

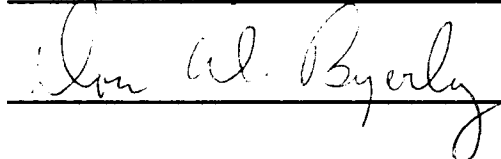
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STRUCTURAL GEOLOGY AND GEOMETRIES OF THE DENTON
DUPLEX ALONG THE FRONTAL BLUE RIDGE, NEAR HARTFORD,
TENNESSEE

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

Lance Christian Robert

June 1987

Dedication

This thesis is dedicated to my wife Adrienne.

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ABSTRACT

The frontal Blue Ridge in east Tennessee is marked in many places by narrow-discontinuous exposures of Lower-Cambrian Chilhowee Group rocks (+/- Shady Dolomite and Rome Formation). The Denton duplex is one of these exposures that until now has not been mapped in detail. It is complexly faulted into eight separate thrust blocks. The stratigraphy and structure of each block are described in detail.

Several reports in the past describe the thrusting of the area as hindward progressive (i.e., progressing from northwest to southeast). In addition, Keller (1980) interpreted the Great Smoky fault as a late - cross-cutting fault that offsets pre-existing thrust sheets.

Mapping of the study area shows that the Denton duplex consists of individual horse blocks that are part of a complex fault system of which the Great Smoky fault is the principal fault. Each horse block was plucked from the footwall of the fault as it ramped through the Chilhowee Group. Balanced cross-sections show that the average angle at which the fault cut up-section is between 15 and 20 degrees.

Fault contour maps and balanced cross-sections show that the successive stacking of these horse blocks, combined with progressive deformation in lower-younger

sheets of the Valley and Ridge rocks, folded the overlying Great Smoky thrust sheet into a broad anticline-syncline pair. The cross-sections and restored sections also show that the English Mountain thrust block (also composed largely of Chilhowee Group rocks), to the northwest of the study area, has a "flat" geometry and therefore must restore to the southeast of the Denton duplex.

Late high-angle extensional normal faults cut earlier structures (thrusts), locally placing younger rocks on older ones.

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CHAPTER I

INTRODUCTION

(A) Purpose

The goal of this study is to: 1) provide a detailed geologic map of the area with cross-sections and interpretations; 2) describe structural geometries and rock fabrics and relate them to the structural history of the area; and 3) re-examine previous reports near the study area and relate them to the structural history using recently developed structural theories. Emphasis will be placed on descriptions of the geometries of the folded faults along the Blue Ridge-Valley and Ridge boundary.

(B) Regional Geology

The Southern Appalachians are part of a mountain chain that extends most of the length of the eastern United States. In Tennessee and North Carolina, the chain can be divided into three physiographic provinces: Valley and Ridge, Blue Ridge, and Piedmont from northwest to southeast, respectively (Figure 1). The provinces differ in relief, rock type, and degree of metamorphism, as well as in structural style. The Valley and Ridge is dominated by Paleozoic sedimentary rocks, whereas the Blue Ridge is

Figure 1. Location of the study area along the Blue Ridge front. Enlargement shows the general geology of the area according to Rodgers (1953).

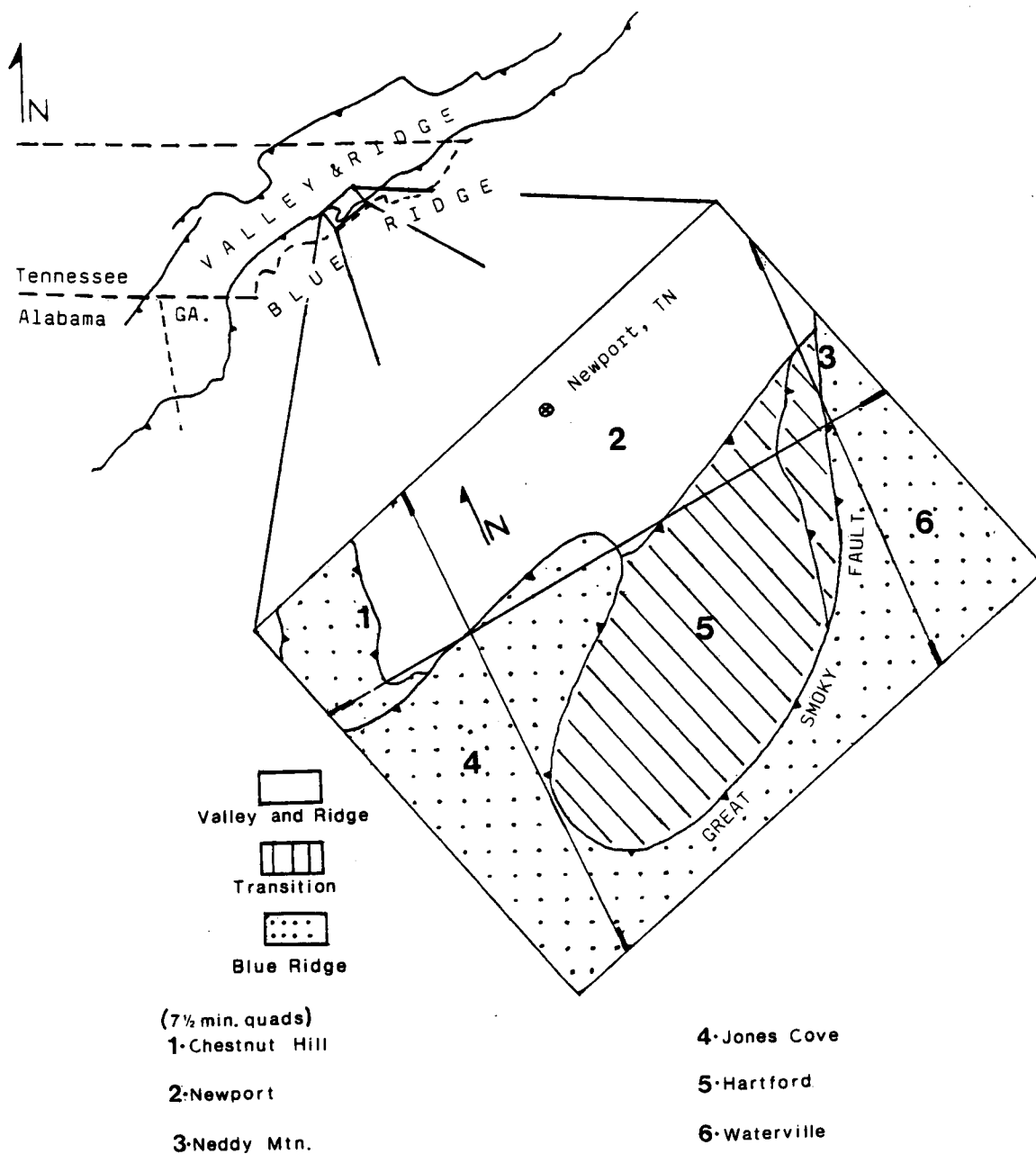


Figure 1

dominated by Grenville basement and late Precambrian Ocoee Group sedimentary rocks. The boundary between the Valley and Ridge and the Blue Ridge provinces is marked in many places by narrow, discontinuous belts of Chilhowee Group rocks. These rocks are commonly exposed as erosional remnants (klippen) of thrust sheets or in windows in which the overlying thrust sheet has been eroded. As shown in Figure 2, English Mountain is a synclinal half-klippe, whereas the Hot Springs window and the Denton Duplex are anticlinal.

The boundary fault has been given several names along its length. Keith (1927) introduced the name Great Smoky fault as a name for the Blue Ridge "border fault". Subsequently, the name has been used inconsistently along portions of the frontal Blue Ridge.

(C) The Field Area

The study area is located approximately 10 miles south of Newport, Tennessee in Cocke County (Figure 1). Cosby and Hartford are the two largest communities located within the field area, although several other small communities are present (Plate 1). The area includes portions of two 7.5- minute quadrangles, Hartford (173 SW) and Newport (173 NW), and is approximately 8 miles long and 6 miles wide. Access to and through the area is good ; I-40 runs north-

Figure 2. Compilation map of the frontal Blue Ridge adjacent to the field area showing the major structural features. Lines with barbs represent thrust faults and dotted lines represent formation contacts. Lettered-straight lines represent locations of cross-sections in this report. EM - English Mountain , DD - Denton duplex, HSW - Hot Springs window.

