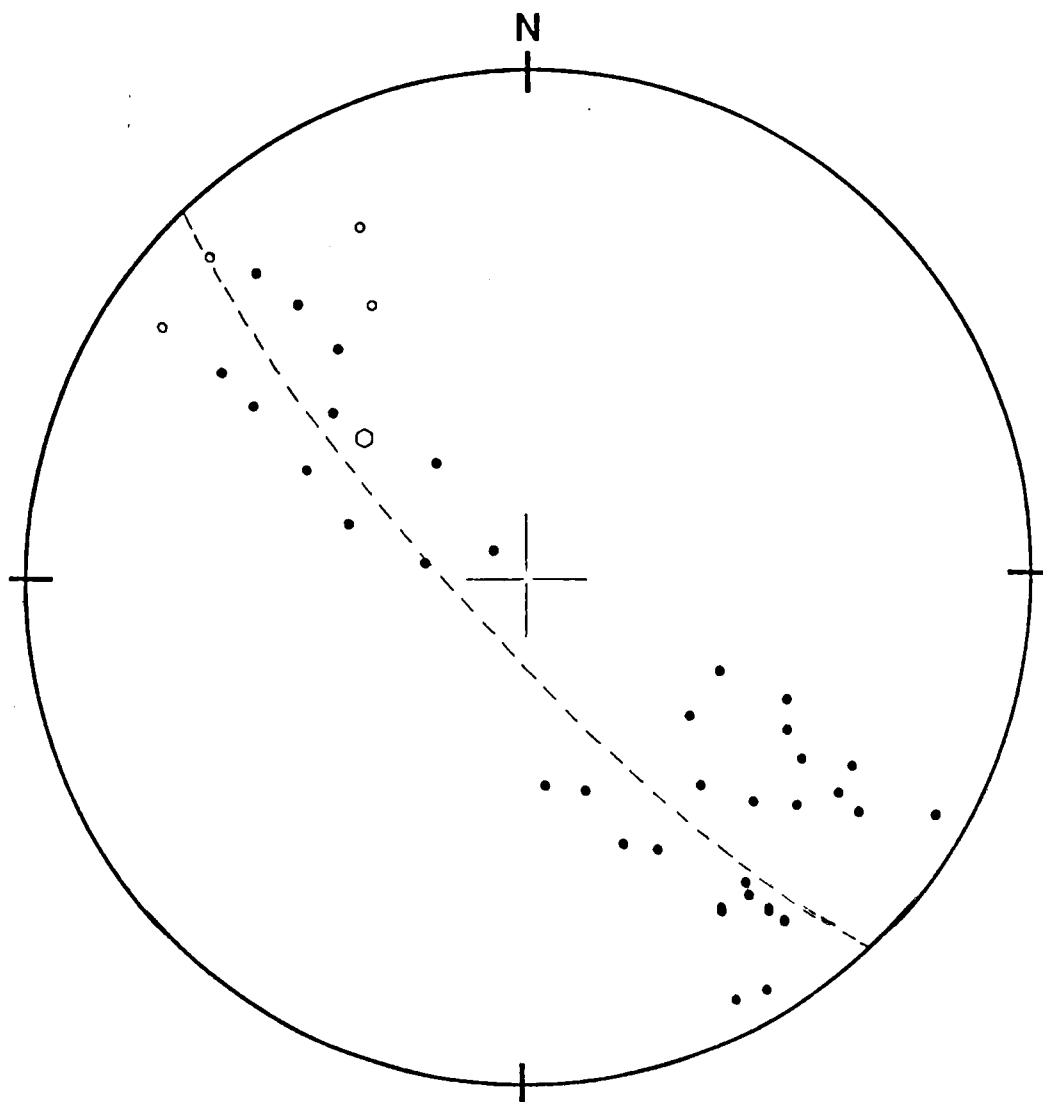


Figure 6. Fabric orientation data from Outcrop 3. $N_{So} = 37$,
 $N_{ap(buckle)} = 1$.

incipient to well defined right-lateral kink folds that are sometimes found on the SE dipping limbs of the larger concentric folds. Figure 7 is a profile constructed along line of section A-A' (See Figure 3, p. 13) and illustrating the relationship between kink folds and a large concentric syncline. The sense of vergence of the right-lateral kink folds is opposite to that expected for drag folds formed on the SE dipping limb of the syncline, suggesting that they may be later than the large concentric fold.

The SE dipping limb of the syncline is crosscut by two opposed, shallow dipping reverse faults that appear related to the kink folds. The faults crosscut bedding at a high angle, making it unlikely that they are bedding plane faults related to flexural slip of bedding during growth of the syncline. The NW dipping fault is subparallel to the axial planes of most kink folds. This establishes the fault as being subparallel to one of the principal shear planes during kink folding and satisfactorily accounts for its origin. The SE dipping reverse fault is apparently conjugate with the NW dipping reverse fault. Taken together, both faults define a conjugate set of shear planes that establishes a subhorizontal attitude for the principal stress axis during kink folding.

Figure 8 is a profile across line of section B-B' (See Figure 3, p. 13). The profile is across an intensely deformed zone at Outcrop 3 (Massergill Road). The major structural features at this outcrop consist of two SE dipping reverse faults that are in the front limb of a large concentric anticline. The displacement on the fault in the

SE

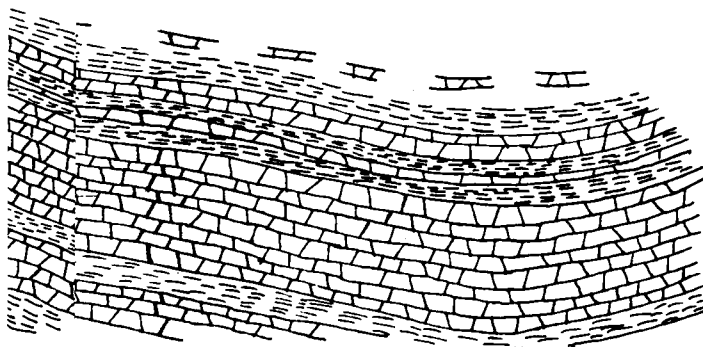


Figure 7. Profile across part of Outcrop 2. Profile is parallel to line of section A-A'.

SE

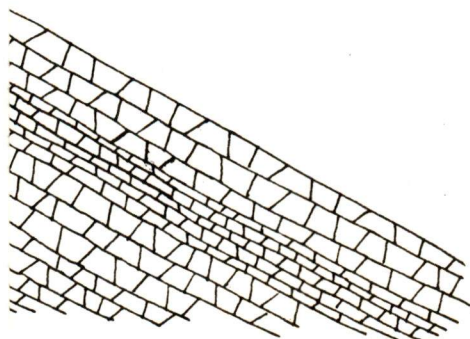


Figure 8. Profile across Outcrop 3. Profile is parallel to line of section B-B'.

center of Figure 8 is unknown, while the displacement on the other fault is approximately 1 m. The fault in the center of Figure 8 is believed to be a fore-limb thrust of the anticline. It is also suspected that movement along this fault resulted in localized overturning of the footwall rocks, resulting in the formation of a drag fold syncline. This syncline was subsequently faulted along its axial plane when a space problem inhibited further tightening of its limbs.

Synopsis. The predominant structural style of deformation exhibited at Outcrops 1 to 3 consists of concentric folding. The concentric folds are characterized by subvertical axial planes, suggesting that external rotation of the folds was minimal. Unrotated concentric folds also suggest that folding took place in a pure shear regime rather than a simple shear regime. This implies that folding occurred while the Chattanooga thrust sheet was static and not in motion. It correspondingly suggests that folding occurred after major movement on the Chattanooga fault had ceased.

Outcrop 4

General Description. Outcrop 4 is located in the north-central section of the Elverton quadrangle. At this locality, a 50 m section of Rome is exposed along Oxier Creek. The average strike and dip of beds in the section is $048/50^{\circ}$ SE. The Rome at this outcrop is in the hanging wall of the Kingston fault (Rodgers, 1953; Hardeman, 1966).

Fabric Analysis. Figure 9 is a plot of linear and planar fabric orientations from this outcrop. Poles to bedding can be fitted to a

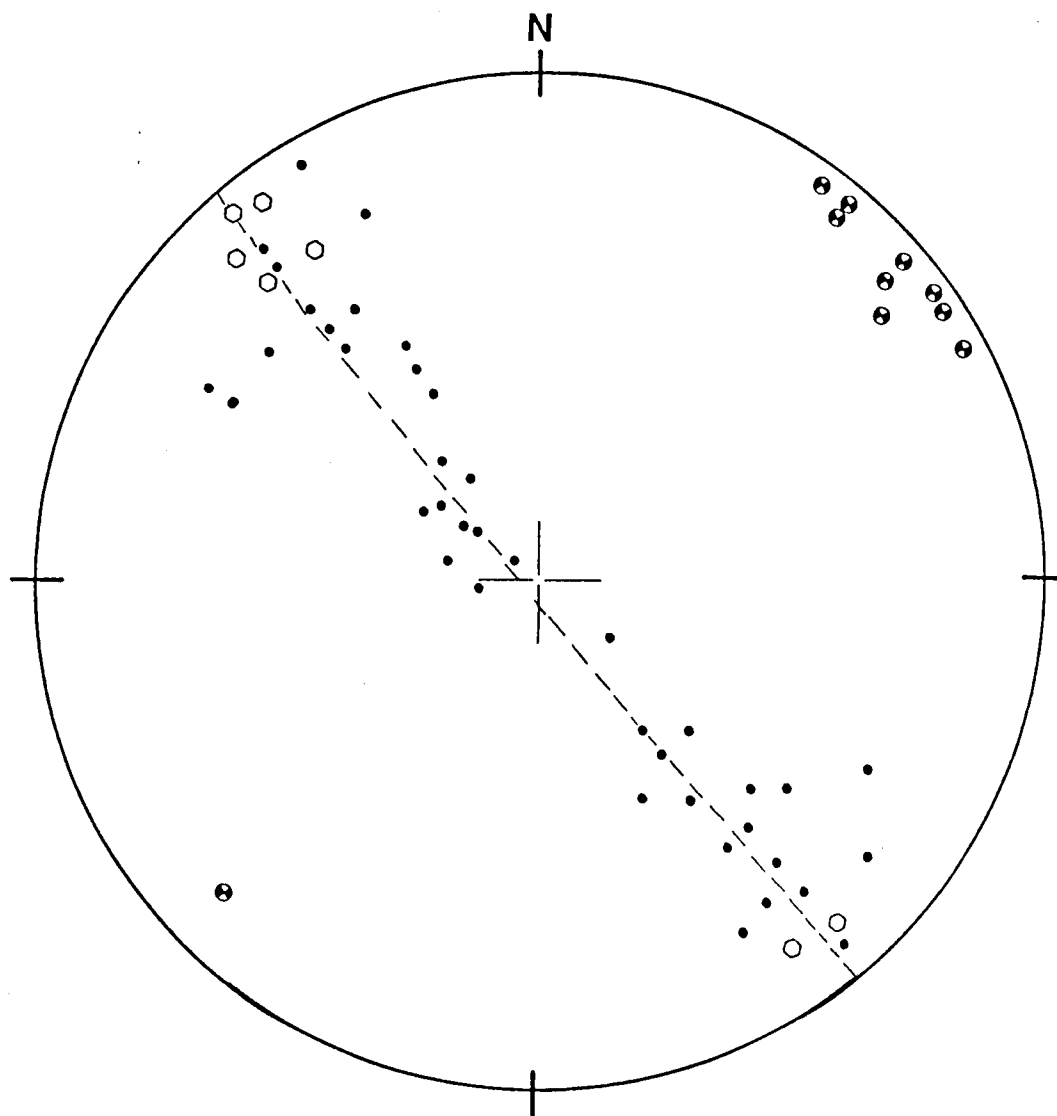


Figure 9. Fabric orientation data from Outcrop 4. $N_{So} = 30$, $N_{b(buckle)} = 7$, $N_{ap(buckle)} = 6$.

NW-SE striking pi circle that defines the ac plane of folding for buckle folds in the Rome. Fold axes are subhorizontal and normal to this plane. Buckle fold axial planes are subvertical.

Discussion. Folds at this outcrop are scarce and are localized within a 5 m section of alternating siltstones and shales, located approximately 15 m down-dip from the base of the section. The folds are moderately open with inter-limb angles ranging from 90-100°. Fold hinges are rounded giving the folds a concentric profile when viewed across the trend of the folds axes.

The folded interval of siltstones and shales exists as a discrete structural discontinuity. The folds are not associated with bedding plane thrusts which suggests that folding took place after bedding had been tilted into its presently SE dipping attitude. The subvertical attitude of the buckle fold axial planes also suggests that external rotation of the folds was minimal and that folding took place in a pure shear regime.

Synopsis. The absence of bedding plane thrusts associated with the buckle folds together with the apparent lack of external rotation experienced by the folds suggests that folding took place after emplacement of the thrust sheet and not during active transport.

Outcrop 5

General Description. Outcrop 5 is located in the south-central portion of the Elverton quadrangle (Figure 1, p. 2). The area comprising

Outcrop 5 is at the SW terminus of a doubly-plunging syncline in the footwall of the Whiteoak Mountain fault. Figure 10 is a modified version of McMaster's (1963) Geologic Map of the Oak Ridge Reservation showing the major structural features of the area. Fabric data was collected from subareas A(1) and A(2).

Fabric Analysis. Within subarea A(1) poles to bedding can be fitted to a N-S trending pi circle (Figure 11). The pi circle defines the ac plane of deformation of an anticline and syncline fold pair that are the major structural discontinuities within subarea A(1). The pole to the ac plane trends 078° and plunges 10° E, which indicates that the axis trend of both folds is oblique to the regional 050° trend of the Whiteoak Mountain fault.

Within subarea A(2) poles to bedding can be fitted to two great circles (Figure 12). One girdle strikes N-S and the other strikes NE-SW. The N-S striking girdle defines the ac plane of folding of three megascopic concentric buckle folds located in the eastern corner of subarea A(2). The trend of their fold axes is oblique to the regional strike of the Whiteoak Mountain fault and subparallel to the axes trends of the folds in subarea A(1). The axial traces of the megascopic folds is shown in Figure 10. The NE-SW striking pi circle defines the ac plane of deformation of an anticline and syncline fold pair that are in the central portion of subarea A(1). The axial traces of the anticline and syncline strike NW-SE (Figure 10) and are normal to the trace of the Whiteoak Mountain fault.

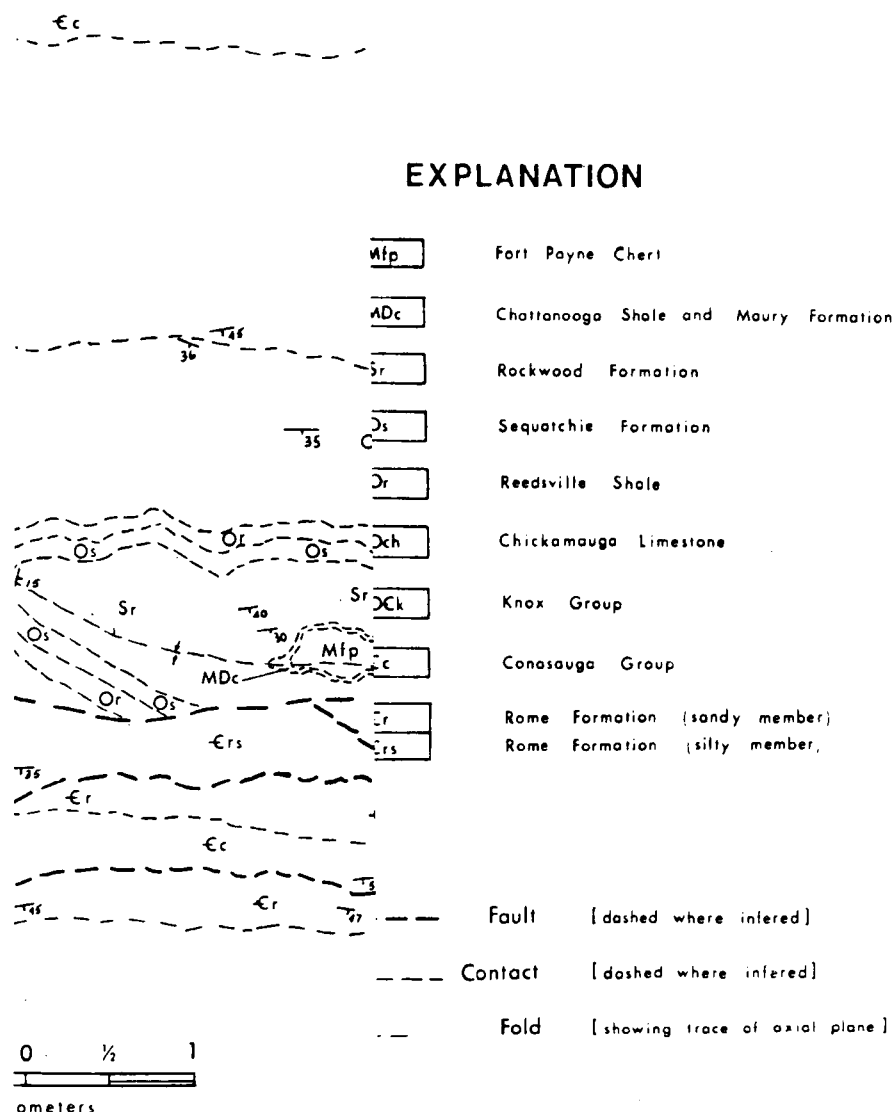


Figure 10. Modified version of McMaster's (1963) Geologic Map of Oak Ridge, showing the extent of the area considered for fabric analysis. Fabric orientation data was collected from subareas A(1) and A(2).

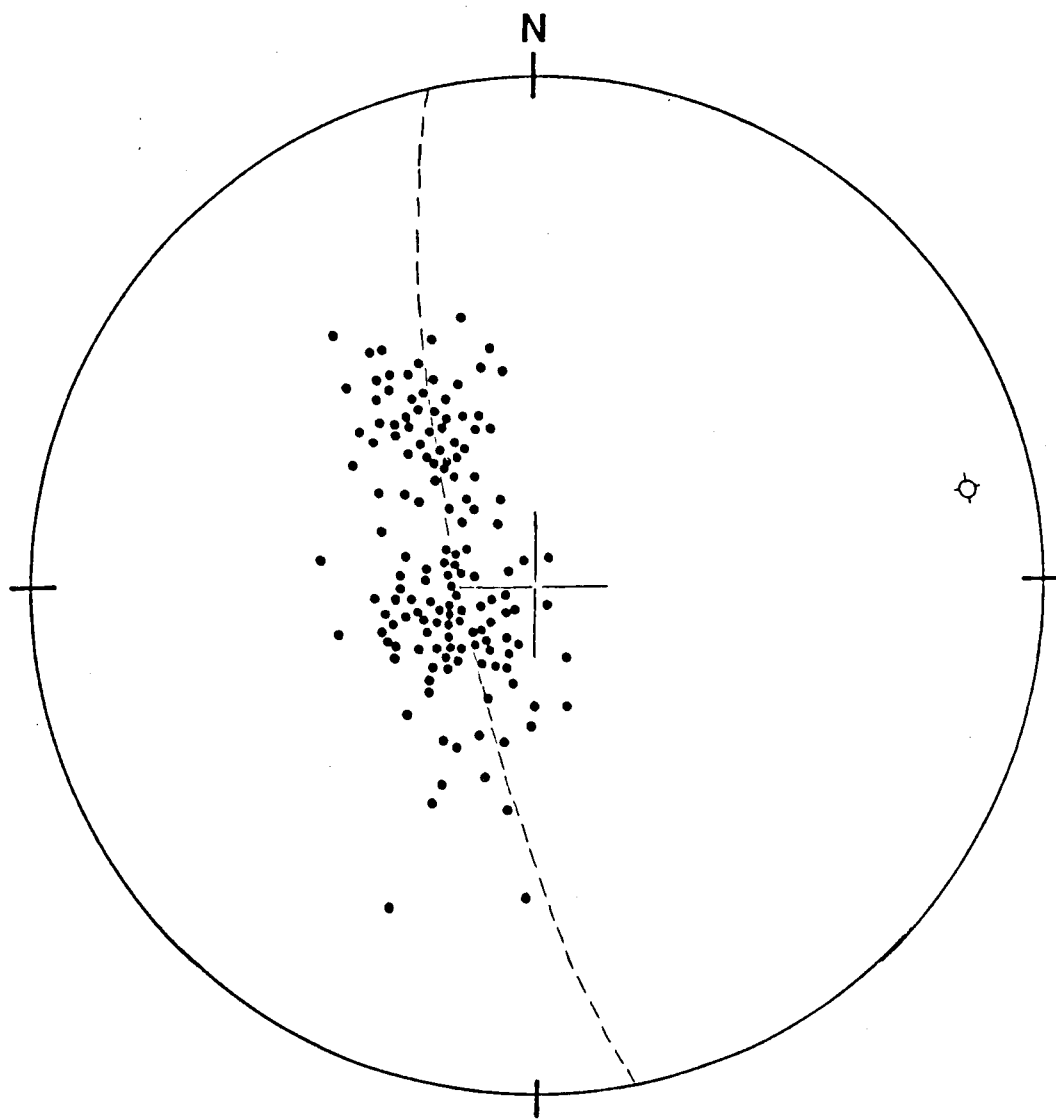


Figure 11. Fabric orientation data from subarea A(1). $N_{So} = 141$.