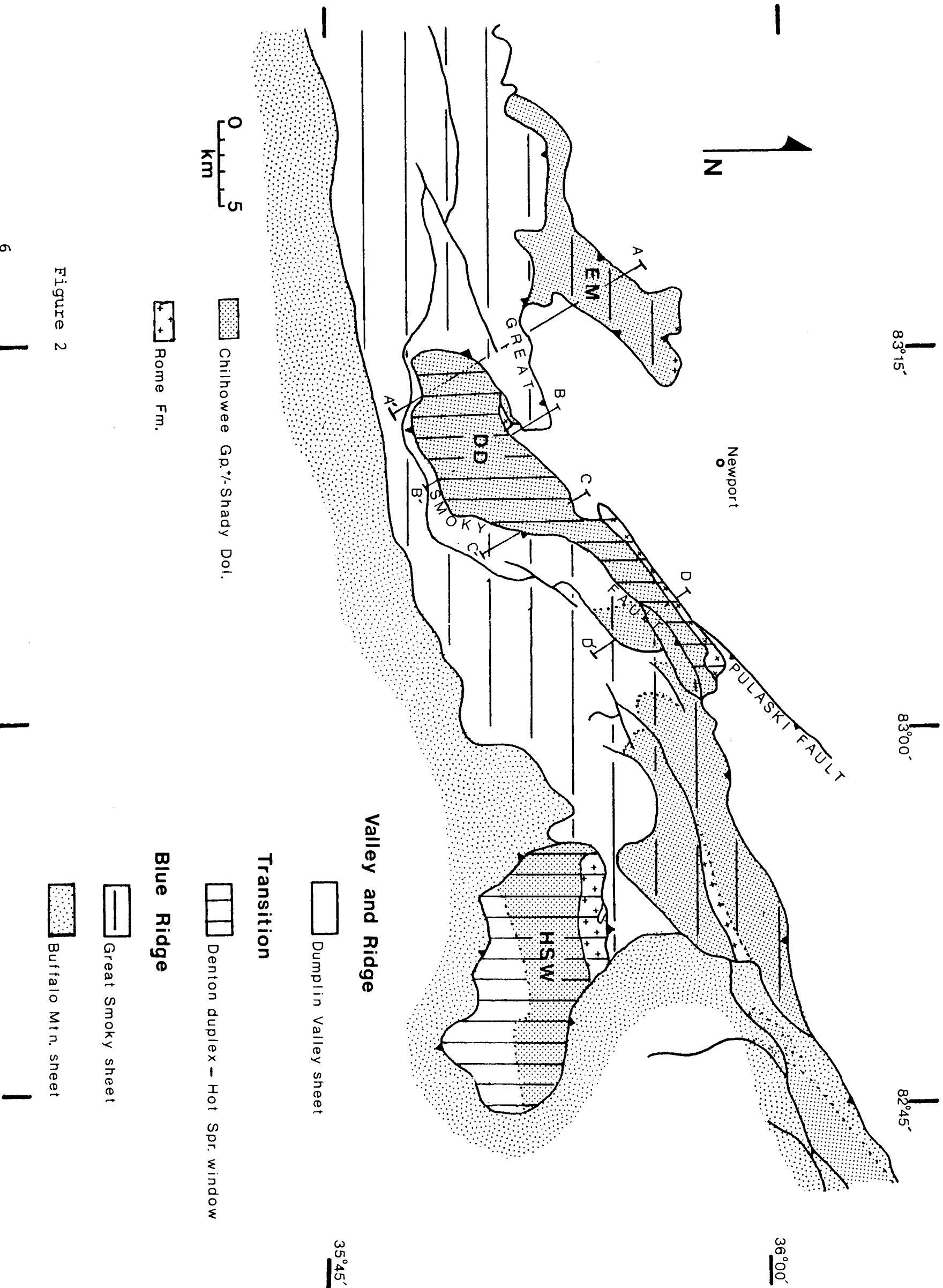


Figure 2

south through the center of the area, the Foothills Parkway runs east-west through the western portion of the area, and Highway 32 curves around the westernmost part of Green Mountain. The eastern portion of the area around Stone Mountain is less accessible, due mostly to the steep relief. This area is covered mainly by county roads, only one of which crosses Stone Mountain.

The maximum relief of the study area is approximately 2400 feet; the lowest areas are along the Pigeon River and to the north where carbonate strata of the Valley and Ridge are exposed. The highest ridge, Halltop Mountain, reaches 3610 feet at its peak. Most of Stone Mountain, however, is above 2800 feet along its entire length.

(D) Previous Work

Although there are many reports on the rocks in adjacent areas, very little work has been done in this study area (Figure 3). Safford (1869), Keith (1895), and Stose (1898) all contributed significantly to understanding the interrelation of the Precambrian, Cambrian, and Late Cambrian-Ordovician rocks in the vicinity. Stose (1898) was the first to recognize that a low-angle thrust fault placed Precambrian Ocoee rocks over the Cambrian-Ordovician Knox Group.

Figure 3. Index map of the region modified from Witherspoon (1982).

Rodgers (1953) published the only geologic map of the present study area in which the Chilhowee Group was divided into formations. Although much of his work was compilation and reconnaissance, it was invaluable as a guide for the present work. Hamilton (1961) and Hadley and Goldsmith (1963) mapped the western and southern boundaries of the field area, respectively. They were responsible for much of the discussion of stratigraphic relations and nomenclature of the Ocoee Supergroup in the vicinity.

Ferguson and Jewell (1951) mapped the area immediately to the east of the study area (Figure 3). More recent work in that vicinity was done by Keller (1980). He mapped and interpreted the rocks in the Neddy Mountain and Waterville 7.5-minute quadrangles immediately northeast and east of the study area. Part of his study included re-examining Ferguson and Jewell's (1951) work, but his interpretations were quite different.

Several reports on the Southern Appalachians include the study area in their maps to demonstrate stratigraphic subdivisions; for example see Stose and Stose (1944; 1949) and King (1949). Other reports in the vicinity include a report on English Mountain immediately to the northeast by Greene (1959), and work by Shekarchi (1959), Bumgarner (1959), and Bearce (1966).

(E) Methods

Geologic mapping was done on a 1:12,000 base map. After drafting, the map was reduced to 1:24,000 scale for managability. Twenty nine thin-sections were prepared for microscopic inspection of structural fabrics, and for lithologic descriptions. Cross-sections were done on a 1:24,000 scale using lithologic thicknesses of adjacent reports or, where possible, using calculated thicknesses from the study area. Structural contour maps of fault surfaces were done on a scale of 1:24,000 and compilation was done on 1:250,000 quadrangle maps.

CHAPTER II

STRATIGRAPHY

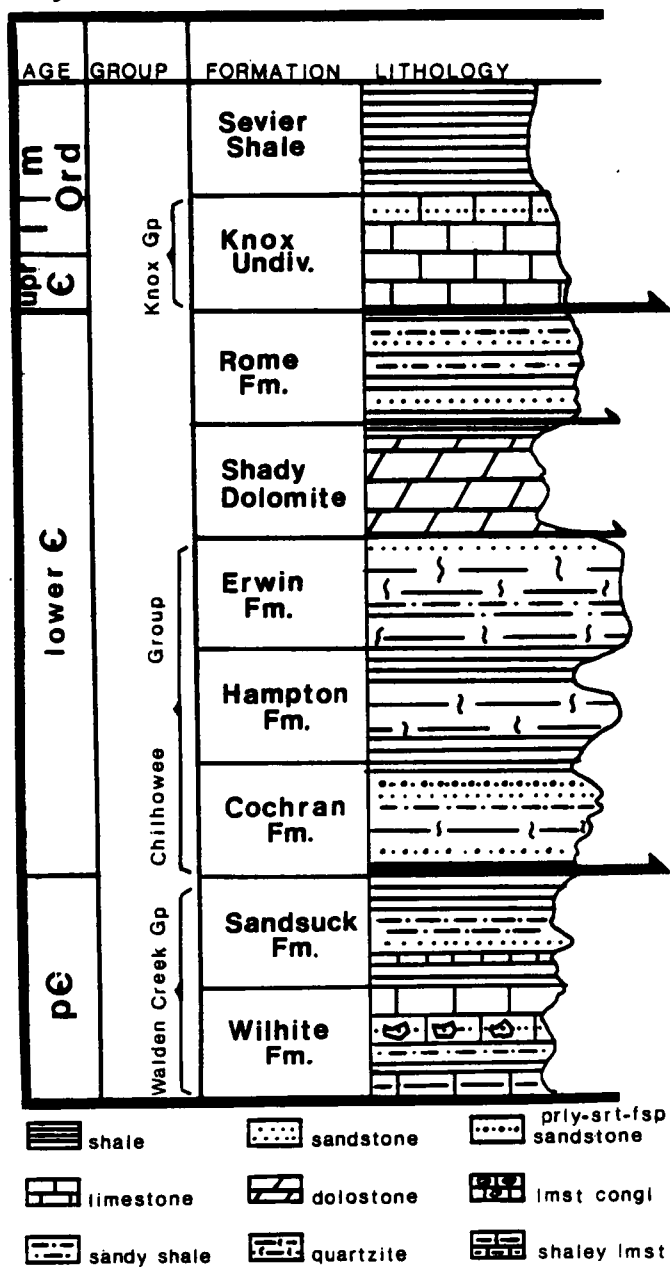
(A) Introduction

Much of the pioneering stratigraphic work near the study area was done by Safford (1869), Stose and Stose (1944 and 1949), Keith (from Keller, 1980), and King (1949). More recently, Ferguson and Jewell (1951), Hamilton (1961), Hadley and Goldsmith (1960), and Keller (1980) have contributed to the understanding of the stratigraphic relationships.

The sedimentary sequence in the study area (Figure 4) can be roughly divided into three groups: (1) Precambrian low-grade metamorphic rocks of the Ocoee Supergroup; (2) Lower Cambrian Chilhowee Group, Shady Dolomite and Rome Formation; and (3) Middle Cambrian to Ordovician carbonate strata of the Valley and Ridge (Keller, 1980). In relation to the Great Smoky fault, these groups of rocks lie in the hanging wall, in a series of imbricated horses, and in the footwall, respectively. Because of structural complexity, very few stratigraphic contacts were observed. Following Hadley and Goldsmith (1951) the rocks of the Ocoee Supergroup, although slightly metamorphosed, will be referred to using sedimentary rock names.

Figure 4. Generalized stratigraphic column for the study area. The thick solid line represents a fault in which stratigraphic section is missing. The Conasauga Group (middle Ordovician) is not exposed at the surface, thus is not included in this column.

Figure 4



(B) Brief Descriptions of Rock Units

Ocoee Supergroup

The Ocoee Supergroup is a thick (>8km) sequence of late-Precambrian, dominantly clastic, metasedimentary rocks that underlies much of the Great Smoky Mountains (Keller, 1980 and Hadley and Goldsmith, 1963). It is in stratigraphic contact with the Precambrian basement complex at its base and with the Chilhowee Group at its top (Hadley and Goldsmith, 1963; Keller, 1980). King et al. (1958) subdivided the Ocoee into three groups of mappable character: the Snowbird Group, the Great Smoky Group, and the Walden Creek Group. Each group is itself divided into several formations.

Rocks of the Ocoee are variably metamorphosed with increasing grade to the southeast (Hadley and Goldsmith, 1963; Hamilton, 1961). These authors noted that even though metamorphic, the rocks retain much of their original sedimentary features. Thus, when naming rocks, no metamorphic terms were used except when they decided that some "metamorphic texture needs to be emphasized".

In the present study area, only rocks of the upper Great Smoky Group and Walden Creek Group are present, although they are not in stratigraphic contact. Walden Creek Group rocks (Wilhite and Sandsuck Formations) are

exposed in the hanging wall along the entire length of the Great Smoky fault, being thrust over rocks of the Chilhowee Group and Knox Group.

The writer made no attempt to modify or adjust the stratigraphy of the Ocoee. Due to poor exposure, no subdivisions were made except where extrapolated from previous work (Plate 1).

Great Smoky Group

Roaring Fork Sandstone

The Roaring Fork Sandstone as mapped by Hadley and Goldsmith (1963) is present immediately southwest of the field area. It is named for the Roaring Fork tributary of the west fork of the Little Pigeon River near Gatlinburg, Tennessee (King et al., 1958). Exposures were described by Hadley and Goldsmith (1963) just south of the field area along I-40. In the type locality, the Formation consists of "moderately metamorphosed medium- and fine-grained feldspathic sandstone, metasiltstone, and minor amounts of slate and muscovite phyllite" (King et al., 1958).

Keller (1980) recognized Roaring Fork in each of the major thrust sheets in the Neddy Mountain and Waterville quadrangles to the east. He informally recognized two members: a lower calcareous arkose and an upper arkose-siltstone member. The lower member "is dominated by pale

green cross-bedded and calcareous arkose and siltstone... The upper member is similar to the Formation elsewhere". The Roaring Fork is underlain by the Longarm Quartzite and is overlain by, and partly intertongues with, the Pigeon Siltstone.

The map relations of the Roaring Fork in the present field area were taken directly from Hadley and Goldsmith (1963) and Keller (1980) because they were not an integral part of this study. For further descriptions of these rocks, see King et al. (1958), Hadley and Goldsmith (1963) and Keller (1980).

Pigeon Siltstone

The Pigeon Siltstone refers to rocks exposed along the Little Pigeon River near Pigeon Forge (King et al., 1958). Although the Formation has been somewhat redefined, the original type locality was retained from Keith (1895). In the type area, the Formation is 3050 to 4575 meters thick, and is composed primarily of metasiltstone and interbedded slate. In the Great Smoky Mountains, Hadley and Goldsmith (1963) reported a maximum thickness of 2135 meters of dark green to dark greyish fine-grained sandstone and metasiltstone to argillite or slate, with a variety of bedding structures.

The Pigeon is compositionally similar to the Roaring

Fork, but differs in that the Pigeon is finer-grained. Keller (1980) recognized the Pigeon Siltstone in each major thrust sheet in his area. He suggested that the Formation was inconsistent in rock type both laterally and vertically where arkose was abundant, and that the Formation in his area was more sandy than the same rocks in the Great Smoky Mountains. The Pigeon immediately to the south of this study area is in fault contact with both the Roaring Fork and the Wilhite Formations along the Dunn Creek and Gatlinburg faults. Farther to the south and east, however, conformable relationships occur between these three formations (Hadley and Goldsmith, 1963, and Keller, 1980). For further descriptions of these rocks, the reader is referred to these authors.

Walden Creek Group

Wilhite Formation

The Wilhite Formation is named for exposures along Wilhite Creek and Long Branch several miles to the west of the study area (King et al., 1958). The name Wilhite slate was originally given to similar rocks of the foothills farther to the west by Keith (1895); however, some revisions have since been made. The name Wilhite, however, has been retained.

Hamilton (1961) described two members of the Wilhite

Formation in the Central Smokies, which locally are "distinct enough for formation rank, however, are not recognizable in areas to the west." He states that the lowest of the members, the Dixon Mountain member, consists predominantly of clastic rocks including sandy siltstone, metasilstone, and some sandstone.

According to Hamilton, the second (upper) member of the Wilhite Formation is the Yellow Breeches member. He further subdivided this member into an upper unit of dominantly limestone, and lower unit of mixed clastic and carbonate rocks. As a whole, this member is described as containing abundant carbonate rocks, "the most obvious of which are thick limestone beds commonly sandy or conglomeratic... Most are grey and some contain as much as 50% rounded quartz grains." Clastic rocks similar to the rest of the formation are also present.

Keller (1980) only recognized the Yellow Breeches member as being similar to the Wilhite subdivisions in the type area, and used local names in describing the rest of the Formation. His four members of the Wilhite were the lower and upper Laurel Fork Siltstone, the Yellow Breeches, and the Big Creek Siltstone members (oldest to youngest).

Following Hamilton (1961), rocks assigned to the Wilhite Formation in this study area belong to the Yellow Breeches member. Although Hamilton divided the member into an upper and lower unit, the writer made no attempt to do

so. The Wilhite here is characterized by mixed clastic and carbonate rocks. In places, clastic rocks are intricately interbedded with carbonate layers whereas elsewhere, whole outcrops of carbonate or clastic rocks are present. The dominant clastic rock type is light brown, green or grey, thinly-laminated, silty shale or slate. Carbonates, where interbedded with the clastic rocks, are dark grey or black micritic limestone. Most of the non-mixed carbonate occurs as light-grey arenaceous, matrix-supported, pebble to boulder conglomeratic limestone. The clasts are made of micritic limestone, with or without quartz sand. Clastic rocks appear to be much more abundant than the carbonate rocks.