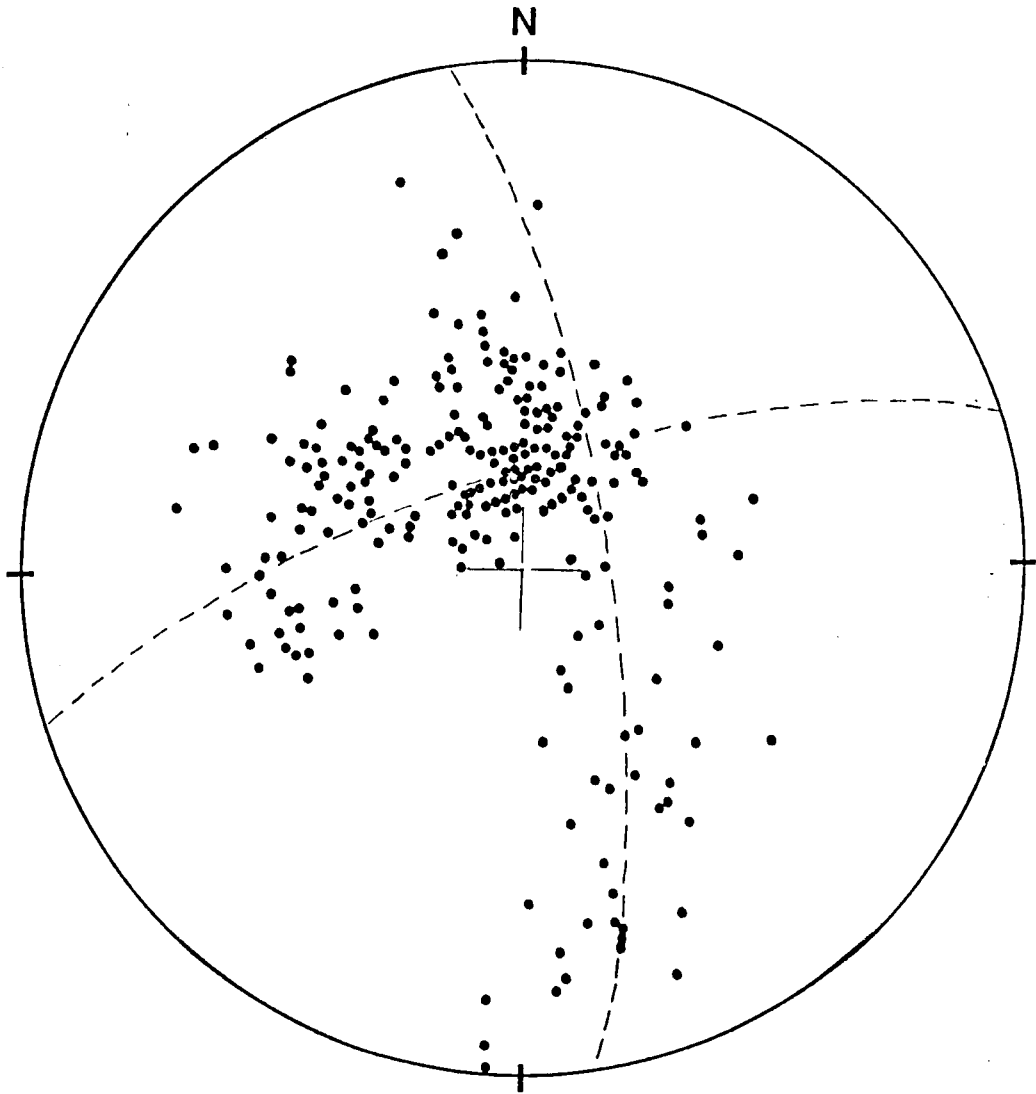


Figure 12. Fabric orientation data from subarea A(2). $N_{So} = 232$.

Figure 13 is a plot of slickensided bedding from the megascopic buckle folds in subarea A(2). The poles and slip linears from the S_0 surfaces can be fitted to a N-S striking pi circle that is subparallel to the S_0 pi circle of the megascopic buckle folds (Figure 12). This indicates that the slip along bedding can be attributed to the folding phase that produced the buckle folds.

Figure 14 is a plot of poles to (hk0) faults found within subarea A(2), with direction and sense of slip indicated by Hoeppener arrows. The fabric data shown in Figure 14 was collected from the quarry shown in Figure 10.

The fabric orientation data presented in Figure 14 show that the predominant sense of movement on most (hk0) faults is left-lateral. However, the left-lateral faults do not show a preferred strike or and consequently do not plot as a distinct maxima in Figure 14. In contrast, the right-lateral faults exhibit a distinctly preferred strike of $090-110^\circ$, but dip either to the N or S. It is likely that the right-lateral faults are conjugate to a specific set of left-lateral faults, but it is not possible to determine which is the correct set. The problem of establishing the correct conjugate shear pair is illustrated in Figure 14 by the fact that two distinct pi circles can be inferred from the distribution of fault planes, each containing the right-lateral faults.

Discussion. The N-S striking ac plane of the folds in subarea A(1) and N-S strike of the ac plane of the buckle folds in subarea A(2)

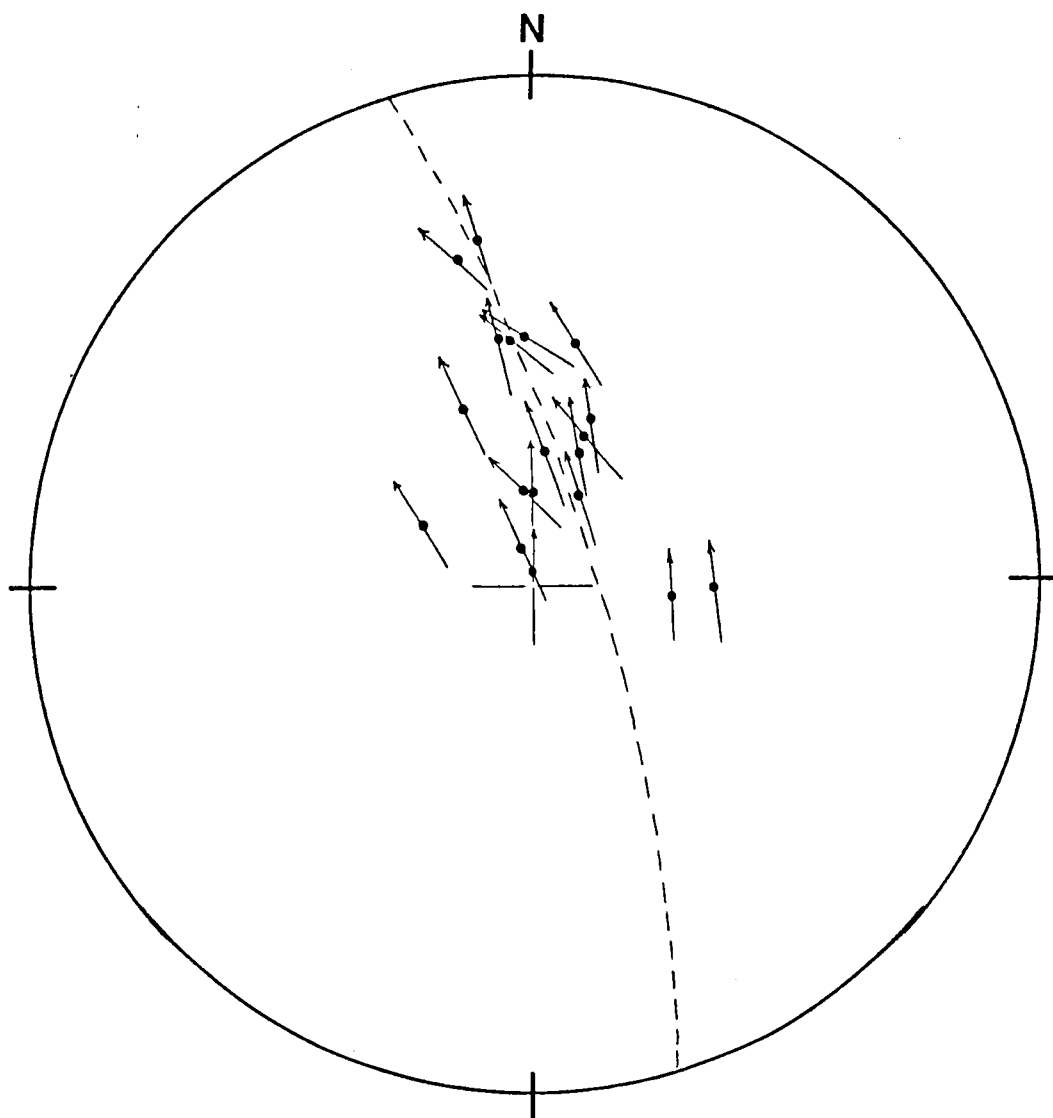


Figure 13. Slickensided bedding planes from subarea A(2). $N_{So} = 19$.

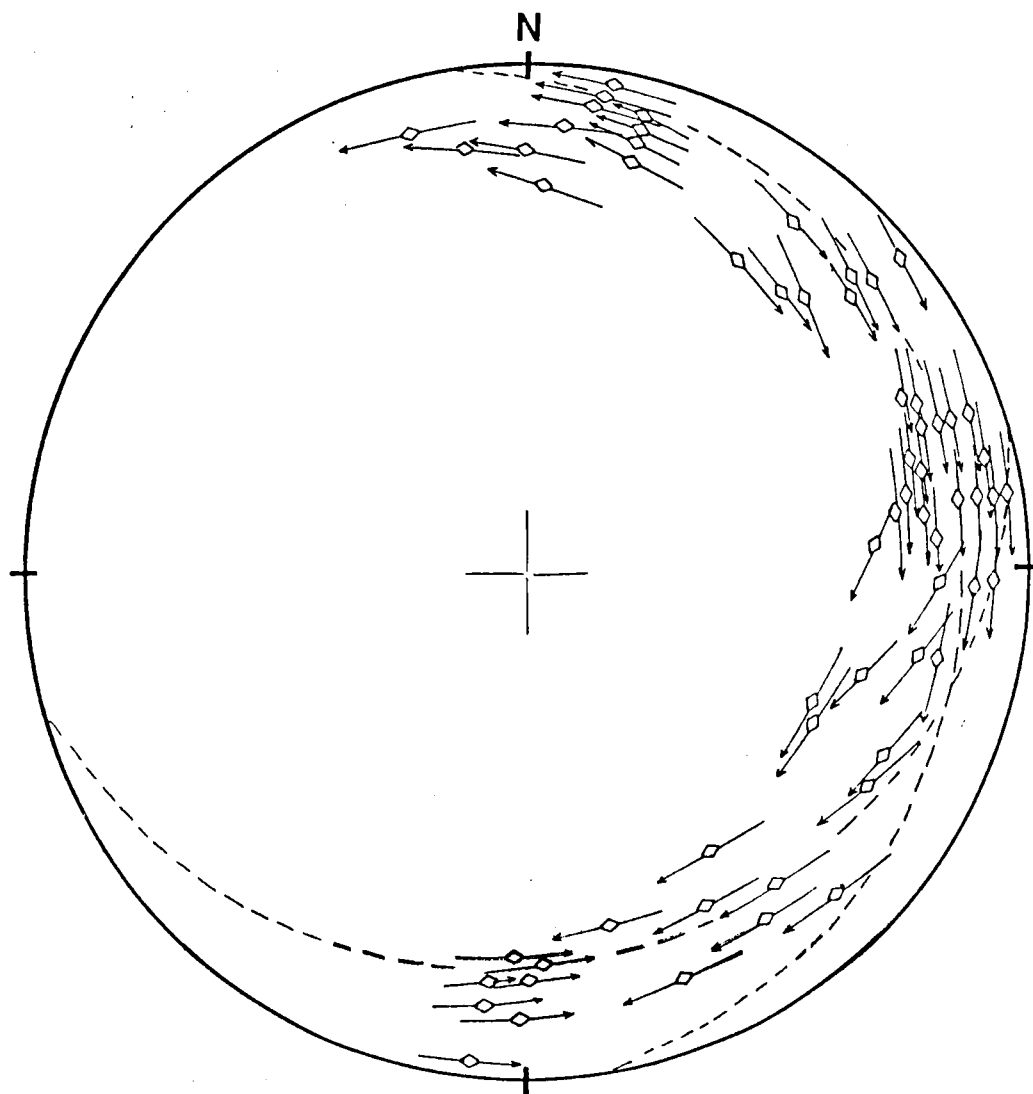


Figure 14. Slickensided (hk0) faults from quarry in subarea A(2).
 $N_{(hk0)} = 62$.

indicate that both fold sets resulted from a N-S directed stress. In addition, the fact that both ac planes strike N-S suggests that both fold sets are of the same age. The N-S directed stress does not appear to have affected the rocks to the SW of Outcrop 5, since no folds were observed in the Chickamauga limestones of that area. It also does not appear to have affected the rocks in the hanging wall of the Whiteoak Mountain fault to the immediate SE of Outcrop 5, since no folds were observed in the Rome Formation. The absence of folds with E-W trending axes in these areas implies that the N-S directed stress only affected the footwall rocks in subareas A(1) and A(2) and was not regional in extent.

The N-S directed stress may have been caused by thrusting on the fault shown in the center of Figure 10, p. 26. The fault trace strikes N-S before it merges with the Whiteoak Mountain fault, which suggests that there may have been a significant component of left-handed shear during thrusting. This may have created a very localized N-S trending directed stress in the footwall block that is responsible for the E-W striking folds in subareas A(1) and A(2).

The fault also appears to be younger than the macroscopic subthrust syncline, since it offsets folded beds of the Conasauga, Knox and Chickamauga Groups. This suggests that the E-W striking folds in subareas A(1) and A(2) represent a folding event that is later than the folding event which produced the subthrust syncline.

The significance of the (hk0) faults with respect to the postulated sequence of folding events is unclear. It can only be speculated that

they may represent an extensional fabric that developed during one and possibly both folding phases.

The age relationship between the E-W striking buckle folds in subarea A(2) and the NW-SE striking folds within the same area is uncertain. The NW-SE striking folds either represent a very early folding phase that predates formation of the subthrust syncline as well as formation of the buckle folds, or they represent a very late folding phase that postdates the two previous folding phases.

Synopsis. The postulated sequence of deformation in the area shown in Figure 10, p. 26, is as follows: With the exception of the NW-SE striking folds, the earliest folding event that can be related to a NW-SE striking directed stress is the folding of the footwall rocks into a NE-SW striking macroscopic subthrust syncline. Since the Whiteoak Mountain fault is not folded, the syncline appears to have formed by drag folding of the footwall rocks during active transport of the Whiteoak Mountain thrust sheet. The former leading edge of this thrust sheet, represented by the wedge of Cambrian Rome Shale and Cambrian Rome Shale klippen in subarea A(2), was subsequently truncated by rethrusting on the fault. Rethrusting on the fault is thought to have been caused by a late wave of horizontal compression that passed through this area. The late wave of horizontal compression is also thought to be responsible for initiating the thrust fault in center of Figure 10, p. 26. Active thrusting on this fault apparently caused a N-S directed stress in subareas A(1) and A(2) resulting in E-W

striking folds. The (hk0) faults found in the quarry could have resulted from an extension parallel to the strike of the macroscopic syncline during folding, or from an extension parallel to the b axes of the buckle folds during folding.

Outcrop 6

General Description. Outcrop 6 is located in the NE corner of the Clinton quadrangle, along a roadcut on U.S. Route 25, approximately 0.85 km S of Clinton, Tennessee (Figure 1, p. 2). This outcrop provides an excellent exposure of the Silurian Rockwood Formation within the core of a subthrust syncline in the footwall of the Whiteoak Mountain fault (Rodgers, 1953; Swingle, 1964; Hardeman, 1966). The back limb of this syncline has been sheared off by a splay from the Whiteoak Mountain fault (Swingle, 1964).

Fabrics in these rocks are defined by left-lateral kink folds, SE dipping mesoscopic thrust faults, (hk0) faults with both a dip-slip and strike-slip component of movement, and a conjugate set of NE and N dipping (h01) faults.

Fabric Analysis. Figure 15 is a plot of poles to S_0 , poles to kink fold axial planes and kink fold axes. Poles to S_0 cluster into a distinct maximum in the NW quadrant of the Schmidt net but are spread into a diffuse maximum in the southern hemisphere. Kink fold axes cluster into two separate maxima in the NE quadrant of the net but poles to kink fold axial planes cluster into one distinct maxima on the Schmidt net.

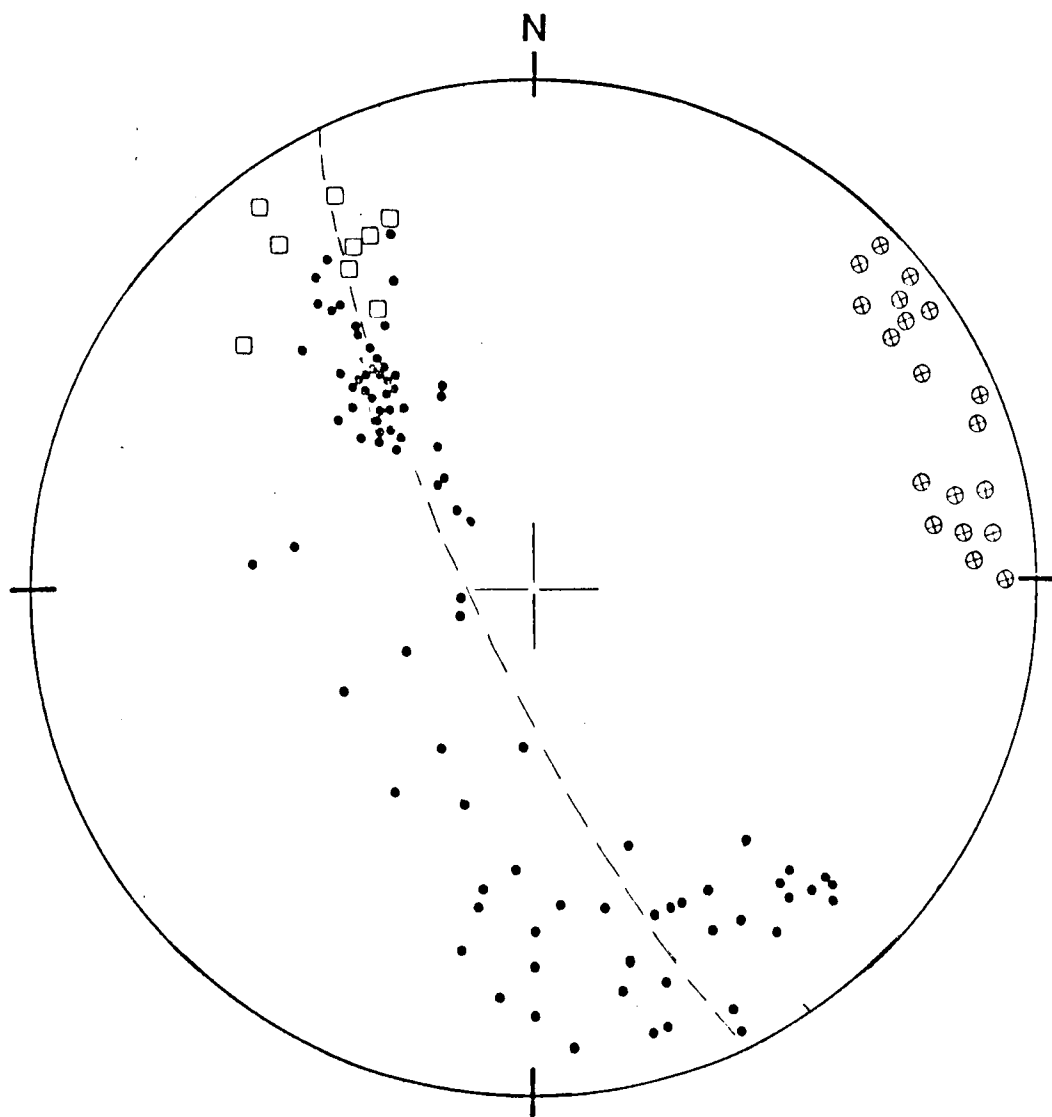


Figure 15. Fabric orientation data from Outcrop 6. $N_{So} = 68$, $N_{b(kink)} = 19$, $N_{ap(kink)} = 6$.

Poles to bedding can be fitted with some degree of confidence to a NW-SE striking π circle that approximately defines the ac plane of folding for the kink folds at this outcrop. Poles to kink fold axial planes lie on the π circle and kink fold axes are roughly normal to this plane.

Figure 16 is plot of poles to slickensided shear surfaces, with direction and sense of slip indicated by Hoeppener arrows. Poles and slip linears of the SE dipping mesoscopic thrust faults together with the poles and slip linears of slickensided bedding surfaces can be fitted to a NW-SE striking π circle. This π circle is roughly parallel to the S_0 π circle of Figure 15 and indicates that kink folding was accompanied by mesoscopic thrust faulting and bedding plane slip.

The second set of (h01) surfaces, consisting of NE and N dipping faults, can be fitted to a N-S striking π circle. Because the poles to the fault surfaces together with slip linears on the fault surfaces define a single ac plane of deformation, these faults are considered to be part of a conjugate set.

Poles to the (hk0) faults together with the slip linears on the fault surfaces can be loosely fitted to a NE-SW striking π circle. This π circle defines the ac plane of deformation for a conjugate set of (hk0) faults that have both a strike-slip and dip-slip component of movement.

Discussion. The diffuse maximum of poles to NW dipping bedding in Figure 15 is a strong indication that the middle-limbs of most kink folds

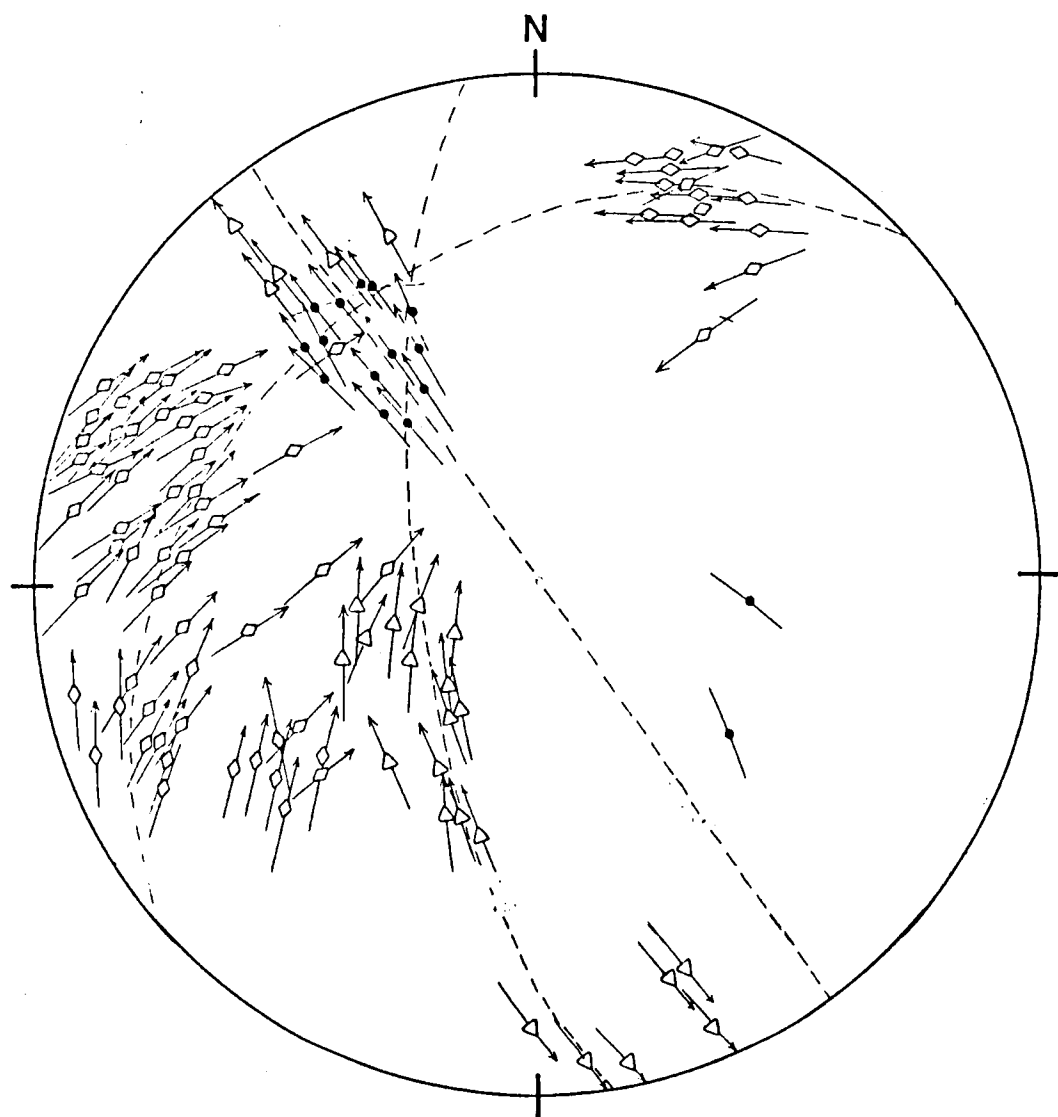


Figure 16. Slickensided shear surfaces at Outcrop 6. $N_{S0} = 14$,
 $N_{(h01)} = 40$, $N_{(hk0)} = 69$.

were subjected to intense shearing strains during folding that resulted in their distortion. The distortion appears to have been experienced only by the middle-limbs of the kink folds since poles to SE dipping bedding in the back-limbs of the kink folds plot as a tight cluster in Figure 15.

The strike of the (hk0) ac plane is roughly parallel to the strike of the kink fold axes (See Figures 15 and 16). This indicates that the (hk0) faults most likely document an extension of bedding parallel to the regional b axis during shortening of these rocks by a NW-SE trending directed stress. If bedding is rotated to horizontal about the regional b axis (Figure 17), it significantly reduces the strike-slip component of movement of the (hk0) faults and greatly increases the dip-slip component of movement. The net loss of the strike-slip component after the rotation, strongly suggests that these are normal faults that have been tilted into their present attitudes. Consequently, it strongly implies that the extension parallel to the regional b axis occurred early in the deformational history of these rocks.

The gently NE-E dipping and steeply N dipping (h01) faults appear to have formed as the result of a gently N-NW plunging directed stress acting upon bedding that was inclined to the principal stress axis. A NW directed stress acting upon inclined bedding adequately accounts for the fact that the faults cross-cut bedding at a high angle. It also accounts for the normal sense of displacement on the gently NE-E dipping faults, and the fact that these faults are conjugate to a set of N dipping reverse faults.

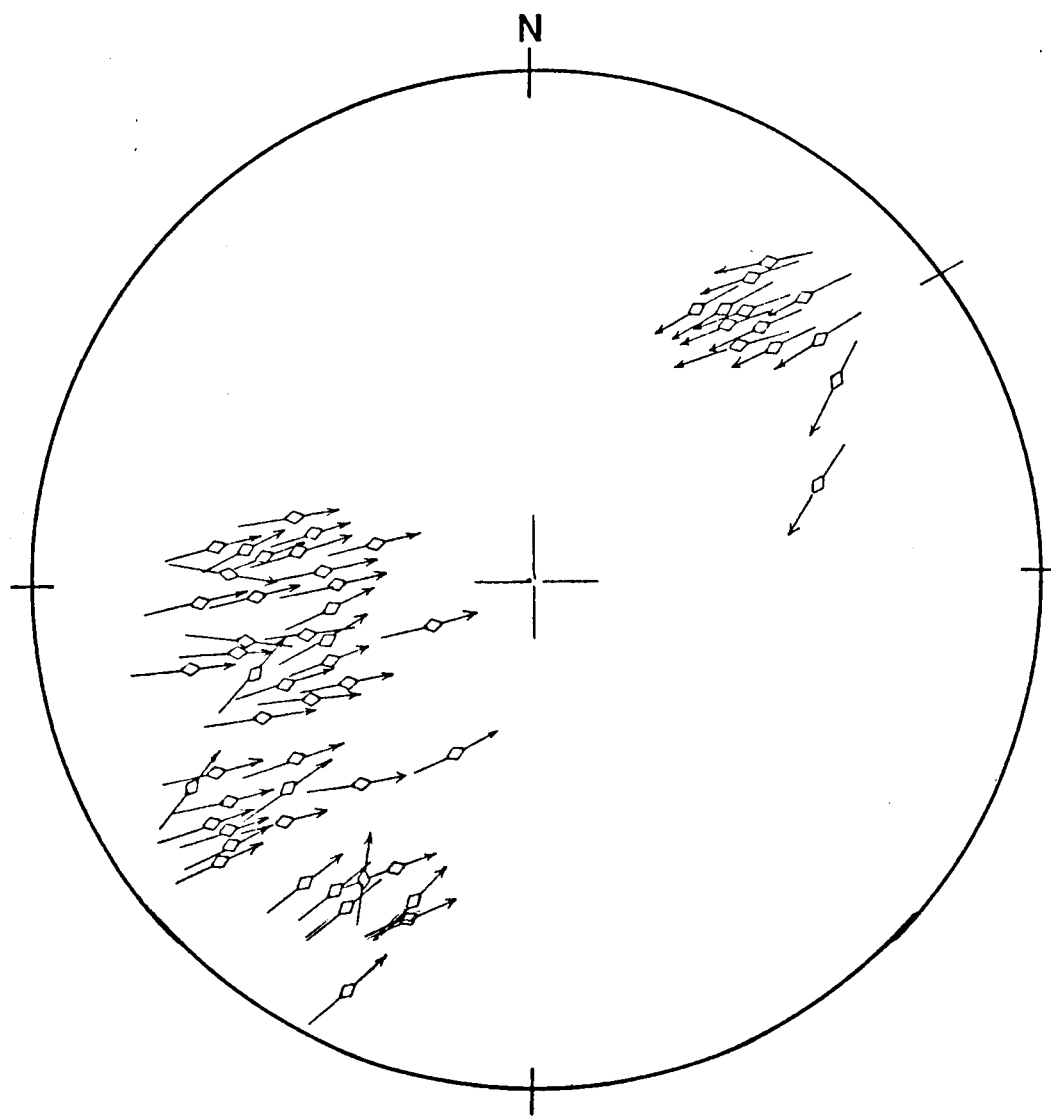


Figure 17. Rotated (hk0) faults from Outcrop 6. $N_{(hk0)} = 69$.

Synopsis. The extensional normal faults appear to be later than the folds because folded fault surfaces were not observed in this outcrop. Since the normal faults apparently formed when bedding was subhorizontal, the absence of folded faults also implies that bedding was subhorizontal at the onset of folding. The conjugate set of NE-E and N dipping (h01) faults appear to have formed after bedding was tilted towards the SE and therefore they are presumed to postdate the folding and the subsequent extension parallel to the regional b.

Outcrop 7

General Description. Outcrop 7 is located approximately 32 km W of Knoxville via State Route 62 (Figure 1, p. 2). The outcrop site is reached by taking a south turn on the first road west of the C.A.R.L. office, and then proceeding 0.5 km along this road.

At this outcrop, lower Cambrian Rome and middle Cambrian Conasauga in the hanging wall of the Copper Creek fault (Rodgers, 1953; McMaster, 1963; Hardeman, 1966) are in concealed thrust contact with middle Ordovician Chickamauga limestones. Structural discontinuities in the hanging wall consist of a conjugate set of (hk0) faults, mesoscopic thrust faults, extensional dip-slip faults and kink folds.

Fabric Analysis. Figure 18 is a plot of bedding poles, kink fold axes, and poles to axial planes. Poles to bedding can be fitted to two distinct π circles. The E-W striking π circle defines the ac plane of folding for kink folds with N-S trending fold axes. The NW-SE striking

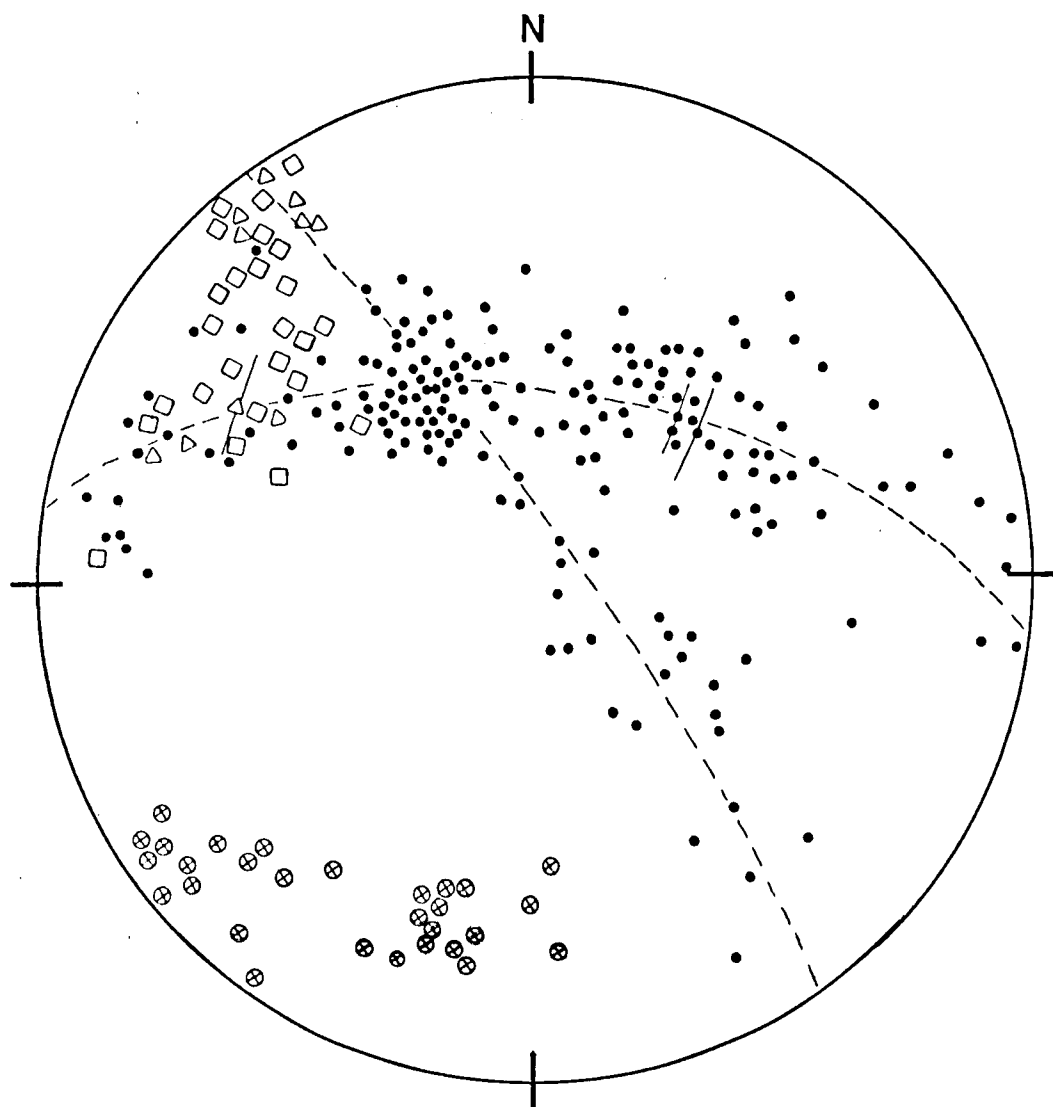


Figure 18. Fabric orientation data from Outcrop 7. $N_{So} = 173$,
 $N_{b(kink)} = 43$, $N_{ap(kink)} = 25$, $N_{(h01)} = 9$.

pi circle defines the ac plane of folding for kink folds with subhorizontal fold axes that trend parallel to the strike of the Copper Creek fault (045-055°).

Figure 19 is a plot of poles to (hk0) fault surfaces, with the direction and sense of slip indicated by Hoeppener arrows. Poles and slip linears can be fitted to a pi circle striking 032° and dipping 25° to the SE. The strike of the ac plane is oblique to the regional strike and suggests that the extension recorded by the (hk0) faults was not parallel to the regional b axis.

Discussion. The close fit of bedding poles to two distinct pi circles with different orientations (Figure 18) signifies that there are two generations of folds at this outcrop. The N-S trending kink folds could not have resulted from the late Paleozoic NW-SE trending layer parallel stress that initiated the Copper Creek thrust fault. Therefore, it is likely that these kink folds predate the NE-SW trending kink folds that are correlative with thrusting along the Copper Creek fault. Since bedding is inferred to have been horizontal at the onset of NW directed thrusting, the early folding probably resulted as the result of a layer parallel E-W directed stress.

The early folding event appears to be coeval with an early E to W directed thrusting event. This is suggested by the presence of N-S trending folds in the hanging and footwalls of mesoscopic thrust faults (See Figure 20). N-S trending folds also occur in groups of tight folds in which the fold limbs are continuous into homoclinal bedding directly above and below the groups of folds (Figure 21).

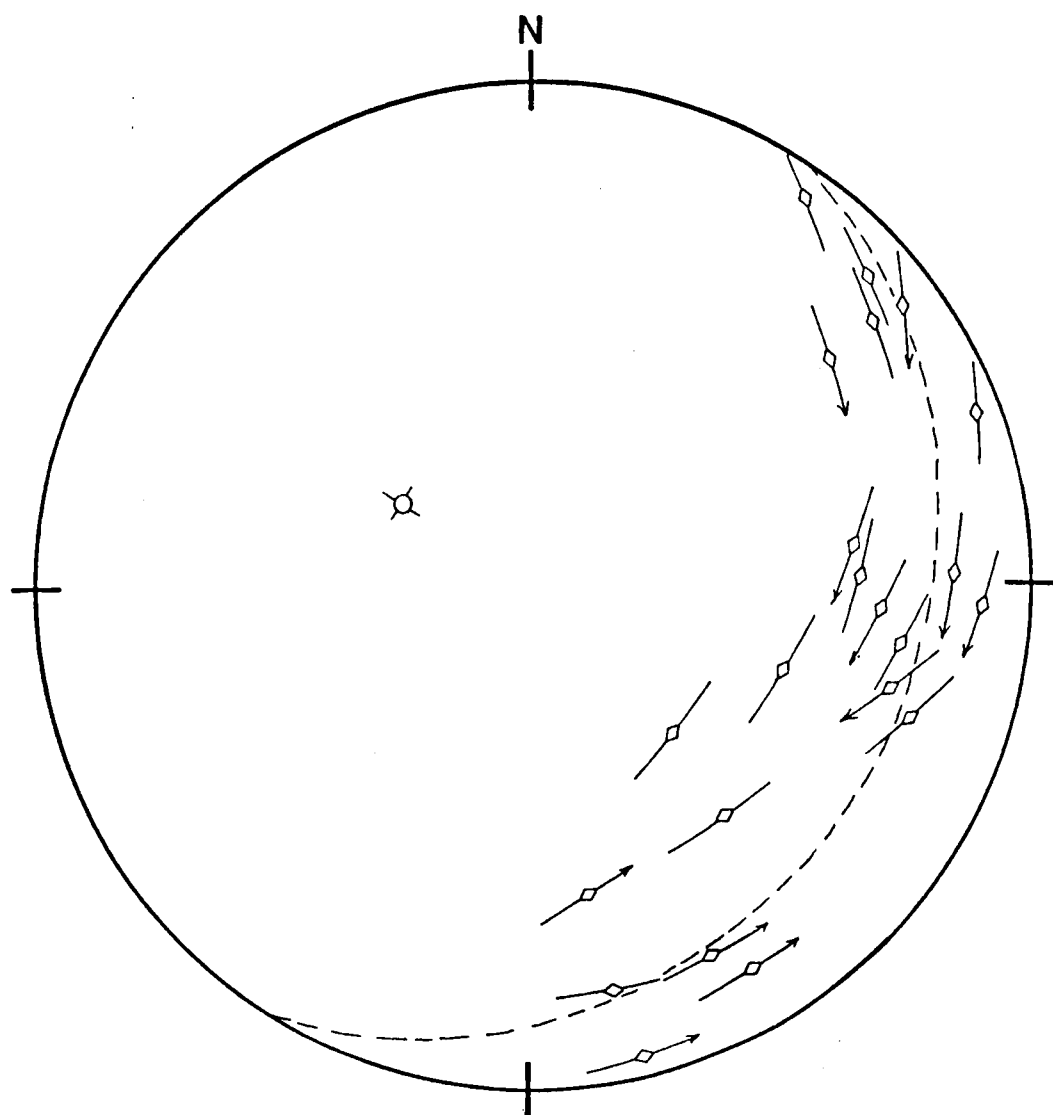


Figure 19. Slickensided (hk0) faults from Outcrop 7. $N_{(hk0)} = 21$.