Sandsuck Formation

The Sandsuck Formation was originally termed Sandsuck Shale by Keith (1895). King et al., (1958) renamed it the Sandsuck Formation and included abundant coarse-grained sandstone which had been placed in the overlying Cochran Conglomerate by Keith (1895).

The Sandsuck Formation is the highest unit in the Walden Creek Group and can be shown to be in stratigraphic contact with the Wilhite Formation below, and with the Cochran Formation above (Keller, 1980; Hamilton, 1961). Both Keller and Hamilton recognized a three fold division

of the Sandsuck: a lower member of siltstone with beds of sandstone; a middle member composed largely of coarse-grained sandstone; and an upper unit of siltstone and sandstone. Both authors noted the poor exposure of this unit and thus, have relatively limited descriptions.

Keller (1980) provided the most thorough descriptions of the Sandsuck immediately to the east of the study area. He placed much of what Ferguson and Jewell (1951) called Unicoi Formation into the upper Sandsuck. His descriptions of the Sandsuck are as follows:

Upper member - dominated by olive green siltstone with numerous thick lenses of arkose and local conglomerate that make the upper contact difficult to recognize.

Middle member - dominated by tan weathering beds of poorly sorted quartzite and arkose, some pebbly or granular, with subordinate fine quartz-pebble conglomerate siltstone.

Lower member - characterized by dark olive green siltstone with interbeds of fine to medium-grained arkose.

The Sandsuck in this study area has been assigned to the middle and upper members by extension of contacts established by Hamilton (1961). The characteristic lithology is thinly interbedded sandstone, siltstone, and shale or slate. Sandstone beds are commonly orange to tan colored, and are moderately to poorly sorted. The most

poorly sorted of the sands often contain feldspar and/or shale chips.

The siltstone, shale, and slate strata are commonly green, grey, or black and, in general, are more thinly bedded than the sandstone beds. Minor carbonate strata are present as thin interbeds of grey, brown, or black micritic shaley(?) limestone. At one locality, a large outcrop of dark grey, light and dark laminated micrite was found. See Appendix I for a detailed description.

Chilhowee Group

The Chilhowee Group is a thick transgressive sequence of craton-derived clastic sediments (Wehr and Glover, 1985). The group name was derived from the "Chilhowee sandstone" of Safford (1856), who defined it based on rocks forming Chilhowee Mountain. The Chilhowee has been shown to be in stratigraphic contact with the Ocoee Supergroup at its base (Hamilton, 1961), and with the Shady Dolomite at its top (Keller, 1980; Ferguson and Jewell, 1951).

The group is characterized by coarse, feldspathic, quartzose, cross-bedded sandstone and orthoquartzite at its base, grading upward into shale and intermittent orthoquartzite. It is finally capped by a thick sequence of fine-grained well-sorted orthoquartzite with interbedded

shale. Keith (1895) and many others since, noticed that the Chilhowee could be divided into two correlative sequences: A northeastern sequence consisting of three formations: the Unicoi, the Hampton, and the Erwin (oldest to youngest). A second southwestern sequence recognized on Chilhowee Mountain consists of the Sandsuck Shale, Cochran Conglomerate, Nichols Shale, Nebo Sandstone, Murray Shale, and the Hesse Sandstone. Later, King (1949), reassigned the Sandsuck to the Precambrian Ocoee.

Stratigraphic variation across structural and depositional strike creates great difficulty in the correlation of Chilhowee strata from one thrust sheet to another. Schwab (1972) suggested that variation in thickness and lithology of the group indicates that the depositional strike may have paralleled late Precambrian tectonic and depositional strike, both of which coincided with the continental margin. He further stated that because these deposits are of shallow-water origin, they were easily affected by relative rise and fall of sea-level, thus, much intertonguing of lithologies occurs. Keller (1980) noted that the Chilhowee Group exhibited substantial thickening and increase in shale southeastward.

In the present study, the writer has applied the three-fold division of the Chilhowee following Ferguson and Jewell (1951); see Figure 4, p. 13. The name "Unicoi

Formation", however, has been dropped following Keller (1980). He used the divisions of Ferguson and Jewell (1951) with minor revisions of their Unicoi and called it the Cochran Formation.

The base of the Cambrian has often been placed at the base of the Chilhowee Group (Keller, 1980; Hamilton, 1961; King, 1949). Although Cambrian fossils have been found in the middle and upper Chilhowee, the assignment of the base of the Cambrian to the base of the Cochran appears to be one of convenience (Keller, 1980).

Cochran Formation

The Cochran Formation was originally named Cochran Conglomerate by Keith (1895) and later renamed Cochran Formation by King (1964). It is considered to be correlative with the Unicoi Formation to the east. Its maximum thickness adjacent to the study area is 1205 meters (Keller, 1980) and its minimum is about 550 meters (Ferguson and Jewell, 1951). Keller stated that the dominant rock type present in his area was "coarse-grained feldspathic grit, conglomerate, and massive quartzite with relatively little shale or siltstone". However, he noted that in the Del Rio sheet (Great Smoky sheet of this report) and Buffalo Mountain sheets, a persistent, thick shale unit was found at the top. Hamilton (1961) described

a portion of the Cochran on English Mountain as "resistant quartzite and coarse-grained sandstone" that caps several ridges in the area. Bearce (1966) described the Unicoi in the Bald Mountains to the northeast as containing quartzite, pyritic sandstone, shale and siltstone, and conglomerate. Greene (1959) used a four-fold division of the Cochran on English Mountain. He recognized: (1) a "lower member" of sandstone, conglomerate and shale; (2) a middle member of white, fine-grained, well-cemented, vitrious quartzite; (3) a "red shale member" composed of silty, micaceous, laminated red shales with maroon arkoses; and (4) an "upper member" of "arkosic sandstone, fine to coarse, poorly sorted, with few heavy minerals." It appears that this four-fold division might be similar to the informal members of Ferguson and Jewell (1951, p.12).

In the study area, the Cochran Formation is composed of a wide variety of rock types that are, in general, laterally. impersistent. The lowermost occurrence of Cochran recognized (Plate 1, block C) consists of green and brown silty shale strata which grade upwards into coarse, pebbly, feldspathic, cross-bedded sandstone and orthoquartzite. Above this, in block E, the Formation grades upward into very poorly sorted, cross-bedded friable sandstone, pebbly conglomerate, minor shale and finally into moderately sorted, well-indurated, moderately clean, quartz sandstone and orthoquartzite. Along Interstate 40

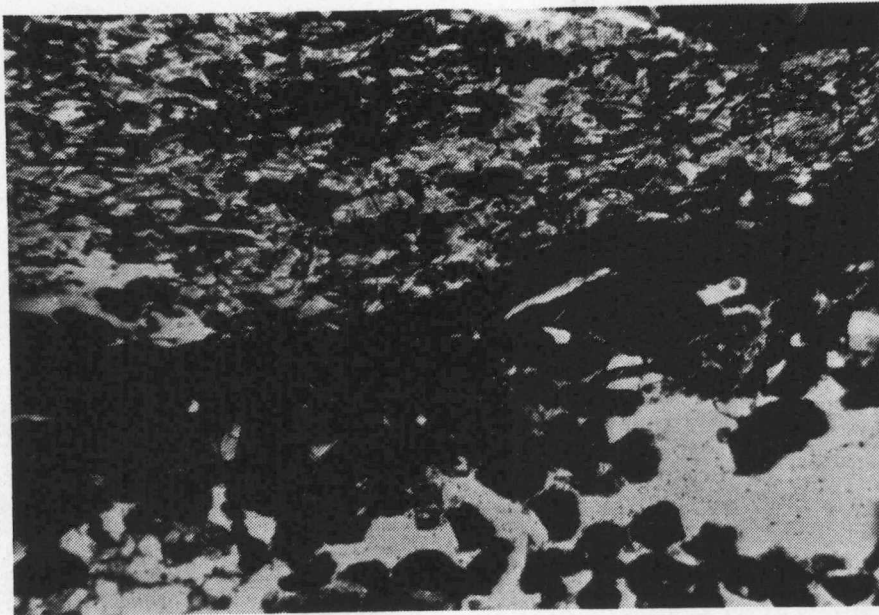
(Locality 6, sample 1, Plate 1) a layer of probable altered tuff is also exposed. It occurs as several thin layers that are in stratigraphic contact with maroon sandstone beds above and below. The majority of the tuff consists of a chlorite matrix with thin, elongate opaque iron-oxide grains. The original composition of the tuff is unknown, but the abundance of iron is indicated by iron-rich chlorite, abundance of iron oxides, and the red color. Figure 5 shows photomicrographs of this tuff.