Figure 20. SE dipping low-angle thrust fault with N-S trending kink fold in the hanging wall.

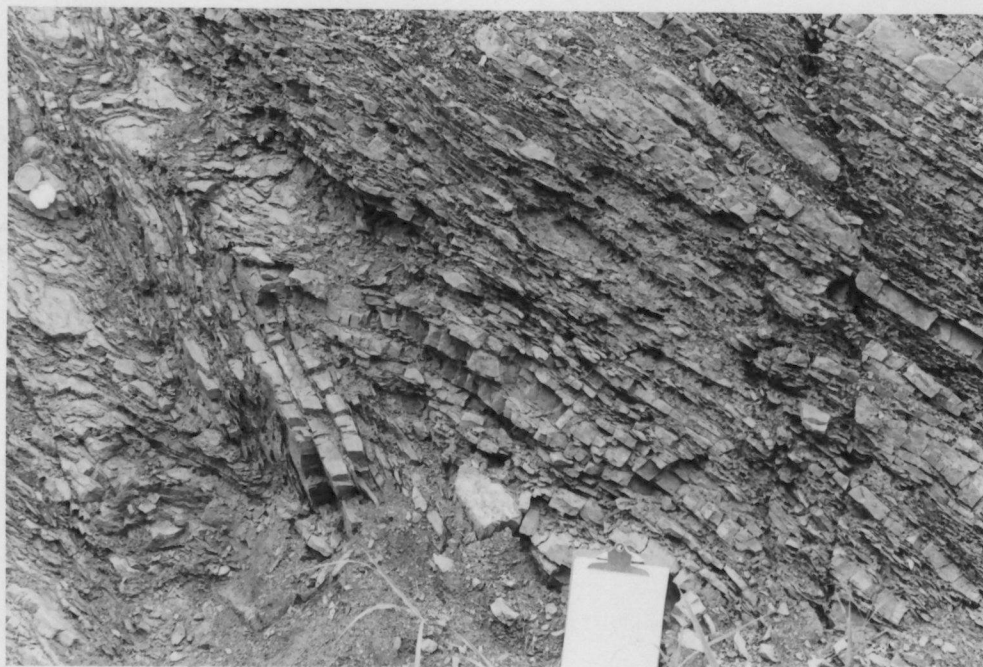


Figure 21. N-S trending kink folds in the Rome with limbs that are continuous into homoclinal bedding both above and below the fold group.

The (hk0) faults at this outcrop most likely record an extension oblique to regional strike that occurred after the E to W directed thrusting and early folding event, but prior to NW directed thrusting. The oblique to regional strike orientation of this extension is suggested by the trend of the (hk0) ac plane, oblique to regional strike (Figure 19). The extension appears to have occurred after E to W thrusting and early folding because N-S trending slip linears, indicative of strike-slip movement, were found on the fault shown in Figure 20. The pole to this fault, together with the direction of slip is plotted in Figure 18. The N-S trend of the Hoeppener linear on this fault is subparallel to the strike of the (hk0) ac plane (Compare Figures 18 and 19), which strongly implies that strike-slip movement on this fault was coeval with the oblique to regional strike extension. Strike-slip movement on the fault appears to have been accompanied by bedding plane slip on beds directly above the fault. This is suggested by N-S trending slip linears that are present on two different SW dipping beds approximately 10 and 15 cm, respectively, above the fault. This slip direction of the beds is represented by Hoeppener linears in Figure 18.

Shortening of bedding in this section of Rome and Conasauga by a NW-SE trending applied stress was accomplished by kink folding and high-angle reverse faulting. Shortening by a NW-SE trending applied stress is indicated because kink fold axial planes and reverse fault planes are parallel to the regional strike (Figure 18). Both kink fold axial planes and reverse fault planes dip steeply to the SE with approximately the same dip. This implies that both the axial planes and

fault planes are subparallel to the same shearing plane associated with a NW-SE trending stress. This is additionally suggested by the fact that faults that are parallel to kink fold axial planes (See Figure 22), indicating folding followed by faulting, have the same strike and dip as reverse faults that cannot be directly correlated with kink folding. Because kink folds are not associated with low-angle thrust faults indicative of layer parallel shortening, it suggests that bedding may have been inclined to the principal stress when folding and high-angle reverse faulting was initiated. This suggests that folding and faulting in this section of Rome and Conasauga occurred after the Copper Creek fault had cut upsection. However, it cannot be established whether this deformation occurred during active transport or after the thrust sheet was emplaced.

High-angle NE-SW striking normal faults pervade the outcrop and suggest an extension parallel to the direction of thrust transport. Normal faults crosscut early N-S trending folds and SE dipping reverse faults. Fault planes dip moderately to the NW and steeply to the SE and they appear to be part of a conjugate system of dip-slip faults. Figure 23 is a photograph of intersecting normal faults in the Rome. Figure 24 is a plot of all measured fault planes in the Rome and Conasauga at this outcrop. The locus of fault plane intersections corresponds to the position of the intermediate stress axis during faulting (Hobbs, Means and Williams, 1976, p. 518). The acute bisectrix of the conjugate shears defines the principal stress axis, and the obtuse bisectrix defines the minimum stress or principal extension axis. The stress axes are labeled P_{int} , P_{max} , and P_{min} in Figure 24.

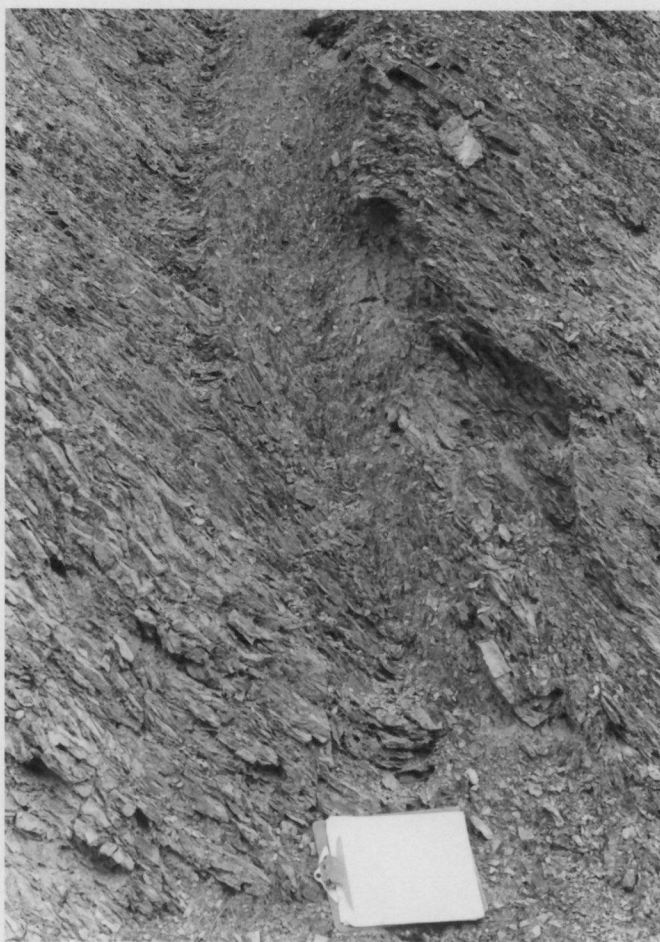


Figure 22. Left-lateral kink folds in the Rome with steeply SE dipping axial planes, and fold axes that are subparallel to the regional structural grain.



Figure 23. Conjugate normal faults in the uppermost Rome sandstones.

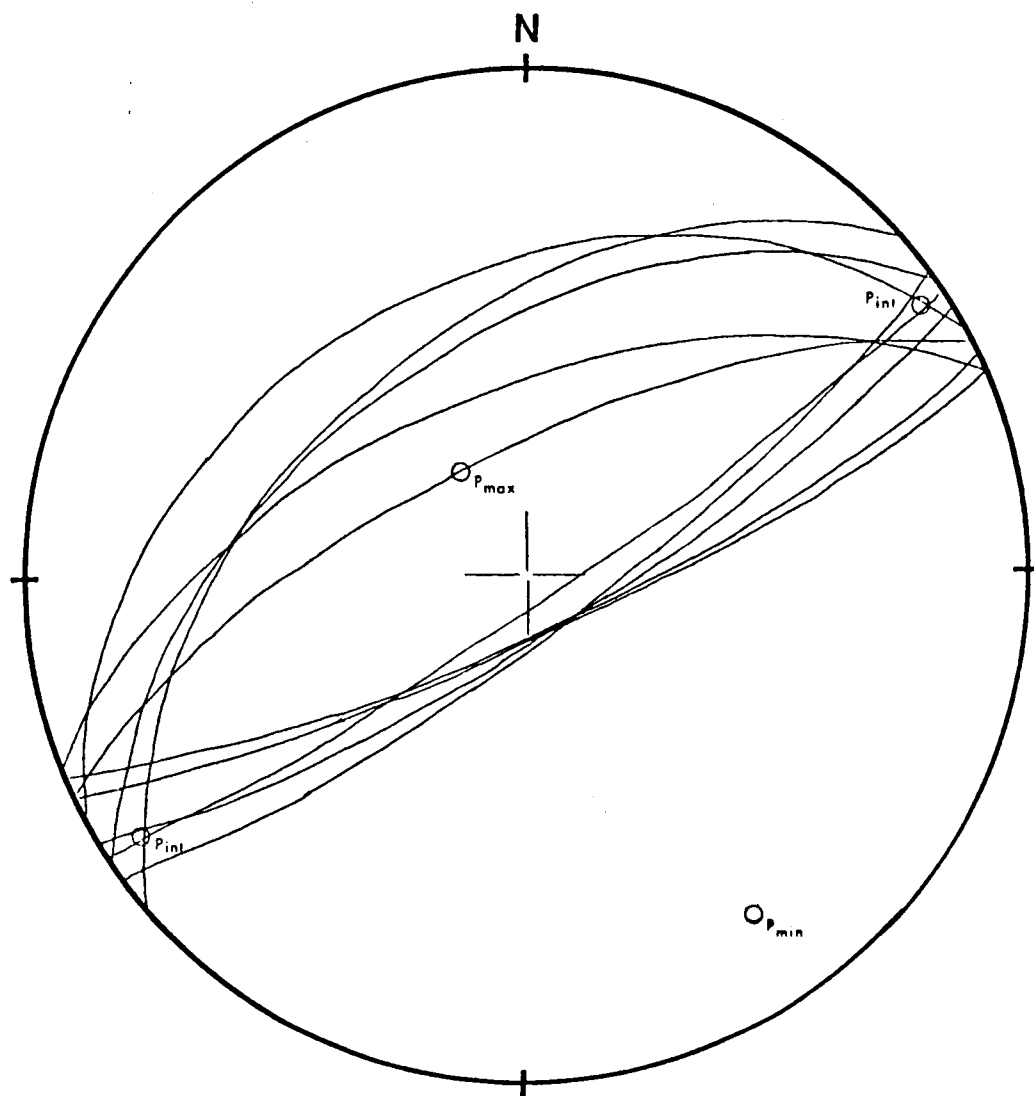


Figure 24. Beta diagram of normal fault planes from the Rome and Conasauga at Outcrop 7, showing the derived principal stress axes.

The principal extension axis for the normal faults at this outcrop plunges approximately 20° to the SE. The extensional axis is subparallel to bedding and indicates a downdip extension. Since the extension axis is parallel to the thrust transport direction, the normal faults probably represent a localized downdip lengthening of bedding after emplacement of the thrust sheet.

Synopsis. The earliest deformation of the Rome and Conasauga at this outcrop resulted from an E-W trending layer parallel stress. This deformation cannot be correlated with late Paleozoic NW directed thrusting on the Copper Creek fault so that it most likely predates thrusting on the fault. This early deformational event consisted of kink folding and E to W directed thrusting which was followed by an oblique to regional strike extension.

Fabrics resulting from a NW-SE trending compressive stress consist of kink folding that is coeval with high-angle reverse faulting. Bedding is inferred to have been inclined to the principal compressive stress because low angle thrust faults indicative of layer parallel shortening are not associated with the kink folds. This deformation is inferred to have occurred after the fault had cut upsection but it cannot be established whether the deformation occurred during transport or after emplacement of the thrust sheet.

The latest deformation of these rocks was the result of a localized downdip lengthening of bedding. Lengthening parallel to bedding is documented by NW-SE striking conjugate normal faults which pervade the outcrop and which crosscut compressional fabrics.

Outcrop 8

General Description. Outcrop 8 is located in the northern half of the Lenoir City quadrangle along a curving roadcut on State Route 95 (Figure 1, p. 2). The outcrop consists of a subvertical section of upper Rome and a lower Conasauga rocks that are in the hanging wall of the Beaver Valley fault (Rodgers, 1953; Hardeman, 1966). The fault is not exposed at this outcrop, but outcrops of Knox on the other side of the road indicate the fault is nearby.

Fabric Analysis. Poles to bedding, with their direction and sense of slip shown by Hoeppener arrows, are plotted in Figure 25. Poles to kink fold axial planes and kink fold axes are also plotted on the same Schmidt net. Poles to bedding can be very loosely fitted to a NW-SE striking pi circle that approximately defines the ac plane of folding for steeply SW plunging kink folds at this outcrop. Poles to kink fold axial planes lie on the ac plane and the maximum of kink fold axes is roughly normal to this plane.

Figure 26 is a plot of (hk0) and (h01) faults at this outcrop, with their direction and sense of slip indicated by Hoeppener arrows. (hk0) faults strike consistently to the NW but have variable NE dips. (h01) fault dip to the SE, but slip on these faults was oblique to their dip.

Discussion. The kink fold axes at this outcrop are parallel to a steeply SW plunging b kinematic axis that cannot be correlated with the subhorizontal NE-SW trending regional b axis of the thrust belt. If

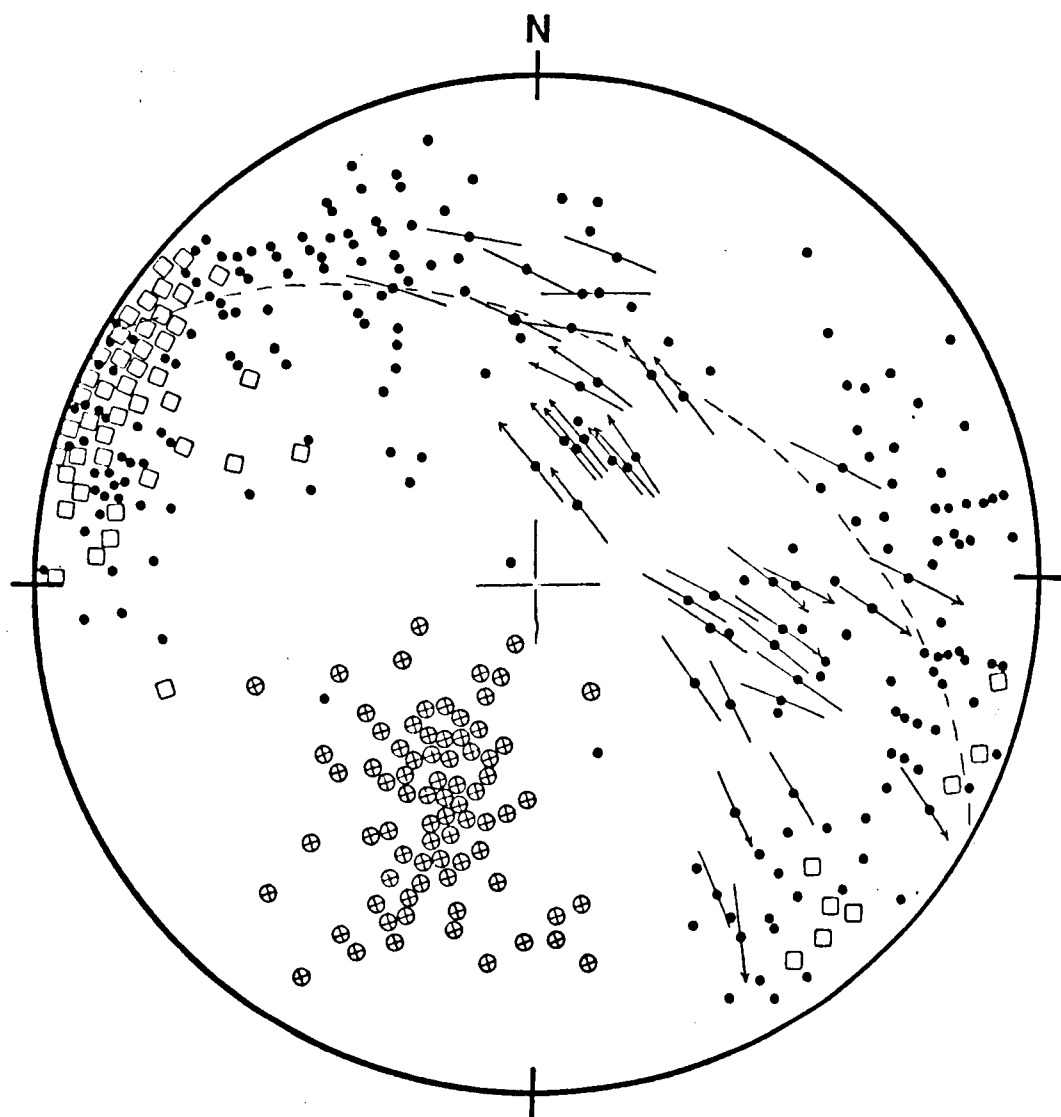


Figure 25. Fabric orientation data from Outcrop 8. $N_{So} = 232$,
 $N_{b(kink)} = 76$, $N_{ap(kink)} = 51$.