In thrust block F, the uppermost part of the Formation is well exposed. It consists primarily of coarse-grained, tan and maroon, feldspathic, micaceous sandstone, laminated silty shale, and minor orthoquartzite. Rocks in thrust block G are probably equivalent to the middle Cochran section as described in block E. They consist of coarse sandstone, shale, and orthoquartzite (possibly the Moccasin Gap member of Ferguson and Jewell, 1951).

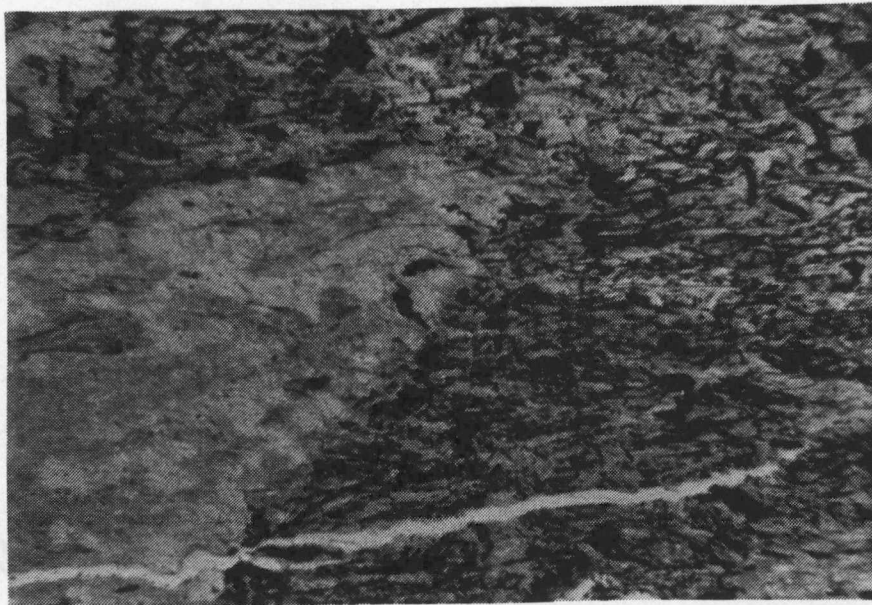
Hampton Formation

The Hampton Formation was named by Campbell (1899) for the town of Hampton, in Carter County, Tennessee. Its maximum and minimum thicknesses near the study area are 940 meters and 213 meters, respectively (Ferguson and Jewell, 1951). Greene (1959) reported the Nichols Slate (Hampton

Figure 5. Photomicrographs of the tuff in the Cochran along Interstate 40. 5A shows the contact of the tuff with underlying hematitic sandstone. 5B shows a relict clast of probable volcanic origin (lighter material).



A



B

equivalent) to be 122 meters thick on English Mountain to the northwest of the study area. Ferguson and Jewell (1951) note a marked thickening to the southeast.

Keller (1980), Oriel (1950), and Ferguson and Jewell (1951) separated the Formation into three members: a lower shale member, a middle quartzite member, and an upper shale member. The lower member is commonly dark green silty shale and siltstone, or where heavily cleaved, a slate. The middle member is well-bedded orthoquartzite with abundant *Scolithus*. The upper member is thicker but often similar to the lower member. It consists of dark green or bluish-grey silty micaceous shale, siltstone, or clayshale with minor orthoquartzite or sandstone layers (Ferguson and Jewell, 1951; Keller, 1980).

Following these authors, the Hampton Formation in the study area is divided into three members. The lower member is composed of green, grey, and brown micaceous shale and siltstone. Exposure of this member is limited. The middle member is composed of one- to three-foot thick beds of orthoquartzite. *Scolithus* tubes and cross-bedding are present sporadically, as are thin shale beds.

The upper member is similar to the lower member in many respects. However, mixed with the shale strata are thin beds of fine-grained sandstone to silty orthoquartzite. Bedding features such as cross-

laminations, graded bedding, and intraclasts are also common.

Erwin Formation

The Erwin Formation was originally named by Keith (1903) for the town of Erwin, in Unicoi County, Tennessee. Later, King and Ferguson (1960) designated rocks exposed along the Nolichucky River south of Unaka Springs as the type section. Ferguson and Jewell (1951) reported that the Erwin ranged from 396 to 518 meters and could be divided into four members: a lower quartzite member, a middle member of thinly bedded orthoquartzite, an upper member of orthoquartzite, and the Helenmode Member at the top. The Helenmode Member consists of greenish, fine-grained glauconitic siltstone and shale, the upper part of which has carbonate cement. Only the Helenmode member was subdivided on their map, however.

In an incomplete section, Bearce (1966) reported up to 701 meters of Erwin in the southwestern Bald Mountains and Oriel (1950) reported that 640 meters were present in the Hot Springs window. On the other hand, Greene (1959) reported that the Erwin equivalents (Nebo, Murray, and Hesse) only reached 366 meters in thickness on English Mountain.

The Erwin Formation in the study area is best exposed

along the Pigeon River, where a nearly complete section has been exposed by erosion and highway construction. The four-fold division of the Formation (Figure 4, p. 14) can be vaguely recognized in the fresh roadcut, but is not mappable elsewhere in the area. In general, the Formation consists of a thick section of massive, Scolithus-bearing, thickly-bedded orthoquartzite separated by a central unit of interbedded sandstone, orthoquartzite, and thin shale beds. The Helenmode member, consisting of glauconitic, poorly sorted sandstone, siltstone, and orthoquartzites is only partially exposed. For a more detailed description, see Appendix I.

Shady Dolomite

The Shady Dolomite was named for Shady Valley by Keith (1903). King et al. (1944) reported that the whole Formation was present underneath the valley, but exposure was very poor. Thorough descriptions were provided of the Shady in northeastern Tennessee with a nearly complete section in the Stony Creek district. They reported that the section was approximately 350 meters thick and could be divided into six members. From oldest to youngest, the members were: (1) the lower white member; (2) the lower blue member; (3) the ribboned member; (4) the middle blue member; (5) the upper white member; and (6) the upper blue

member. For a more detailed description of the Shady in that area, the reader is referred to King et al. (1944, p. 16-27).

The Shady Dolomite in the study area is very poorly exposed; the most commonly observed rock type is white, massive, sacchroidal dolostone. Bedding features are sparse and fractures are numerous. Other observed rock types include blue-grey dense dolostone, algal laminated limey dolostone, and shale to fine-grained quartz sand beds. The more resistant blue-grey dolostone forms a series of knobby ridges within the valley created by the rest of the Formation. By comparing this section with the Stony Creek section of King et al. (1944), the writer tentatively assigns these exposures to the upper third of the Shady.

Rome Formation

The Rome Formation was named for Rome, Georgia by Hayes (1891). The name "Watauga shale" was given to the same rocks in the Del Rio district by Keith (1903) but was later dropped due to the priority of the name Rome.

Near the front of the Blue Ridge province, the Rome is commonly present in association with the Chilhowee Group. Incomplete slivers of Rome have been described in the southwestern Bald Mountains by Bearce (1966), in the front

of the Del Rio District by Ferguson and Jewell (1951), in the Hot Springs Window by Oriel (1950), and on English Mountain by Green (1959).

The most complete section of Rome in East Tennessee near the area occurs in the Shady Valley thrust sheet near Valley Forge where about 366 meters are reported by King et al. (1944). There they described the Rome as consisting mainly of "red, maroon or brown shale, most of which is well consolidated".

In the field area, the Rome is exposed in only two places and consists of thinly bedded, maroon and tan, micaceous shale and siltstone. Both exposures are in the footwall of faults A and D (Plate 1). The Formation at both localities is heavily deformed, and in most places bedding orientations are highly inconsistent.

Conasauga Group

The Conasauga Group is not exposed in the study area.

Knox Group

The Knox Group was first defined by Safford (1869). The Knox Group underlies much of the eastern Valley and Ridge of Tennessee, as well as Virginia.

The carbonate rocks in the northern part of the field area were first shown to be part of the Knox Group by

Rodgers (1953, after unpublished data from Keith). Hamilton (1961), Greene (1959), and Bumgarner (1956) described Knox Group rocks immediately northwest of the field area. Following Bumgarner (1956), the carbonate rocks beneath the Great Smoky fault northwest of English Mountain assigned to the Newala and Longview Dolomite. The Knox group in the rest of the area is undivided. All of the rocks observed are similar to the Newala Formation as described by Bumgarner (1956).

Rocks assigned to the Knox Group in the study area consist predominantly of limestone with some dolomite. The most common rock type consists of light grey, micritic, thinly laminated limestone with sporadic rhombohedral dolomite crystals. The limestone beds commonly contain well-rounded, medium- to coarse-grained quartz sand grains. Where the sand is abundant, the limestone exhibits cross-bedding and scouring. Some of the carbonate sequences of the Knox may be easily confused with the carbonate strata of the Wilhite Formation. One outcrop in particular (Locality 9; Plate 1) along Hwy. 32 near the sharp bend in the road around Green Mountain, consists of thickly laminated, grey, pyritic, glauconitic limestone. Although it more closely resembles rocks of the Knox, it has tentatively been assigned to the Wilhite Formation, because

of its proximity to other Precambrian rocks. No fossils were seen in the Knox.

Sevier Shale

Keith (1895) named the Sevier Shale for exposures northwest of Chilhowee Mountain. It rests unconformably on the Knox Group below (Rodgers, 1953). Rocks assigned to the Sevier Shale occur in the northwestern corner of the field area as mapped by Rodgers (1953). Greene (1959) showed a narrow section of Sevier completely surrounding English Mountain. Sevier Shale is also inferred to act as a glide horizon or "decollement" above Knox Group carbonates, (cross-section A: Plate 2) based on its presence in the footwall of many of the Valley and Ridge faults.

The character of the Sevier in the study area is brown, thinly laminated shale, siltstone, or slate. It is commonly highly deformed due to its proximity to major faults.

CHAPTER III

STRUCTURAL GEOLOGY

(A) Introduction

The boundary between the Blue Ridge and Valley and Ridge physiographic provinces in east Tennessee is placed where late Precambrian Ocoee rocks are thrust over rocks mostly of Late Cambrian to Ordovician rocks of the Knox and Chickamauga Groups. Intermittently exposed along this boundary are blocks of Lower Cambrian Chilhowee Group commonly with Shady Dolomite and/or Rome Formation. The thrust faults, which place these older rocks on top of younger ones, are characteristically highly folded and imbricated. In the past, the rocks have been reported to record two or more orogenic events (Hamilton, 1961; Keller, 1980). Relationships of one major thrust sheet to another along the Blue Ridge-Valley and Ridge boundary have been variously interpreted in the past, partly due to gaps in detailed mapping and partly due perhaps to misunderstandings of thrust-system geometries.

The present study area has not been assigned to a major thrust sheet and until now has not been mapped in detail. Immediately to the east, Keller (1980) mapped and interpreted the rocks of the Neddy Mountain and Waterville 7.5 minute quadrangles. His structural interpretations

differ from this report and those of other reports in the vicinity. This study will attempt to describe and interpret the folded fault geometries in the area, and relate the results to nearby areas of the frontal Blue Ridge.

(B) Local Structural Relationships

In the study area, two major thrust sheets are exposed. The lowest rocks are in the trailing edge of the Saltville thrust sheet. The main overlying thrust sheet is the Great Smoky sheet. Between these two sheets is a series of imbricated thrust slices consisting of Chilhowee Group, Shady Dolomite, and Rome Formation. These slices are interpreted to be rootless horse blocks (plates 2 and 3) that are not assigned to a major thrust sheet. In relation to the Great Smoky thrust sheet, they occupy the same footwall structural position as the Hot Springs sheet to the east in the Hot Springs Window. However, because they are probably not connected below the surface, the field area is herein assigned to a series of small thrust blocks termed the "Denton duplex", a name modified from Witherspoon (1982). This interpretation is in disagreement with both Ferguson and Jewell (1951) and Keller (1980). Reasons for this will be discussed in Chapter 4.

Rodgers (1953) stated that "it is tempting to see the the rocks [in the present study area] as the Pulaski fault

reappearing for a short distance from under the mountain faults, but more likely it is a higher fault." The Pulaski fault disappears beneath the Meadow Creek Mountain fault about 12 km to the northeast of the present field area (Figure 2, p. 5).

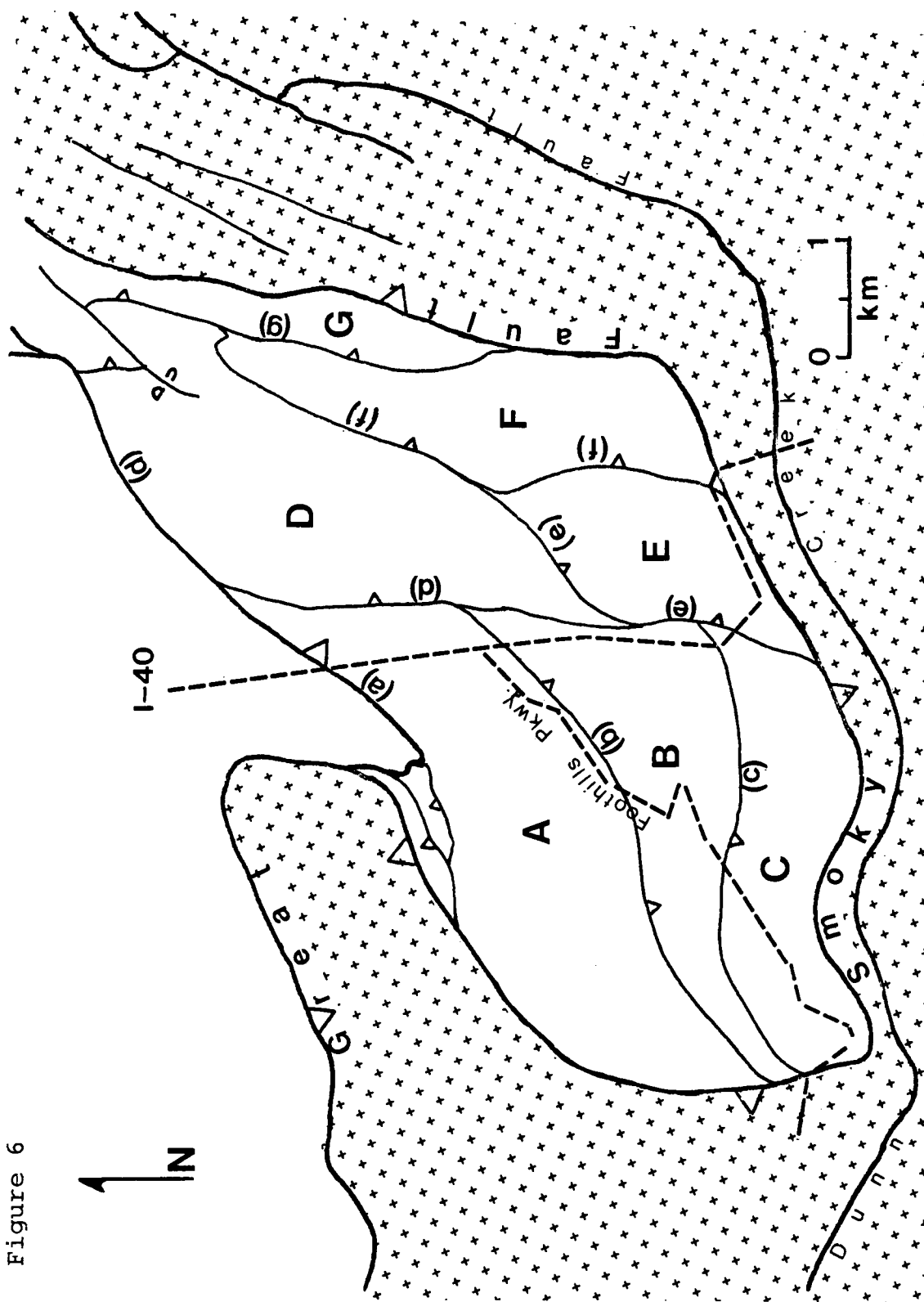
Within the study area, the Denton duplex is subdivided into seven major fault blocks. They are lettered (A) through (G) from lowest to highest, respectively (Figure 6).

(C) Faults

The study area includes a thrust system composed of one major overlying thrust fault, with seven or more imbricate faults. Due to poor exposure these faults are rarely visible. However, strained rocks on each side of the fault were commonly observed. The faults within the field area are assigned to one of three groups: major thrust faults (Great Smoky thrust), imbricate thrust faults (faults A-G), and high-angle normal faults.