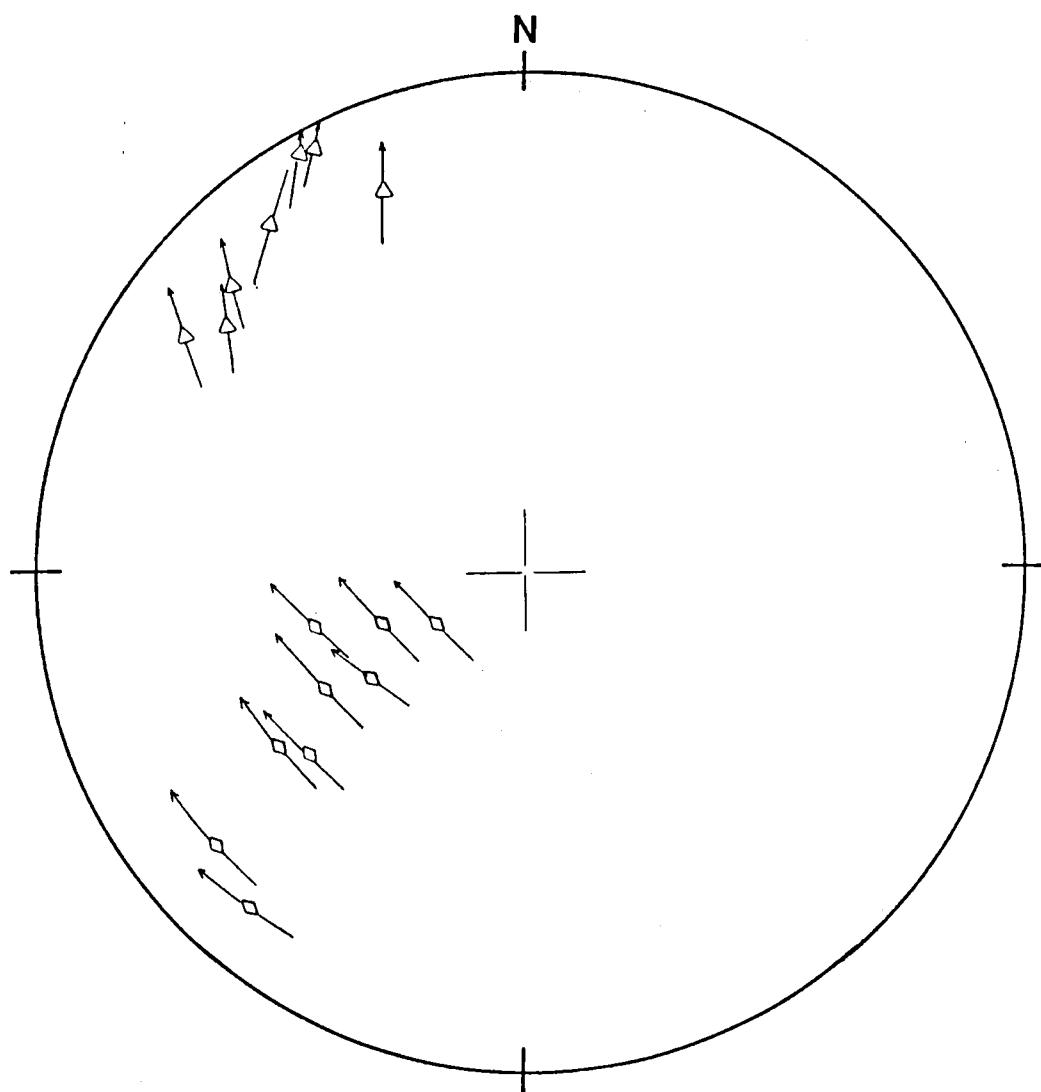


Figure 26. Poles to (h01) and (hk0) faults from Outcrop 8, with direction of slip indicated by Hoeppener arrows.
 $N_{(n01)} = 7$, $N_{(hk0)} = 9$.

bedding is rotated to horizontal about the regional strike, the fold axes rotate to horizontal in a N-S orientation (Figure 27). The N-S orientation of the fold axes after the rotation suggests that folding was the result of an E-W trending layer parallel stress. An E-W trending layer parallel stress cannot be correlated with NW directed thrusting on the Beaver Valley fault. This indicates the folds predate thrusting on the fault and probably predate the late Paleozoic imbrication of the Paleozoic shelf.

Bedding at this outcrop is attenuated by boudinage. The long axes of the boudins are subparallel to the kink fold axes (Figure 28), which implies that boudinage occurred during early folding. The presence of boudins on the limbs of the kink folds suggests that the folds were tightened to the limit where strain release by flexural slip was not possible. Beyond this limit, flexural flow became the predominant mechanism of strain release.

The (hk0) and (h0l) faults at this outcrop are correlative with a NW-SE trending stress. This is indicated by the NW trend of slip linears on the faults (Figure 26). The (hk0) faults crosscut subvertical to steeply SE dipping bedding, as well as the early kinks (Figure 29). Because they crosscut subvertical beds at a low angle, it suggests that bedding was inclined to the principal stress when faulting was initiated. Faulting on (h0l) shear surfaces probably also occurred when bedding was subvertical and inclined to the principal stress. This is suggested by the angular relation of bedding to the (h0l) faults. In every case, the dip of the fault was less than the dip of the beds it crosscut.

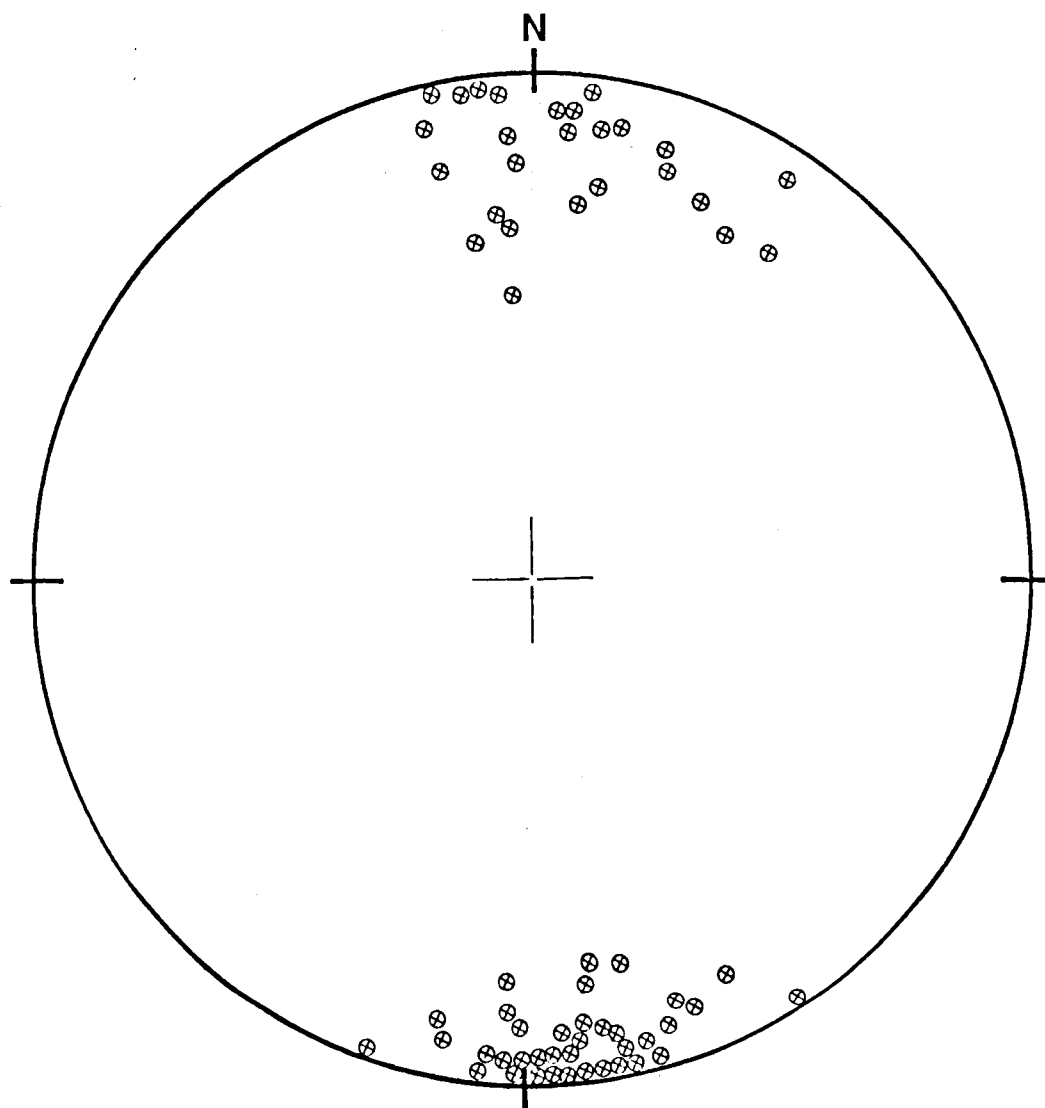


Figure 27. Rotated kink fold axes from Outcrop 8. $N_{b(\text{kink})} = 76$.



Figure 28. Slabbed kink fold showing boudinaged limbs. Fold axis is normal to the polished surface.



Figure 29. Steeply SE dipping and steeply SW plunging kink folds that are crosscut by gently NE dipping (hk0) fault.

Synopsis. The earliest tectonic fabric in the rocks at this outcrop consists of a set of kink folds that predate NW directed thrusting on the Beaver Valley fault. The kinks are associated with boudinage that occurred during early folding.

Subsequent tectonic fabrics formed as a result of a NW-SE trending stress acting upon subvertical beds. These fabrics consist of SE dipping (h01) and NE dipping (hk0) faults.

Outcrop 9

General Description. Outcrop 9 is located in the NE corner of the Lenoir City quadrangle, at the I-40 W/I-75 S interchange (Figure 1, p. 2). At this locality, I-40 W cuts through Beaver Ridge and exposes the Beaver Valley fault (Rodgers, 1953; Nalewaik, 1961; Hardeman, 1966). Chickamauga limestones in the footwall of the fault are undeformed and dip consistently to the SE. In contrast, Rome and Conasauga in the hanging-wall are intensely folded. The Beaver Valley fault strikes 50° and dips 45° to the SE at this outcrop.

Fabric Analysis. Figure 30 is a plot of poles to bedding, with direction and sense of slip of bedding indicated by Hoeppener arrows. Poles to axial planes and kink fold axes are plotted on the Schmidt net, as well. Poles to bedding can be loosely fitted to a NW-SE trending pi circle that defines the ac plane of folding for kink folds in the Rome and Conasauga. Poles to kink fold axial planes lie on the ac plane and kink fold axes are subnormal to this plane.

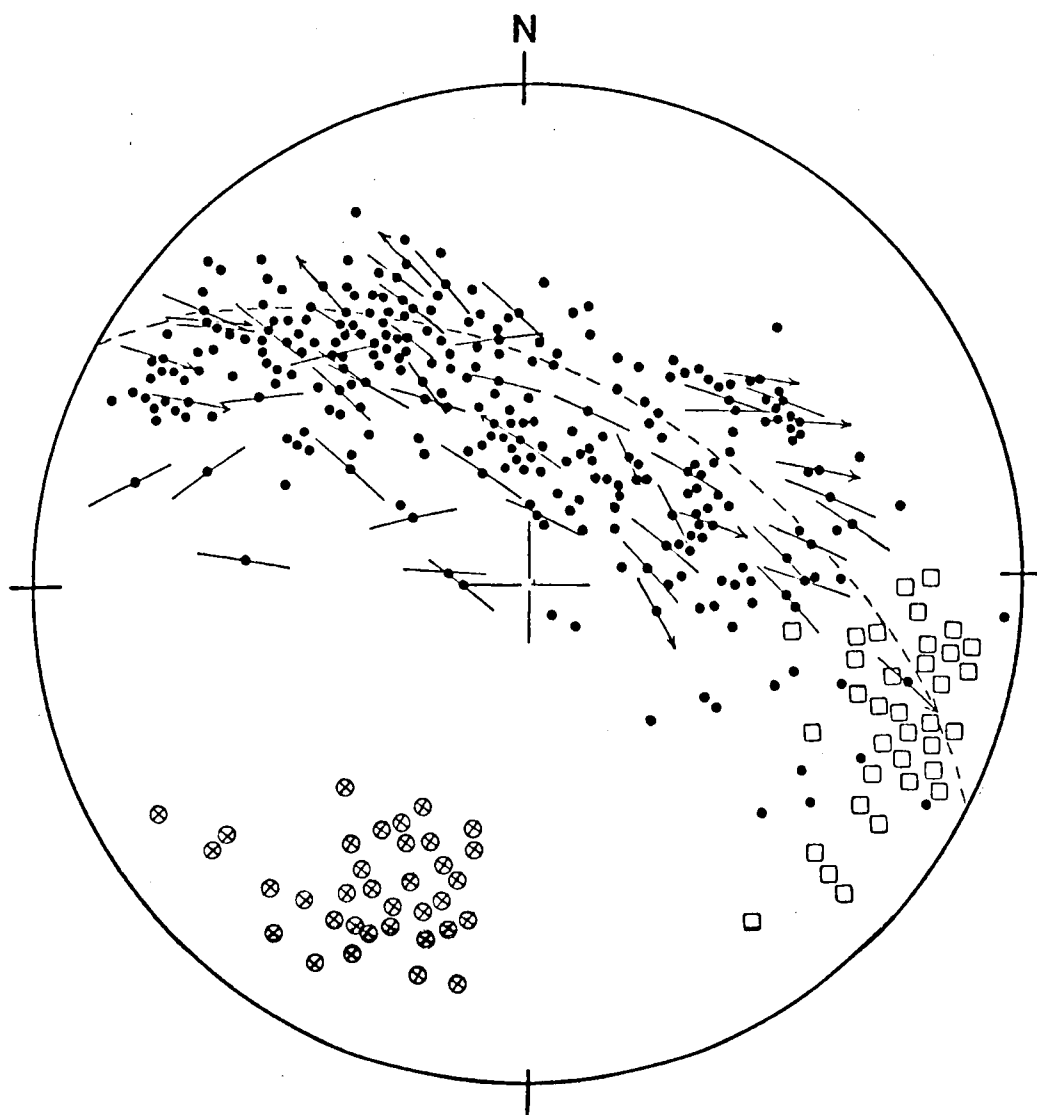


Figure 30. Fabric orientation data from Outcrop 9. $N_{So} = 253$,
 $N_{b(kink)} = 35$, $N_{ap(kink)} = 35$.

Discussion. The kink folds at this outcrop are left lateral kinks which are enclosed in steeply SE dipping to subvertical beds. This accounts for the NW dip of their axial planes.

The steep SW plunge of the kink fold axes suggests that they are an early set of folds that predate thrusting on the Beaver Valley fault. If bedding is rotated to horizontal about the regional strike, the fold axes rotate to subhorizontal in a N-S orientation (Figure 31). In their rotated positions, the N-S orientation of the fold axes suggest the kink folds resulted from an E-W layer parallel stress. This stress cannot be correlated with NW directed thrusting on the fault, and indicates that the folds predate NW directed thrusting.

The folds at this outcrop appear to have been distorted during NW directed thrusting. This is suggested by the scatter of bedding poles and by the criss-crossing trends of slip linears on bedding (Figure 30).

Synopsis. The folds at this outcrop cannot be correlated with NW directed thrusting. They are a fabric that predates NW directed thrusting on the Beaver Valley fault. Fold distortion appears to be correlative with thrusting.

Outcrop 10

General Description. Outcrop 10 is located in the NE corner of the Bearden quadrangle (Figure 1, p. 2). The outcrop is a roadcut along a secondary road that is parallel to the L&N railway, which cuts through Beaver Ridge at this locality. A 50-60 m section of Rome in the

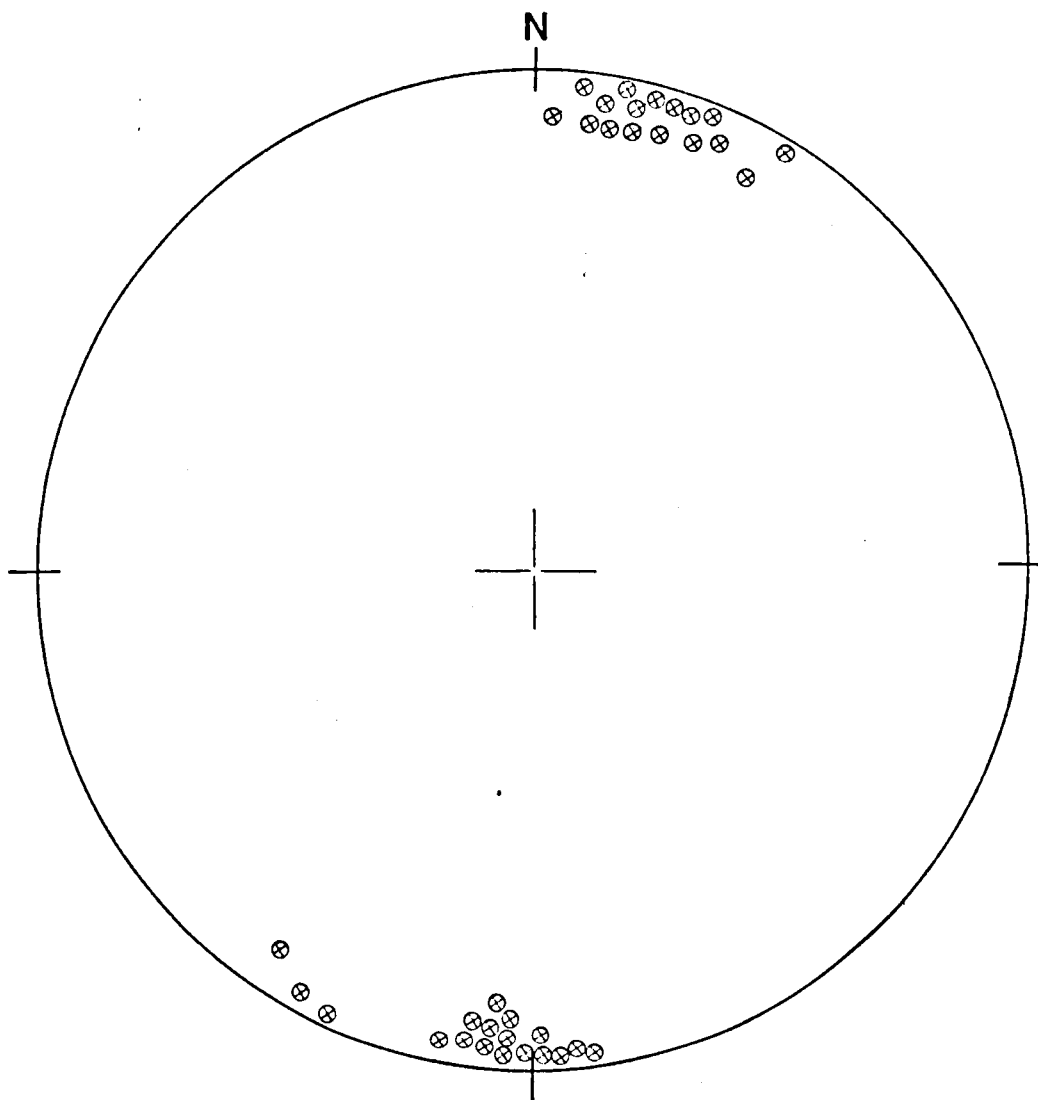


Figure 31. Rotated fold axes from Outcrop 9. $N_{b(kink)} = 35$.

hanging-wall of the Beaver Valley fault (Rodgers, 1953; Cattermole, 1960; Hardeman, 1966), is exposed at this outcrop.

Fabric Analysis. Figure 32 is a plot of poles to bedding, poles to kink fold axial planes and kink fold axes at this outcrop. Poles to bedding and poles to kink fold axial planes can be fitted to a NW-SE striking pi circle. This pi circle defines the ac plane of folding for right-lateral kink folds in the Rome. Kink fold axes are subnormal to this plane.

Discussion. Conjugate sets of kink folds were not observed at this outcrop. This suggests that the NW dipping axial planes of right-lateral kink folds (See Figure 33) are conjugate to the basal shear plane of the Beaver Valley fault. It also implies that bedding was inclined to a subhorizontal NW-SE trending stress when folding was initiated.

It is possible that folding may have occurred when further movement on the fault was impeded, perhaps by a lack of sufficient pore water in the lower Rome shales directly above the fault. Pore water depletion would effectively restrict frictionless gliding of the lower Rome on the shear surface. The accumulated strain in the hanging-wall beds, resulting from a NW-SE trending subhorizontal stress acting upon inclined bedding, would then be released by folding.

Synopsis. The folds at this outcrop developed from a NW-SE trending stress acting upon bedding inclined to the principal stress axis. Folding is thought to have occurred after the leading edge of the thrust sheet had arrived at the surface.

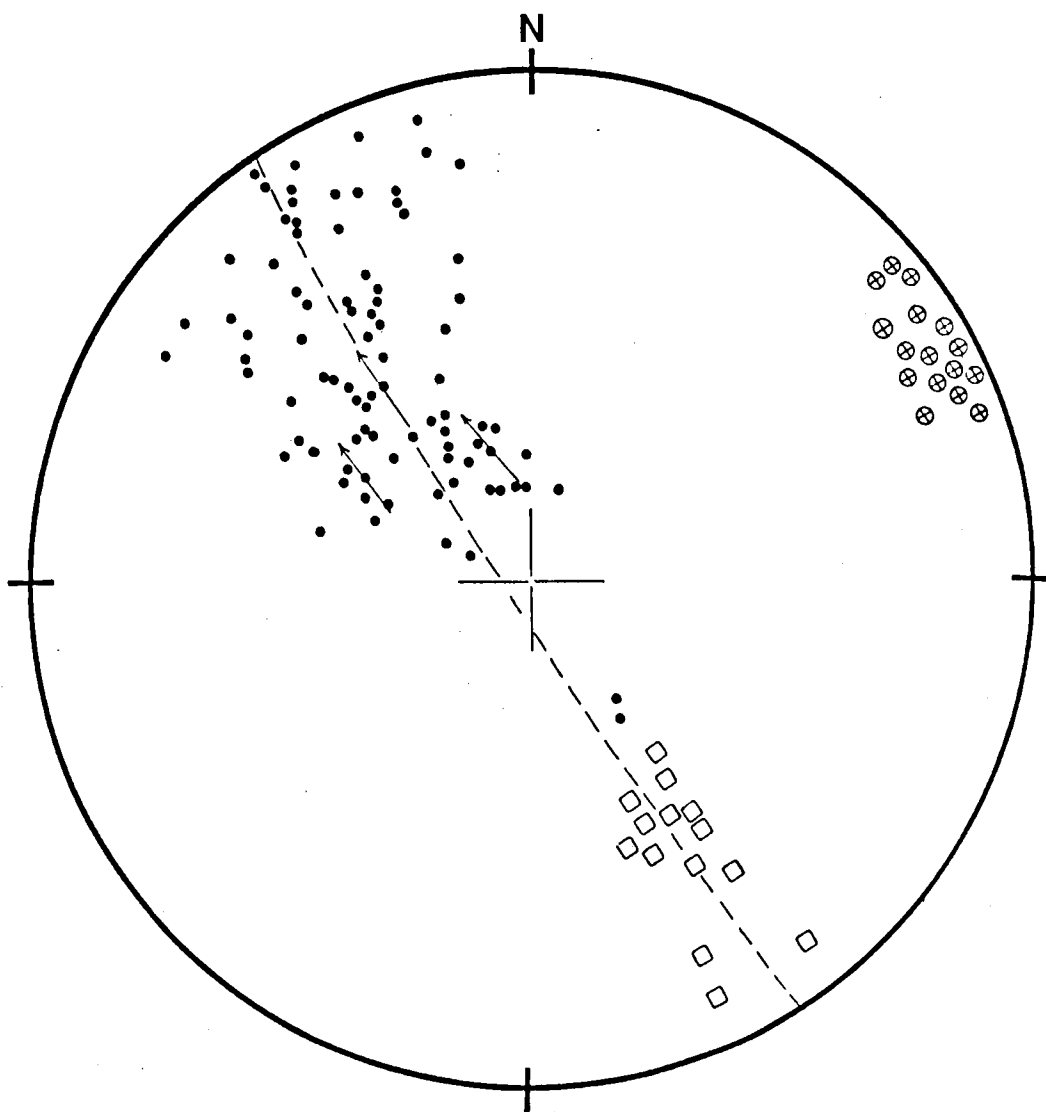


Figure 32. Fabric orientation data from Outcrop 10. $N_{So} = 81$,
 $N_{b(kink)} = 19$, $N_{ap(kink)} = 16$.



Figure 33. Right-lateral kink fold in the Rome at Outcrop 10.

Outcrop 11

General Description. Outcrop 11 is located approximately 5 km N of Knoxville, via U.S. State Route 441 (Figure 1, p. 2). U.S. Route 441 cuts through Beaver Ridge at this locality and exposes the Beaver Valley fault (Rodgers, 1953; Cattermole, 1966; Hardemank 1966). Here, the Rome is in thrust contact with overturned SE dipping Knox (Cattermole, 1966). The fault strikes 045° and dips 25° to the SE at this exposure.

The footwall rocks are brecciated at this outcrop. The brecciated zone is localized to a 5 m interval directly beneath and subparallel to the fault. A thin 1-2 cm layer of what appears to be mylonitized dolomite is present on the fault plane. The footwall rocks are regionally folded into a macroscopic syncline, but mesoscopic folds and faults were not observed in this section of Knox.

Fabric in the hanging-wall Rome consists of steeply SE dipping bedding and kink folds. Fabric orientation data was collected only from the hanging wall.

Fabric Analysis. Figure 34 is a plot of poles to bedding, with direction and sense of bedding plane slip indicated by Hoeppener arrows. Poles to kink fold axial planes and kink fold axes are plotted on the same Schmidt net. Poles to bedding and kink fold axial planes can be fitted to a E-W trending pi circle that defines the ac plane of folding for kink folds in the Rome.

Discussion. Kink folds at this outcrop are discordant to the regional structural grain. They apparently document an early E-W

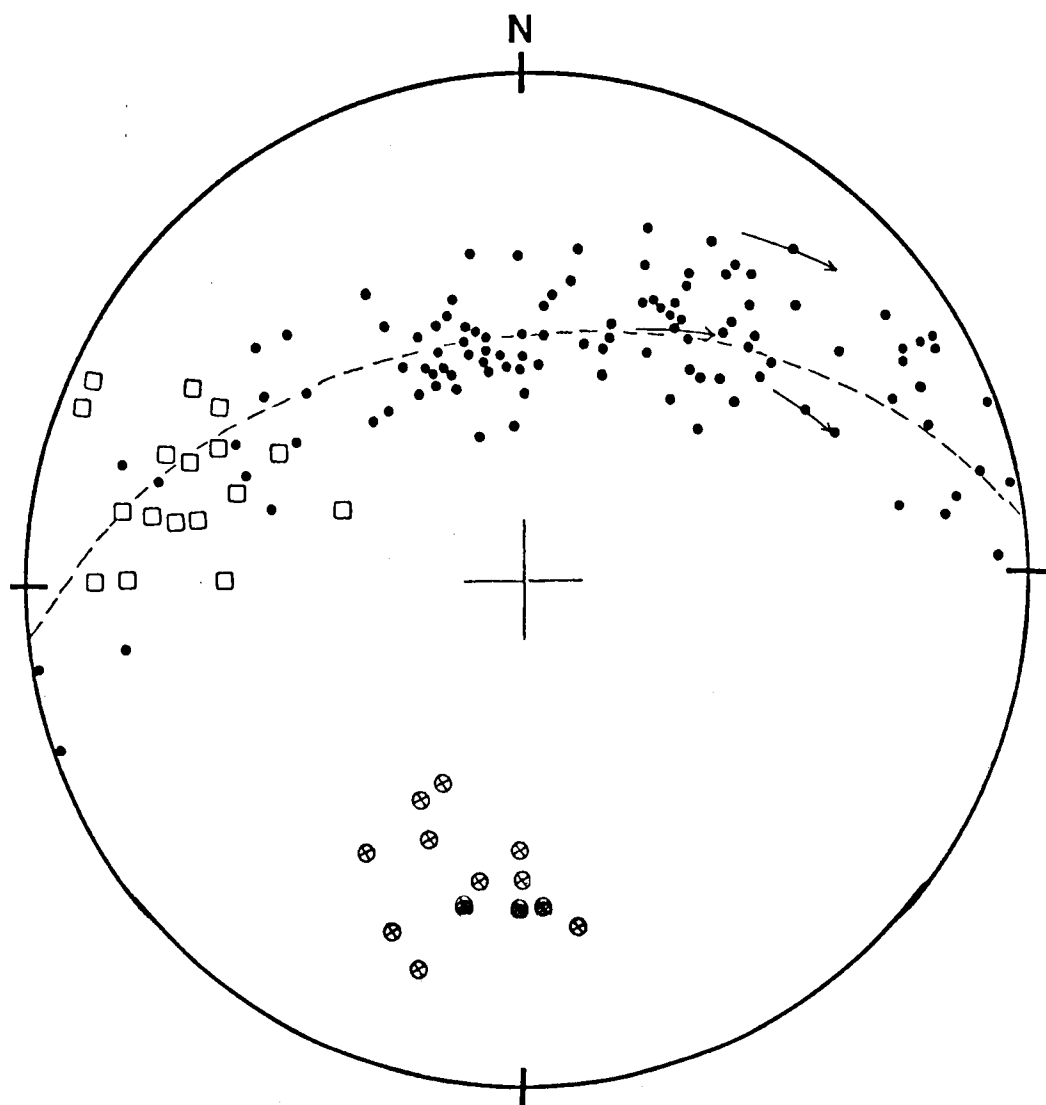


Figure 34. Fabric orientation data from Outcrop 11. $N_{S0} = 110$,
 $N_{b(kink)} = 17$, $N_{ap(kink)} = 17$.

trending compression and folding event that occurred prior to NW directed thrusting on the Beaver Valley fault. Tectonic fabrics correlative with NW directed thrusting on the fault were not observed in the Rome.

The brecciation of the footwall rocks is most likely tectonic in origin. This is suggested by localized occurrence of brecciated rocks within a 5 m thick zone directly beneath the fault. Brecciation is correlative with NW directed thrusting on the fault.

Synopsis. Kink folds in the hanging wall predate NW directed thrusting on the fault. Brecciation of the footwall rocks is correlative with NW directed thrusting.

Outcrop 12

General Description. Outcrop 12 is located approximately 3 km N of Knoxville via U.S. Route 441 (Figure 1, p. 2). At this locality, U. S. Route 441 cuts through Sharps Ridge and exposes the N branch of the Saltville fault (Rodgers, 1953; Cattermole, 1960; Hardeman, 1966; Penley, 1973). There the Rome is in thrust contact with steeply SE dipping Chickamauga limestones. The fault strikes 062° and dips 56° to the SE at this exposure.

Fabric in the footwall consists of steeply dipping brecciated and shattered beds. The brecciated zone is approximately 1 m thick and is directly beneath and parallel to the fault.

Fabric in the hanging wall consists of steeply SE dipping beds and left-lateral kink folds. Low angle thrusts are associated with the

kink folds. Fabric orientation data was collected principally from the hanging-wall.

Fabric Analysis. Figure 35 is a plot of poles to bedding, poles to kink fold axial planes and kink fold axes from the hanging-wall Rome. Poles to low angle thrusts are plotted on the same Schmidt net. Poles to bedding, kink fold axial planes and thrust faults can be fitted to a NW-SE striking pi circle that defines the ac plane of deformation for these fabrics. Kink fold axes are subhorizontal and normal to this plane.

Discussion. The kink folds in the hanging wall are associated with low-angle thrust faults, which suggests they both probably formed during early NW-directed thrusting on the Saltville fault. Because the fold axial planes and thrust fault planes presently dip to the NW, they probably have been passively rotated in a clockwise direction. The rotation probably occurred as bedding was tilted towards the SE as the Saltville fault ramped over the underlying Beaver Valley thrust sheet.

The brecciation in the footwall rocks is probably tectonic in origin. Its occurrence within a narrow 1 m thick zone directly beneath the fault is suggestive of tectonic brecciation.

Synopsis. Fabric in the hanging-wall of the Saltville fault is correlative with early NW directed thrusting on the fault. Subsequent to the formation of this fabric, the folds and thrusts were passively rotated during ramping.

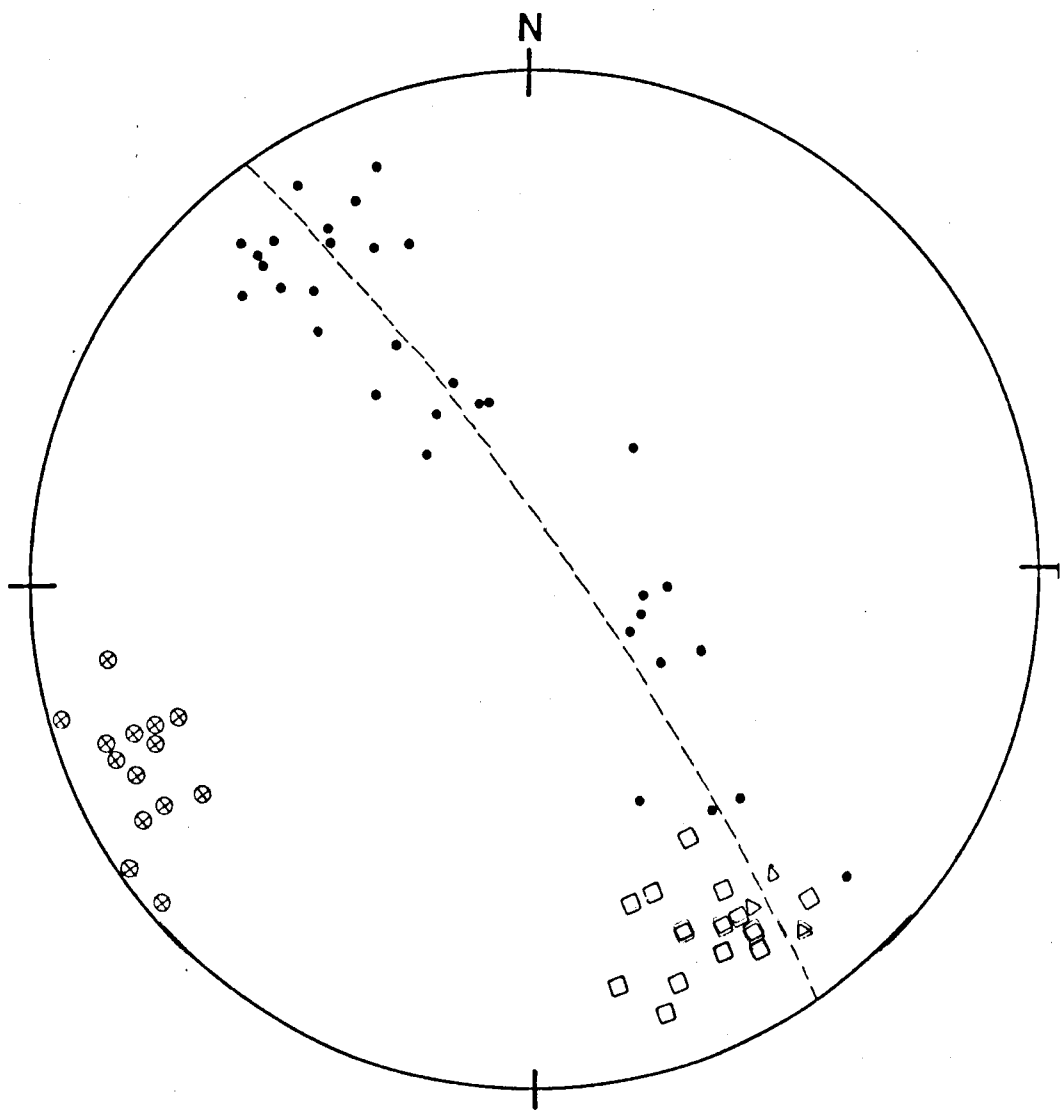


Figure 35. Fabric orientation data from Outcrop 12. $N_{So} = 32$,
 $N_{b(kink)} = 14$, $N_{ap(kink)} = 14$, $N_{(h01)} = 2$.

The brecciation of the footwall rocks appears to be tectonic in origin and is correlative with thrusting on the fault.

Outcrop 13

General Description. Outcrop 13 is located within the North Knoxville city limits, approximately 300 m SE of the cross-over of I-640 and U.S. Route 441 (Figure 1, p. 2). The outcrop is in the parking lot behind Cas Walker's supermarket.

At this locality the S branch of the Saltville fault is exposed. The Rome is in thrust contact with middle Cambrian Rutledge limestones of the Conasauga Group (Cattermole, 1966; Penley, 1973). At the fault contact, the Rome is overturned to the SE. the overturned beds were identified by the presence of ripple marks on the underside of beds, worm trail molds on the upper surfaces of bedding planes and by overturned cross-bedded laminae within single beds. The Rutledge Limestone in the footwall is stratigraphically upright and dips to the NW. The Saltville fault strikes 055° and dips 70° to the SE at this outcrop. The major structural features in the Rome section adjacent to the fault are shown in Figure 36. Figure 37 is a continuation of the profile showing the major structural features in the Conasauga.

Fabric Analysis. Figure 38 is a plot of poles to bedding, poles to buckle fold axial planes and buckle fold axes from the Rome section shown in Figure 36. The poles to planar fabric elements are widely scattered, but they can be loosely fitted to a NW-SE striking pi circle. Buckle

NW

SE

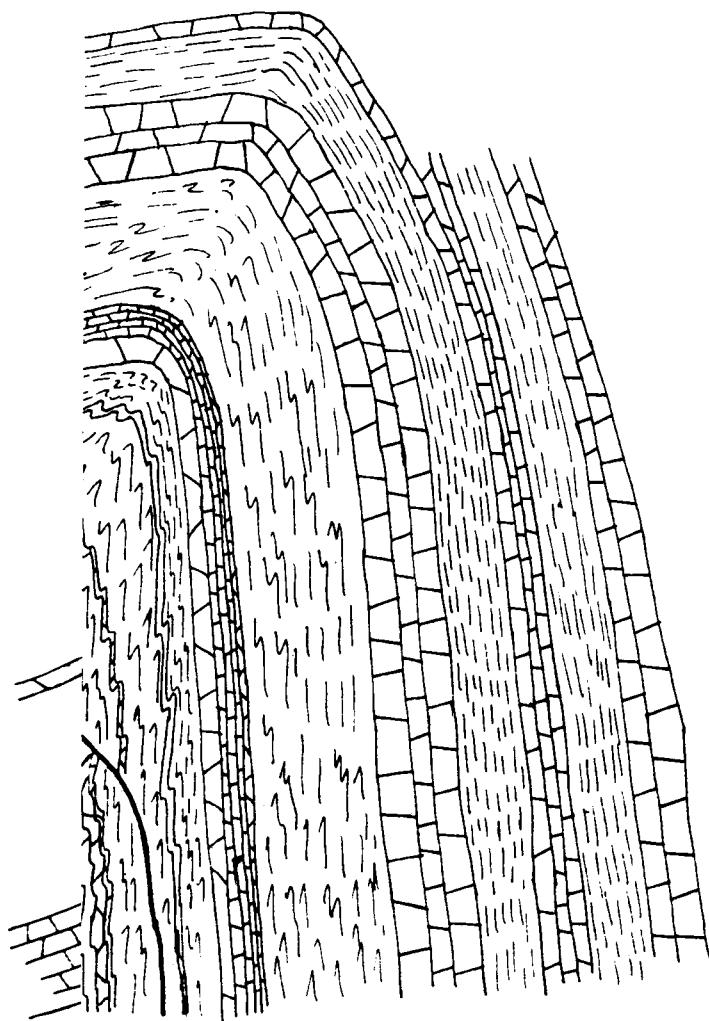


Figure 36. Profile across Outcrop 13 showing the major structural features adjacent to the Saltville fault.