The Great Smoky fault: The Great Smoky fault trace (modified from Rodgers, 1953 and Hadley and Goldsmith, 1963) has a "Z"-shaped pattern approximately 32 km long that winds through the field area. It places rocks of the Great Smoky thrust sheet over the Denton Duplex and Saltville sheets.

Figure 6. Index map of the study area showing fault nomenclature and associated thrust blocks as discussed in this study. Each fault is named for the fault block it underlies.



The actual trace of the fault was not observed. In numerous places, however, highly strained rocks of both the hanging wall and footwall were observed. Along Interstate-40, where the road parallels the Great Smoky fault, numerous exposures of disturbed Cochran Formation are present. The rocks here are broadly folded and, in places, heavily fractured. Bedding orientations are highly variable because of the proximity of the fault.

Along Highway 32 near the westernmost part of Green Mountain (Plate 1), the Great Smoky fault is closely located between outcrops of heavily sheared and fractured Cochran and Ocoee Supergroup rocks.

Imbricate faults: These faults branch from the Great Smoky fault and are restricted to within the Denton Duplex. There is no indication that any of them cut into the overlying Great Smoky thrust sheet. Seven of these faults were mapped (Figure 6 and Plate 1). They show various amounts of displacement and juxtapose only Chilhowee Group, Shady Dolomite and Rome Formation rocks. Commonly, the faults are poorly exposed and their location is typically inferred from mapped formation truncations.

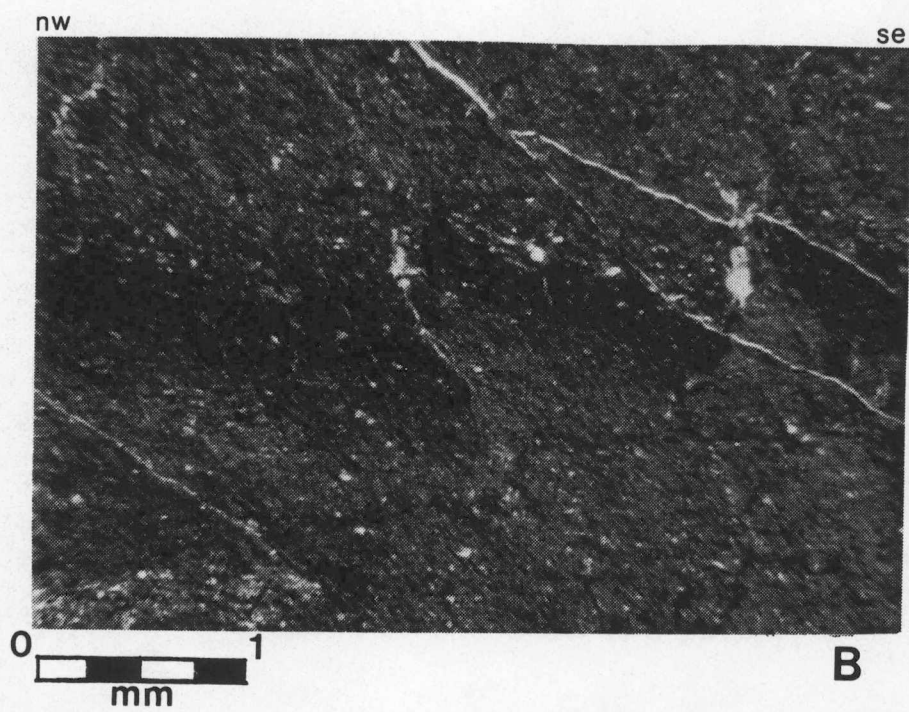
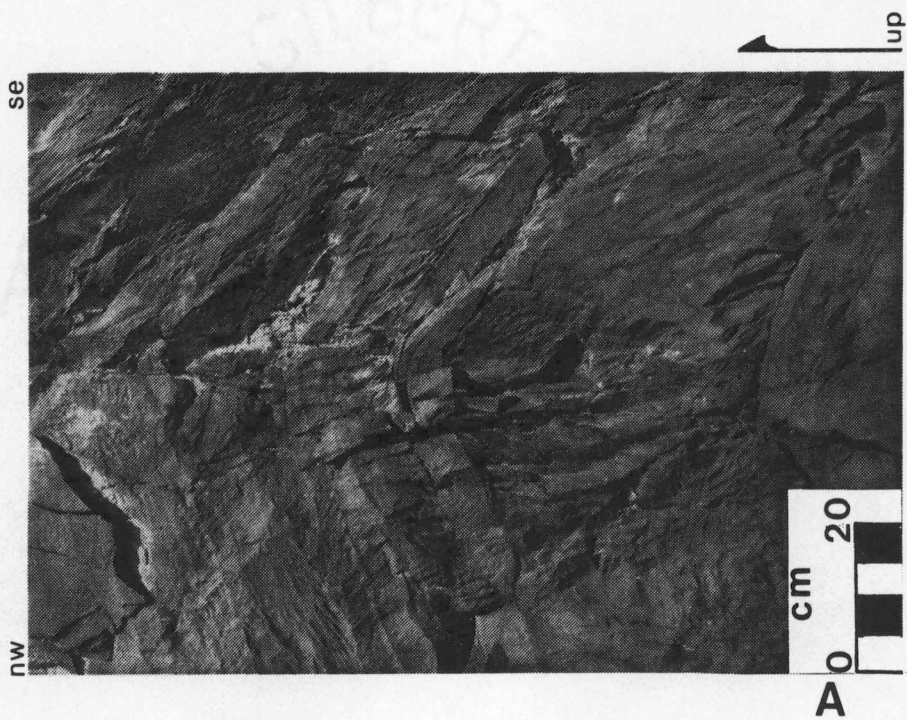
Fault A in the study area places Erwin Formation, Shady Dolomite, and Rome Formation over Knox Group rocks. Insofar as the horses in the duplex are limited in lateral extent as well as in width, faults A and D are the floor faults of the duplex. Fault A has a branch point with the

Great Smoky fault west of the Pigeon River (Plate 1 and Figure 6) near the re-entrant of the Great Smoky fault.

Fault B, along the first mile or so of the Foothills Parkway (Plate 1) places Erwin Formation, which strikes northwestward, against Shady Dolomite. This strike belt of Erwin Formation thins dramatically from east to west, and thus is probably faulted over the Shady Dolomite rather than being in normal stratigraphic order. What appears to be an outcrop of this fault exists along Interstate 40 near the Foothills Parkway exit (Locality #10; Plate 1) where Erwin Formation, +/- the Helenmode member, is in contact with disturbed Shady Dolomite.

Fault C is exposed along Interstate 40 at the base of Rich Top Mountain where it merges with fault E. Interbedded sandstone and shale strata of the Hampton Formation, in the footwall of the fault, are heavily folded and sheared. Cleavage is well developed near the fault (Figure 7 and Locality #5, Plate 1) and decreases in intensity over a distance of several tens of feet. Slickensides are present along many of the cleavage selvages and are sub-axial planar to the folds, their average being 032° with 60° - 70° dips to the southeast. The fold axes trend roughly 047° with plunges of about 20° . Elsewhere, this fault is inferred from contact truncations,

Figure 7. (A) Photograph of fold and associated sub-axial planar cleavage in the Hampton Formation near the Pigeon River (Locality #5; Plate 1). (B) Photomicrograph of the cleavage seen in (7a). Vergence is to the southeast in both photos.



changes in outcrop thicknesses, and along its westernmost trace by topography.

Fault D is interpreted as a branch from fault E. Stratigraphic separation on the fault is minor in the sense that it places upper Erwin over other Chilhowee Group rocks over the western part of its length. However, along the eastern part of its length it places Erwin Formation over Knox Group rocks and marks the floor of the duplex. The fault was observed along an old road that goes to Buzzard Roost (Locality #11; Plate 1) on the east side of the Pigeon River, where it consists of a heavily weathered, light- and dark-banded mylonite zone. The zone is approximately eight meters thick and trends approximately 045° with dips of about 46° to the southeast. The composition of the rock is difficult to discern because of the heavy weathering, but it appears to consist of sheared feldspathic sandstone or quartzite. A few weathered feldspar grains were found intact.

A small sliver of heavily cleaved and sheared maroon and green siltstone and silty shale to slate was observed at the mouth of Polly Elbert branch (Plate 1). This is probably a small sliver of Rome Formation in the footwall of fault D. It may also indicate that slices of Rome Formation are involved in lower parts of the Denton duplex. Fault D is also well located along Sweetwater Road, south of Piney Mountain, where folded limestone beds of the Knox

Group are in contact with sheared and fractured Cochran Formation.