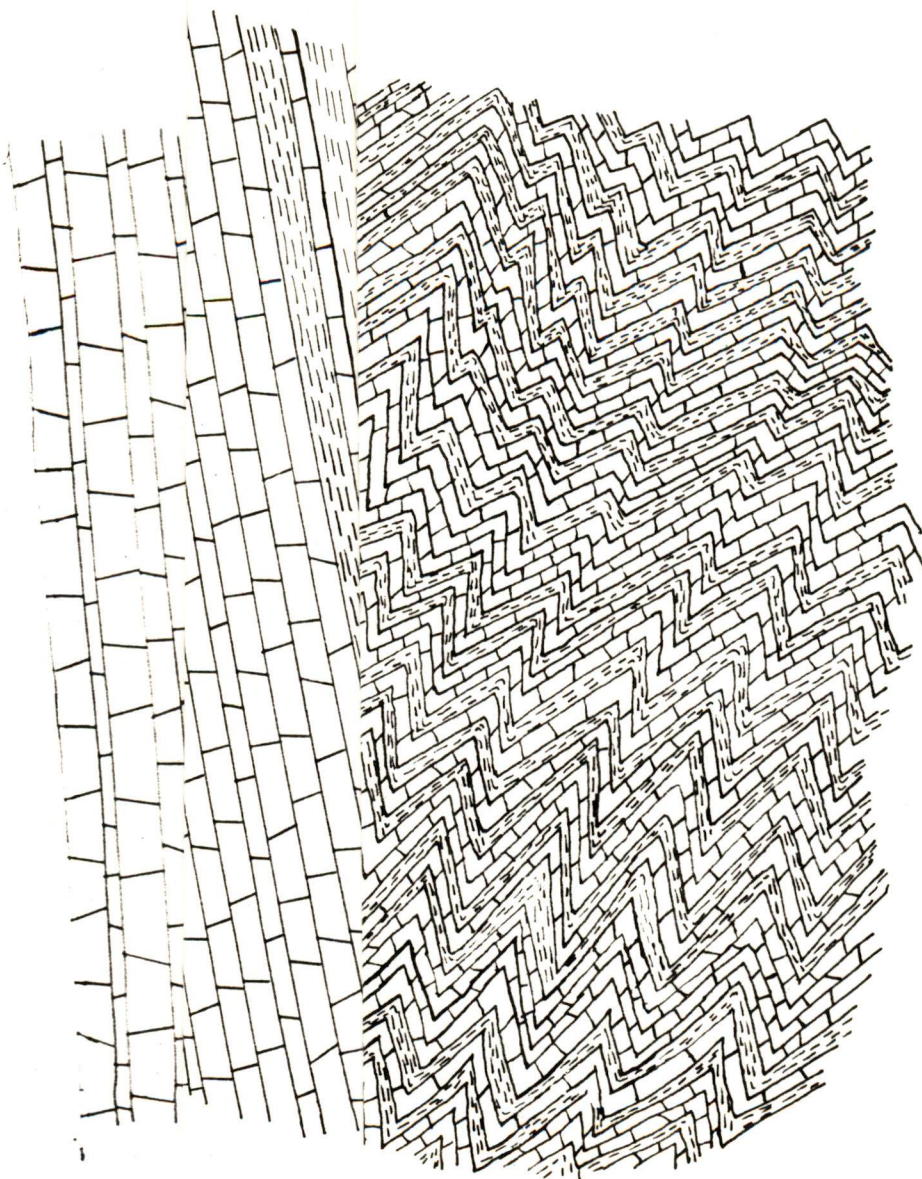


Figure 37. Profile across Outcrop 13 continued.

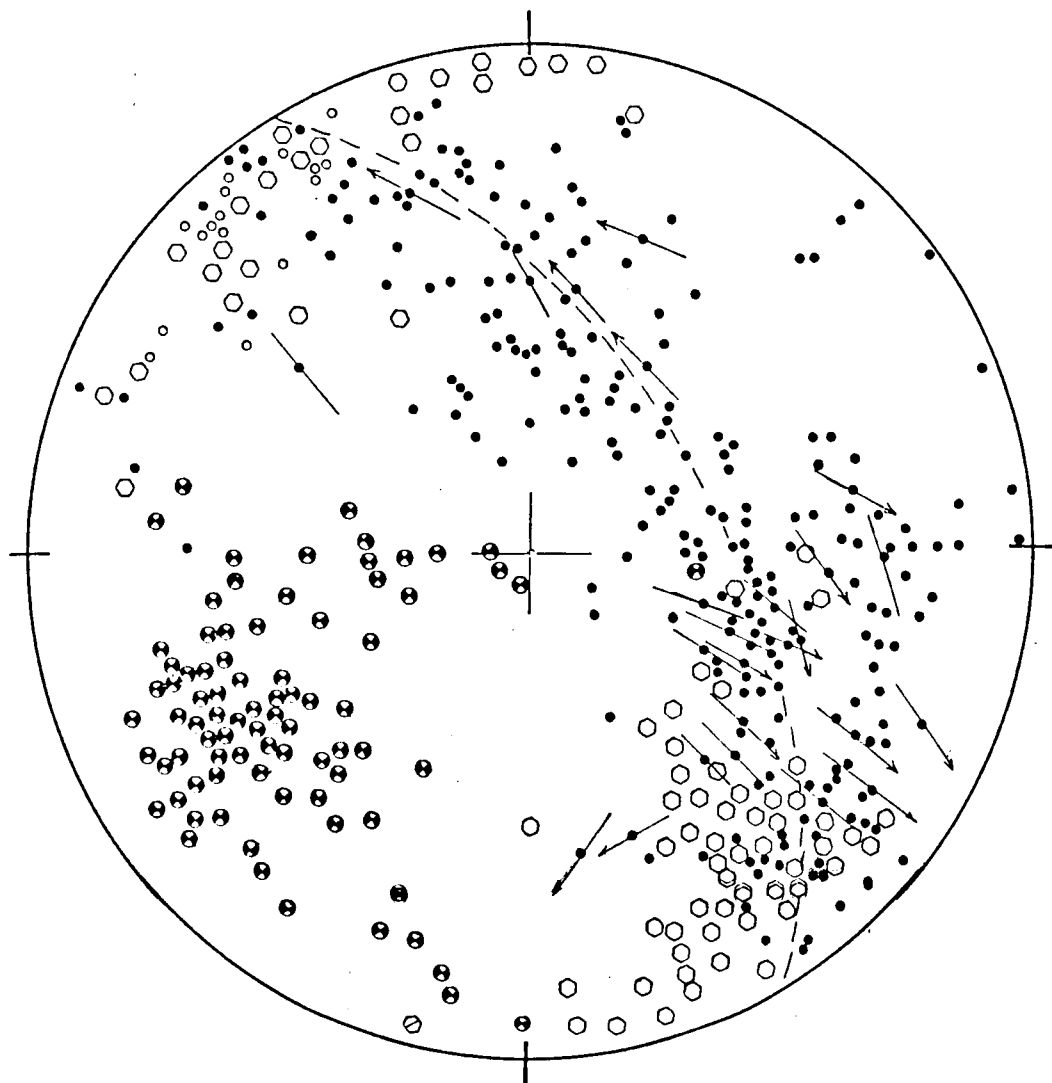


Figure 38. Fabric orientation data from the Rome section adjacent to the Saltville fault. $N_{So} = 256$, $N_{b(buckle)} = 104$, $N_{ap(buckle)} = 76$.

fold axes plot in a dispersed maximum that is subnormal to the π circle. The scatter of linear and planar elements in Figure 38 reflects the distorted morphology of minor folds within the tightly appressed cores of larger folds in this section.

Figure 39 is a plot of poles to bedding, poles to kink fold axial planes and kink fold axes from the Conasauga section shown in Figure 37. Poles to planar fabric elements can be fitted to a NW-SE striking π circle. Steeply SW plunging kink fold axes are subnormal to this plane.

Discussion. Bedding in the limbs of the larger buckle folds is folded into numerous smaller folds (Figure 36). These folds apparently formed when the larger folds were more open and bedding was inclined gently to the principal stress axis. Simple shear associated with bedding plane slip cannot lead to shortening of bedding as bedding surfaces are planes of no longitudinal strain during fold development (Ramsay, 1967, p. 397). Consequently, the smaller folds must have formed early in the development of the larger folds, when bedding was inclined gently to the principal shortening axis.

Tightening of the larger fold limbs has resulted in significant distortion of the minor folds within the cores of the larger folds. Apparently, the minor folds were subjected to shearing strains great enough to distort their original geometry when the cores of the larger folds were appressed by tightening of the fold limbs. The space problem within the cores of the larger folds was eventually resolved by faulting. This appears to be the origin of the fault that cuts through the core

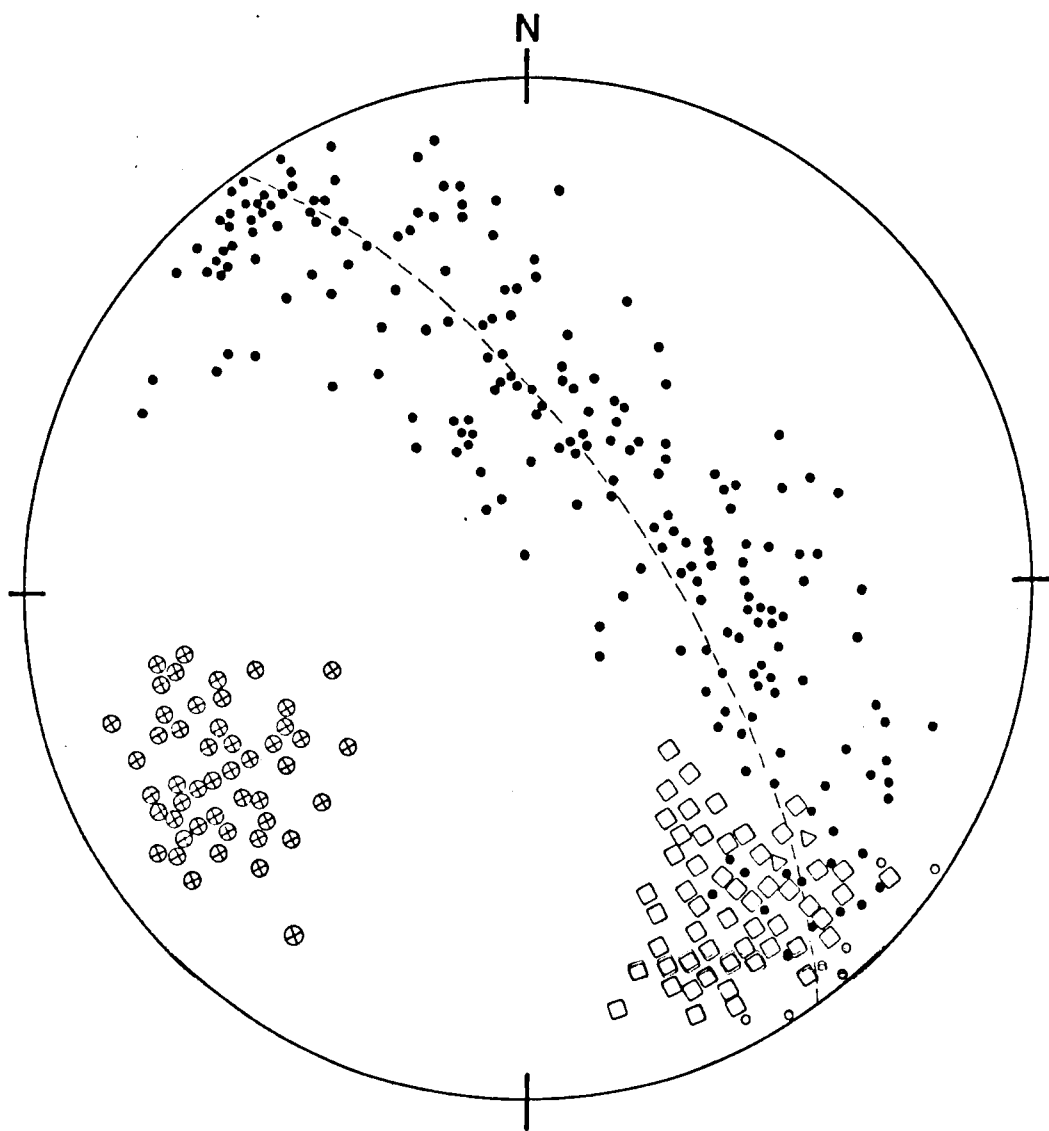


Figure 39. Fabric orientation data from Conasauga section at Outcrop 13.
 $N_{So} = 207$, $N_{b(kink)} = 47$, $N_{ap(kink)} = 61$, $N_{(h01)} = 2$.

of the large anticline and follows the axial plane of the adjacent syncline in the SE section of Figure 36. The SE dipping back limb thrust off the anticline that is adjacent to the faulted syncline appears to have a similar origin.

The anticline immediately adjacent to the Saltville fault (Figure 36) is overturned to the NW. This suggests the fold was initially upright and later rotated into the direction of thrust transport during thrusting. Additional tightening of the fold limbs probably occurred as it was overturned. This is suggested by the presence of extremely tight minor folds with nearly parallel opposing limbs inside its core.

In Figure 37, the entire sequence of steeply dipping Rome and folded Conasauga shale is the SE dipping backlimb of the large anticline in the SE section of Figure 36. Structural fabrics in this section consist of two overturned NW dipping thrust faults and kink folds.

Of particular importance in this section is the low-angle thrust fault that dies out into the axial plane of a kink fold above the fault (Figures 36 and 40). This relationship indicates that kink folding is coeval with low-angle thrusting. The steep SW plunge of kink folds in this section (Figure 39) also suggests that kink folding and low-angle thrusting may predate the NW-SE trending layer parallel stress responsible for buckling bedding into the large buckle folds shown in Figure 36. If subvertical bedding is rotated to horizontal about its strike, the kink fold axes rotate to subhorizontal in a N-S orientation (Figure 41). This indicates that low angle thrusting and kink folding most likely resulted from an E-W trending layer parallel stress. An E-W

NW

SE

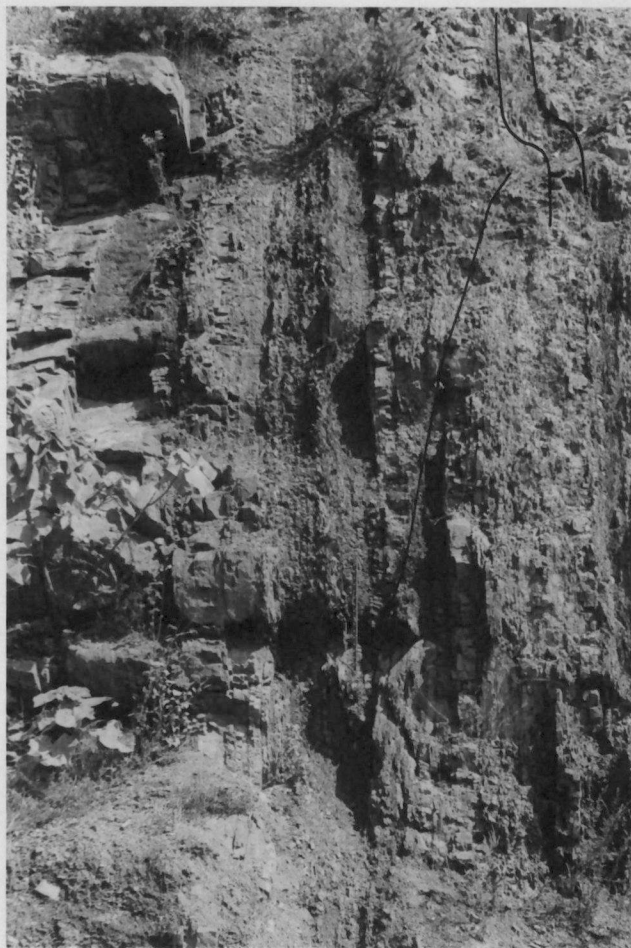


Figure 40. Overturned low-angle thrust at the Rome/Pumpkin Valley contact. Fault dies out in kink fold near upper right corner.

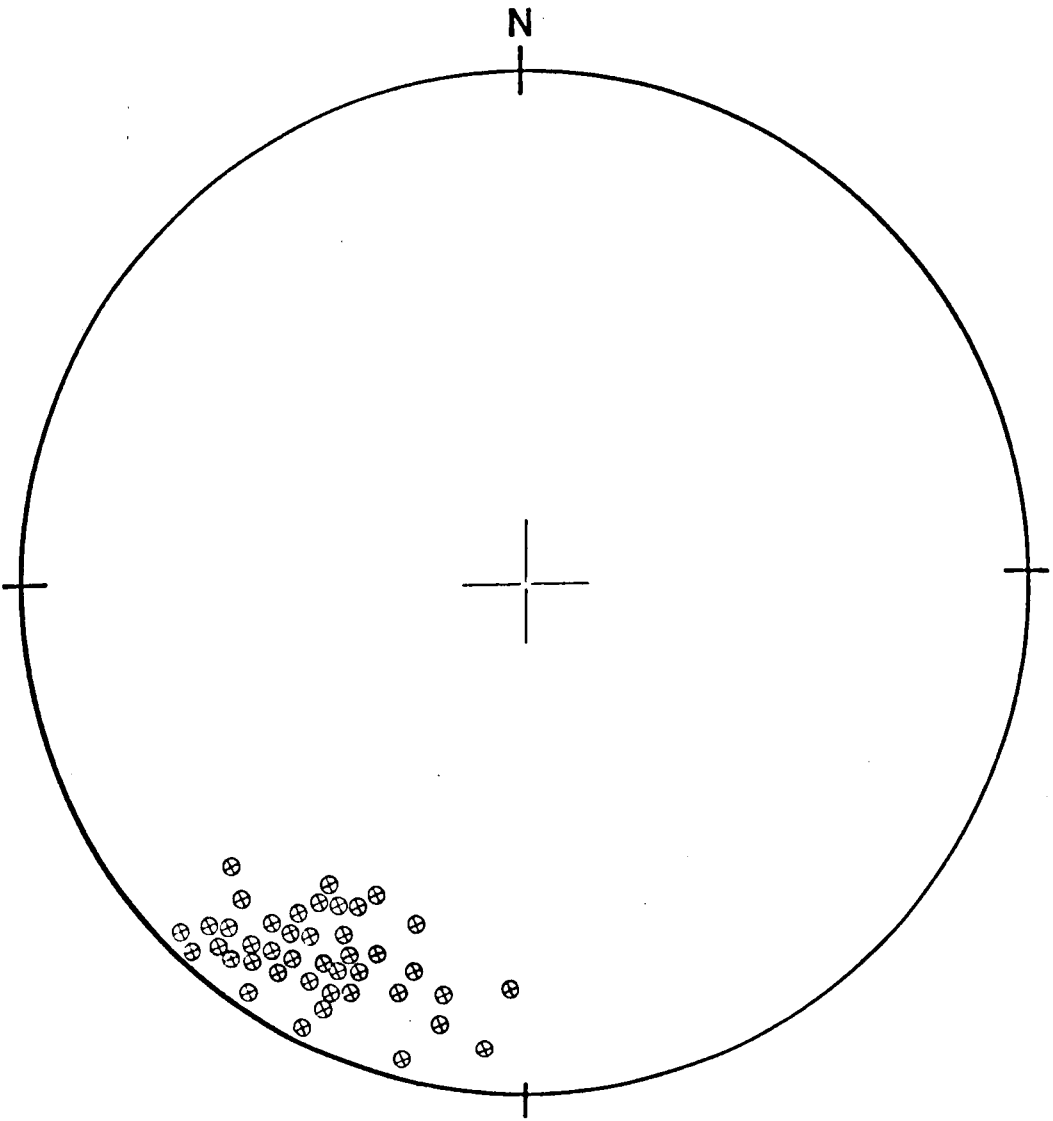


Figure 41. Rotated kink fold axes from the Conasauga section at Outcrop 13. $N_{b(kink)} = 47$.

trending layer parallel stress cannot be correlated with NW directed thrusting or buckle folding. Consequently, the low-angle thrusts and kink folds apparently predate NW directed thrusting on the Saltville fault, as well as the buckle folds in Figure 36, p. 72.

Synopsis. The youngest tectonic fabric in this section of Rome and Conasauga consists of low-angle thrust faults and kink folds that formed in response to an E-W trending layer parallel stress. These fabrics cannot be correlated with NW directed thrusting on the fault and apparently document an early tectonic event that predates NW directed thrusting.

Fabrics at this outcrop that can be correlated with a NW-SE trending layer parallel stress consist of buckle folds. Buckling appears to be associated with folding of the Saltville fault in the subsurface (Roeder, Yust and Little, 1978), followed by subsequent rethrusting on the fault (this report).

CHAPTER IV

REGIONAL SYNTHESIS

The mesoscopic fabric data presented in the preceding chapter provides the necessary pre-requisite to a comprehensive kinematic analysis of regional deformation within the study area. The analysis is performed within the context of the macroscopic structural relationships presented on two balanced cross sections (Figures 42 and 43) across the study area (See Figure 1, p. 2). The subsurface interpretation is based on the principles of thin-skinned tectonics developed by Rodgers (1949), Bally et al., (1966) and Dahlstrom (1970).

Structural Analysis 1

Cross section A-B-C (Figure 42) is a composite section that includes subsections A-B and B-C (Figure 1, p. 2). Offset between subsections is approximately 5 km.

Within the area containing Outcrops 1-3 (Figure 3, p. 13), the dip of the Chattanooga fault is inferred to be 15-25° to the SE. This estimate is based on the extensive outcrop width of Rome and the low dips of bedding.

The concentric folds in the leading edge of the Chattanooga thrust sheet imply folding under low confining pressures and near surface conditions. This suggests folding in the frontal zone of fabric zonation (Roeder, 1973). In addition, the subvertical attitude of buckle fold axial planes suggests that folding occurred within a regime

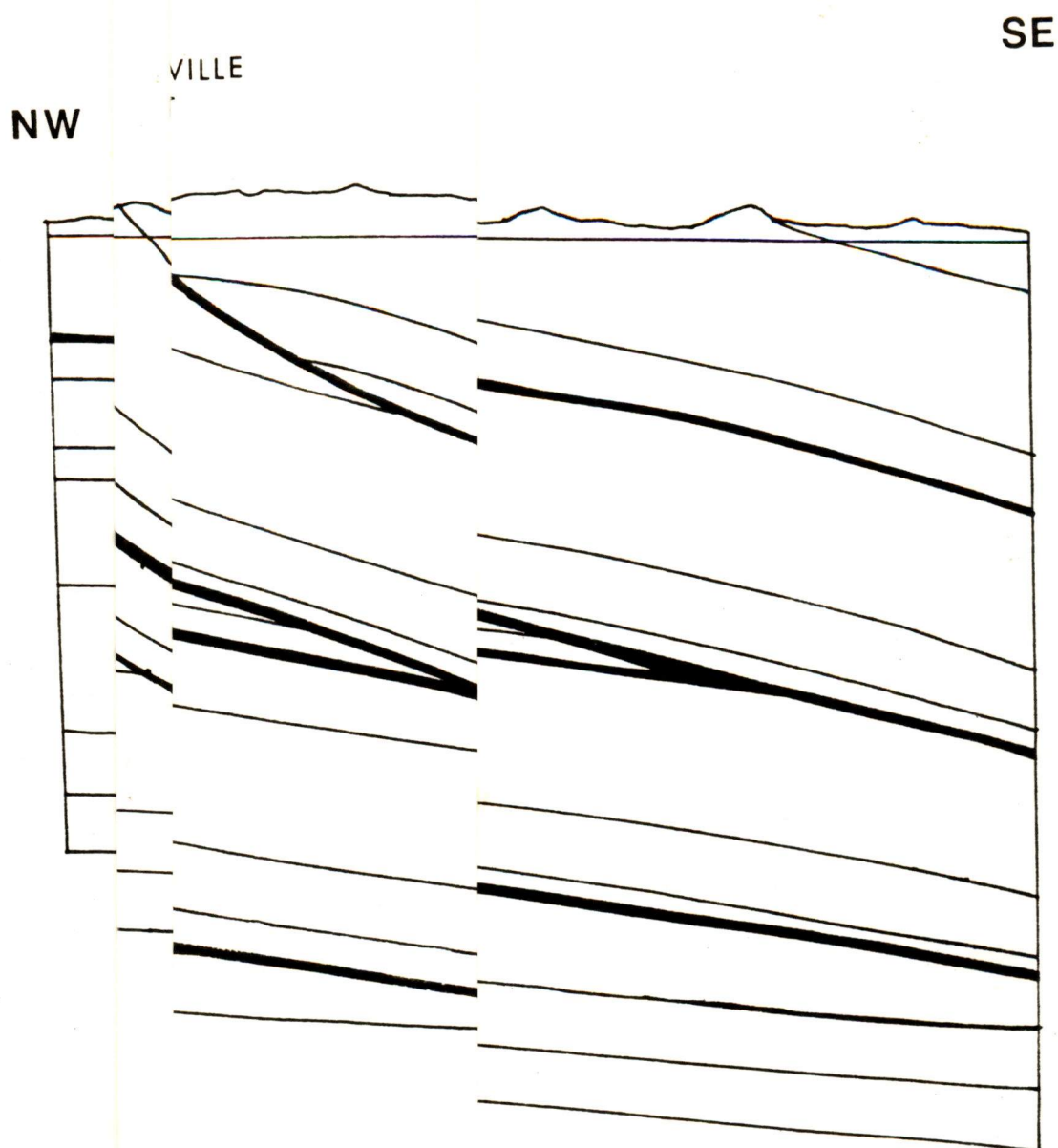


Figure 42. Geological structure section along line of section A-B-C.

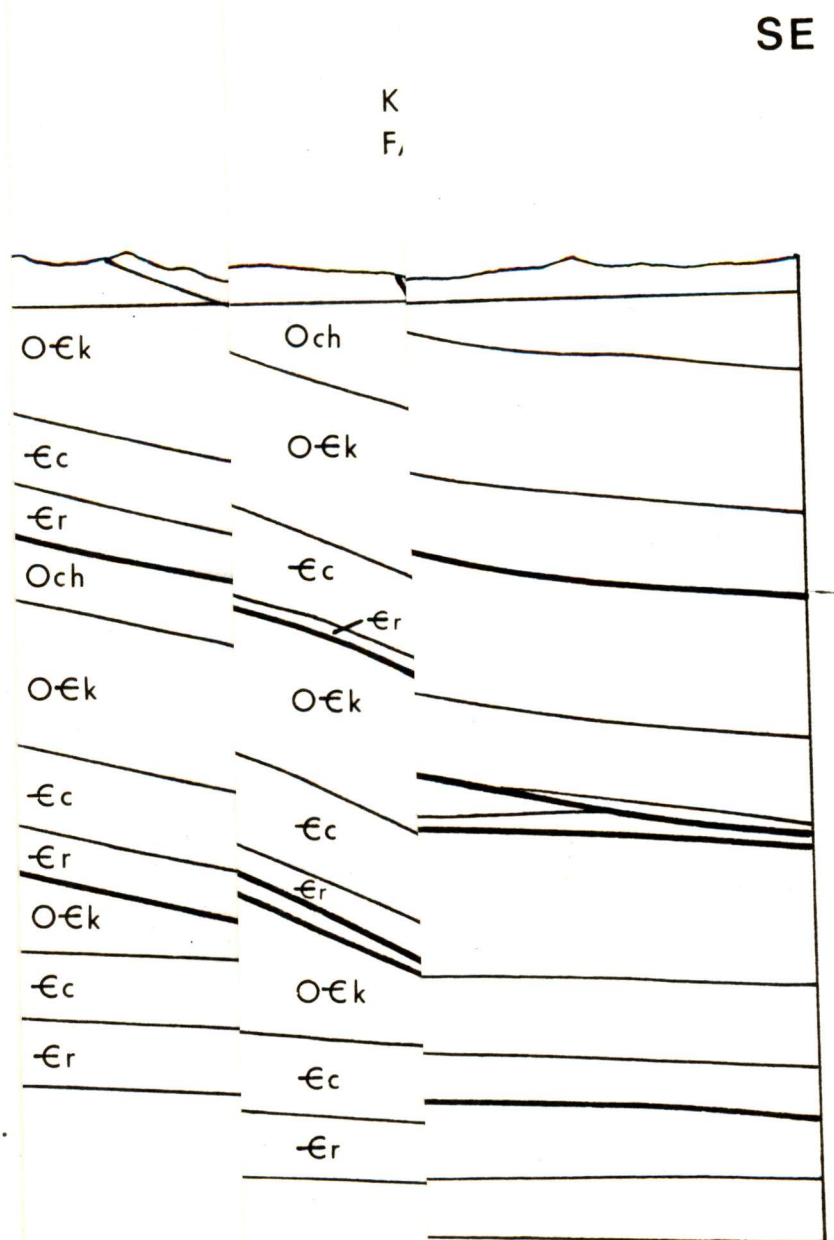


Figure 43. Geologic cross section along line of section D-E.

of pure shear rather than simple shear. This indicates that folding probably occurred while the thrust sheet was static and not in motion.

The inferred environment of folding suggests that it took place after the leading of the thrust sheet had arrived at the surface. This implies that the folds may be the result of a late wave of horizontal compression that affected this area subsequent to emplacement of the Chattanooga thrust sheet.

The Kingston and the unnamed fault that is in front of the Whiteoak Mountain fault are interpreted to sole out into the underlying Rome at the base of the Chattanooga thrust sheet. There are two reasons for proposing this interpretation. First, the shallow surface dip of the Chattanooga fault suggests that the fault maintains its shallow dip for a considerable distance in the subsurface before it soles out into the basal detachment zone. Second, the steeper surface dips of the Kingston and the unnamed fault enables these faults to be curved back in a sledrunner fashion until they intersect the underlying Rome.

The unnamed fault between the Kingston and Whiteoak Mountain fault is distinctly different from the macroscopic bedding plane thrusts on either side of it. This fault crosscuts at a high angle previously folded bedding in a subthrust syncline in the footwall of the Whiteoak Mountain fault. This suggests that the fault is a late structural feature related to re-deformation of the footwall syncline. Thrusting on this fault appears to have been accompanied by additional folding of the footwall rocks. This is suggested by folds with E-W trending axes to the SW of the fault (Figure 10, p. 26). These folds may reflect

deformation in response to a localized N-S trending compression created by a left-lateral component of movement on the fault. Polyphase deformation is also believed to be responsible for the random orientation of left-lateral faults shown in Figure 14 (p. 31). These faults appear to have formed by an extension subparallel to the regional strike during initial folding of the footwall rocks of the Kingston thrust sheet.

Macroscopic folding of the footwall rocks beneath the Whiteoak Mountain fault apparently occurred prior to development of the Chattanooga thrust fault. This is suggested by the structural fabric relationships within a different subthrust syncline (Outcrop 6) located to the NE of Outcrop 5 (See Figure 1, p. 2). At this outcrop, mesoscopic kink folds on the SE dipping limb of the syncline are crosscut by a conjugate system of faults that have both a strike-slip and dip-slip component of movement. Rotation of bedding to horizontal about the regional strike effectively removes the strike-slip component, which suggests the faults are a conjugate system of dip-slip faults that were rotated into their present attitude. Since the faults crosscut the kink folds, it also implies that folding occurred when bedding was horizontal. The Schmidt net operation of rotating ^{the} bedding to horizontal is equivalent to restoring the Chattanooga thrust sheet to its pre-ramp position. This suggests that folding of the footwall rocks beneath the Whiteoak Mountain fault probably occurred as the fault started to ramp over undetached subhorizontal bedding in the subsurface.

The Copper Creek fault is interpreted to be a shallow dipping fault in the subsurface. This is suggested by the extensive outcrop width of gently dipping Knox in the back of the thrust sheet.

Structural fabrics in the leading edge of the Copper Creek thrust sheet (Outcrop 7) reveal the existence of an early deformational phase that apparently predates NW directed transport of the Copper Creek thrust sheet. This event is represented by kink folds with N-S trending axes that are associated with low-angle thrust faults. It is also represented by a conjugate system of (hk0) faults that record an extension oblique to regional strike, subsequent to folding (Figure 18, p. 41).

The geologic significance of this fabric in terms of the evolution of the thrust belt is not clear. This is principally because the fabrics are found in early Cambrian and middle Cambrian age rocks so that it is conceivable that they represent a deformational event that is pre-Alleghanian. In this regard, a detailed mesoscopic fabric analysis of Silurian and younger age rocks exposed elsewhere in the thrust belt should reveal if the early deformational event affected post-Taconic rocks.

At Outcrop 7 (Figure 1, p. 2) there is a combination of compressional fabrics that record the strain history of the rocks during NW transport of the Copper Creek thrust sheet. Compressional fabrics consist of left-lateral kink folds and steeply SE dipping reverse faults that are subparallel to the kink fold axial planes. Since the faults are not low-angle thrust faults that can be correlated with initial transport of the thrust sheet, it appears as if kink folding and high-angle reverse faulting occurred subsequent to ramping of the Copper Creek thrust fault over the underlying Whiteoak Mountain thrust sheet.

The extensional fabrics consist of a conjugate system of NE-SW striking normal faults that crosscut the early N-S trending kink folds and the high-angle reverse faults. The extension responsible for this fabric is subparallel to the dip of bedding as shown by Figure 25 (p. 53).

It is unlikely that the normal faults developed in a regime of simple shear during active transport of the thrust sheet. Instead the brittle deformation probably took place while the thrust sheet was static and not in motion. A possible explanation that might account for the faults is that they are the distal result of polyphase thrusting on the Whiteoak Mountain fault. Polyphase thrusting on the fault may have caused a bedding parallel extension in the back of the Whiteoak Mountain thrust sheet, which also affected the leading edge of the Copper Creek thrust sheet.

The Beaver Valley fault is interpreted to merge in the subsurface with the underlying Copper Creek fault. The reasons for proposing this interpretation are as follows: First, the steep dip of bedding in the back of the Beaver Valley thrust sheet suggests that the fault dips steeply in the subsurface. Second, the shallow subsurface dip of the underlying Copper Creek fault enables the Beaver Valley fault to be curved back sledrunner fashion until it intersects the Copper Creek fault.

Polyphase deformation of the footwall rocks is expressed by a folded splay in front of the Beaver Valley fault. The agent responsible for folding the splay is inferred to be an underlying splay off the Copper Creek fault.

Structural fabrics in the hanging wall of the Beaver Valley fault on section A-B-C (Outcrops 8 and 9) reveal the existence of an early deformational event similar to the one reported at Outcrop 7. At Outcrops 8 and 9 folds with N-S trending axes are the primary representatives of the early deformational phase. At Outcrop 8, N-S trending folds are crosscut by NE dipping (hk0) and SE dipping (h01) faults, in which the direction of slip on the fault surfaces is to the NW (Figure 27 and 28, pp. 56, 57). These faults document slippage on (hk0) and (h01) shear planes that were established by a NW-SE trending horizontal stress that acted upon bedding inclined steeply to the principal stress axis. Apparently faulting postdated the arrival of the leading edge of the thrust sheet at the surface.

Further NE along strike (Outcrop 10), fabrics in the hanging wall of the Beaver Valley fault suggest only one phase of deformation that is related to NW transport of the Beaver Valley thrust sheet. These fabrics consist of right lateral kink folds that are interpreted to be conjugate to the basal shear plane of the major fault.

To the SE of the Beaver Valley fault are the Saltville and Knoxville faults. Both of these thrust faults are inferred to be subhorizontal in the subsurface, based on the extensive outcrop widths of gently dipping Knox and Chickamauga within these thrust sheets.

The base of the Saltville thrust sheet is presumed to be underlain by Rome because the fault brings Rome to the surface further NE along strike. In contrast, the oldest rocks brought to the surface by the Knoxville fault are middle Cambrian shales. This suggests that the

Knoxville fault abandoned the Rome during early transport of the thrust sheet by ramping into the overlying Conasauga shales. The Knoxville thrust sheet is gently folded in the SW part of the study area, presumably by a splay off the underlying Saltville fault.

Structural Analysis 2

In cross section D-E (Figure 43, p. 83) the subsurface relationships between the Copper Creek through Knoxville thrust sheets are basically the same as shown in Figure 42 (p. 82). The major difference is in the thrust sheet relationships to the NW of the Copper Creek fault. Within the NE part of the study area (Figure 1, p. 2) the Chattanooga and Kingston faults are not present. The Chattanooga fault merges with the Jacksboro fault and Kingston fault dies out in middle Cambrian shales. In addition, the Whiteoak Mountain fault splits to form the Hunter Valley and Wallen Valley faults. The split is interpreted by Roeder, Gilbert and Witherspoon (1978) to have resulted as a consequence of polyphase rethrusting on the Whiteoak Mountain fault. Polyphase rethrusting resulted in truncation of the former leading edge of the Whiteoak Mountain thrust sheet.

Mesoscopic structural fabric data relevant to cross section D-E was collected from the hanging wall of the Beaver Valley thrust fault and the two branches of the Saltville fault.

Structural fabrics from the Beaver Valley thrust sheet (Outcrop 11) consist entirely of kink folds with N-S striking fold axes (Figure 34, p. 67). These folds are interpreted to be of the same age as the N-S striking folds at Outcrops 7, 8 and 9.

The Saltville fault is folded in the subsurface into an anticline and syncline fold pair. The SE branch of the fault is interpreted to be a back limb splay off the underlying anticline. The NW branch represents the former leading edge of the thrust sheet.

The rocks in the hanging wall of the SE branch have been complexly deformed as a result of folding in the subsurface followed by rethrusting on the fault (Figures 36 and 38, pp. 72, 74). The buckle folds at Outcrop 13 are interpreted to have developed during folding of the Saltville fault in the subsurface. Rethrusting on the fault resulted in overturning of the folds immediately adjacent to the fault.

At the same outcrop, a set of steeply SW plunging kink folds in the Conasauga is correlative with an E-W trending compression. This fold set is associated with low angle thrust faults. Both fabrics appear to predate NW directed thrusting on the fault and are interpreted to be of the same age as the N-S trending folds at Outcrops 7, 8, 9, and 11.

Summary

The earliest deformational event recorded in the rocks of the study area is correlative with an E-W trending layer parallel stress. Fabric resulting from this compression consists of low-angle thrust faults and N-S trending kink folds. This fabric was found in the Rome and Conasauga of the Copper Creek, Beaver Valley and Saltville thrust sheets. The age of this fabric is uncertain.

Tectonic fabric that can be correlated with initial NW directed thrusting consists of low-angle thrust faults that are associated with

NE-SW trending kink folds. This fabric was only found at one outcrop in the study area (Saltville fault). Its limited occurrence in the study area suggests that the NW-SE trending layer parallel stress was accommodated primarily by slip on the basal shear plane of the thrust sheets.

Most tectonic fabric in the hanging-walls of the thrust sheets in the study area are correlative with a NW-SE trending stress that acted upon bedding inclined to the principal stress. These fabrics consist of steeply SE dipping (h01) faults (Copper Creek and Beaver Valley thrusts), gently dipping (hk0) faults (Beaver Valley thrust), left-lateral kinks with steeply SE dipping axial planes (Copper Creek thrust) and right-lateral kinks (Beaver Valley thrust). These fabrics apparently developed after the thrust fault had ramped over the underlying thrust sheet, which caused bedding to become inclined to a horizontal shortening axis. It is not possible to establish whether these fabrics developed while the thrust sheets were in motion or if these fabrics are indicative of deformation of a static thrust sheet.

Fabrics in the hanging wall of the thrust sheets that can be correlated with deformation of a static thrust sheet consist of concentric buckle folds with subvertical axial planes (Chattanooga and Kingston thrusts). Upright folds imply folding in a regime of pure shear that cannot be correlated with active thrusting on a fault. In one special case, buckle folds in the hanging-wall of the Saltville thrust are overturned to the NW. These folds developed during folding of the Saltville fault in the subsurface and were subsequently overturned by rethrusting on the fault.

The majority of footwall exposures in the study area did not contain mesoscopic tectonic fabric. Mesoscopic tectonic fabric was found principally within two subthrust synclines in the footwall of the Whiteoak Mountain fault. Mesoscopic structural fabrics within the southwesternmost syncline suggest that a complex interplay of compressional and extensional deformation took place during growth of the syncline. At least two folding events that are separated by an extensional event are recorded in the rocks within this syncline. The first is documented by the development of the syncline itself. Folding was followed by an extension subparallel to regional strike. Fabric indicative of this extension consists of (hk0) faults at the SW end of the syncline. The second folding phase is represented by concentric folds with E-W trending axes at its SW end. This event is correlative with a late wave of horizontal compression that caused rethrusting on the Whiteoak Mountain fault.

Mesoscopic structural fabric relationships within another subthrust syncline to the NE of the first, suggest that initial folding of the footwall rocks occurred before development of the Chattanooga thrust fault. Within this syncline, mesoscopic kink folds on its SE dipping limb are crosscut by a conjugate system of dip-slip faults that have been tilted into their present attitude. These structural fabrics developed when bedding was subhorizontal and were subsequently tilted to the SE by ramping of the Chattanooga fault over subhorizontal bedding. Initial folding of the footwall rocks probably occurred during ramping of the Whiteoak Mountain fault over undetached subhorizontal bedding in the subsurface.

Tectonic fabric at two other footwall exposures in the study area consisted of tectonic breccia in the footwalls of the Beaver Valley and Saltville fault. Mesoscopic faults and folds were not observed at these exposures.

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