Fault E has the most stratigraphic separation of any of the imbricate faults. The greatest stratigraphic separation along it occurs on the northwest side of Rich Top Mountain where the fault places upper Cochran over upper Erwin rocks. The fault is well-exposed along Interstate 40 near Locality #5 on Plate 1, where a steep canyon has been cut by the Pigeon River. Here, the trace of the fault is easily visible from the highway (especially in the winter when vegetation is sparse), where rocks of the Erwin have been overturned immediately below the fault. Elsewhere, the trace of the fault was inferred from lithologic changes with the aid of topography. In Landin Cove, the fault is placed where distorted shale strata of the Hampton Formation are found to lie above dense quartzite beds of the Erwin Formation. In Pigeonroost Hollow, the fault is located at the termination of massive exposures of Erwin quartzite beds. The northeasternmost trace of the fault is inferred from topography and changes in bedding orientations. Dense, white quartzite beds are prominent near Low Gap, and the structure is based mainly on bedding orientations.

Fault F was nowhere actually observed. Its presence was inferred from changes in bedding orientations and

stratigraphic separation. Stratigraphic separation on this fault is minimal, because in most cases it places upper Cochran on top of upper Hampton rocks, and lower Hampton on upper Erwin rocks. The precise junction of faults (E) and (F) is uncertain because of the lithologic similarity between quartzite strata of the Hampton and Erwin Formations.

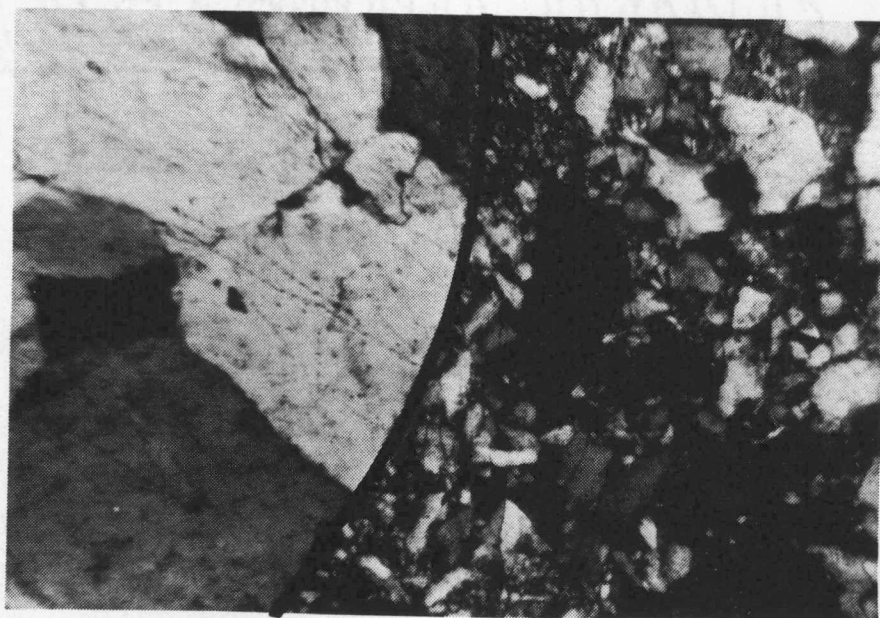
Fault G, is modified from Rodgers (1953), and merges with the Yellow Springs Mountain fault (Plate 1) of Ferguson and Jewell (1951). It is inferred to have once been continuous along the easternmost boundary of the field area. The fault is closely located near Bearpen Ridge (Locality #12; Plate 1), where disturbed rocks and a change in lithology are observed. Near Low Gap, the trace of the fault is also closely delineated between outcrops of differing rock types. Near the eastern edge of the study area, normal faults are interpreted to laterally displace the fault approximately 1350 m to the southwest. The fault then continues its northeasterly trace (modified from Rodgers, 1953) along Crumb Hollow.

In addition to the faults A-F, two smaller thrust faults are present in the northwestern part of the field area where they bound two small horse blocks (Locality #2; Plate 1 and Figure 6, p. 39). One of these horses, composed of Rome Formation, is interpreted to be bounded by a small imbricate of the floor fault that has not been

named. The fault has only minor displacement and places Shady Dolomite over Rome Formation. The other of these horse blocks is composed of Cochran Formation, and both faults bounding it are interpreted as being part of the roof fault of the thrust system.

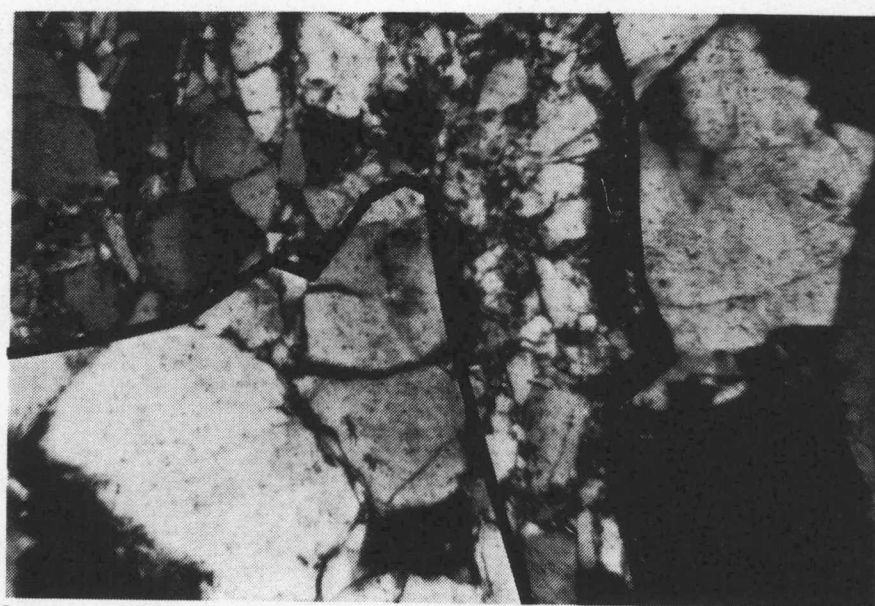
Normal Faults: Near the easternmost extent of this block (Plate 1), two steeply dipping normal fault offset fault G. Brecciated Erwin Formation, associated with this fault, is found in the stream valleys and along the small road in Whitesprings branch (Locality #7; Plate 1). The breccia consists of large, angular clasts of quartzite in a matrix of finer-grained, intensely brecciated quartz grains (Figure 8 A and B and Plate 1). Clasts range in size from several centimeters to several microns. Undulatory extinction and subgrain formation are ubiquitous. Triple junction grain boundaries between original sand grains were a primary feature of the rock. This breccia is well exposed in the stream valley just west of the located sample #3 (Plate 1) where a wide zone weathers out as a large ledge up to two meters high and about one meter wide. The zone at this locality trends about 045° with a dip of 60° to 80° to the northwest. Float of this breccia was found all the way to the eastern margin of the field area and probably continues further to the northeast.

Figure 8. Brecciated Erwin Formation. Original quartzite texture (labelled) can be seen in both photographs. Brecciated quartz material of varying sizes fills the spaces between the larger clasts.



A

0 1
mm



B

0 .25
mm

(D) Minor Fabrics

Rock fabrics of the area include microscopic crenulation folds, map-scale folds, inferred subsurface folds, cleavage, mylonite, breccia, joints, and fractures. For this reason, fabrics in the area will be described by the thrust sheet or block starting with the structurally lowest sheet.

Rock cleavage in this study is described and classified according to the scheme proposed by Powell (1978; Figure 9). This scheme provides morphological classifications rather than uncertain genetic ones. Four measurable parameters are used to distinguish major morphologic types of cleavage. They are:

- (1) The spacing of cleavage domains
- (2) The shape of cleavage domains (Figure 9b)
- (3) The microlithon fabric (Figure 9c)
- (4) The portion of rock occupied by cleavage domains

Table (1) lists cleaved samples showing their lithology and cleavage classification. Figures 10, 11, and 12 show a select group of photomicrographs of these cleaved samples and Figure 13 shows an equal area net plot of all observed cleavage.

Saltville Thrust Sheet: Folds in this sheet include large map-scale folds such as the Newport anticline (Witherspoon, 1982) and small outcrop-scale folds that are concentrated near faults (Plate 1 and 2). The folds and

Figure 9. Cleavage classification according to
Powell (1978).

Figure 9

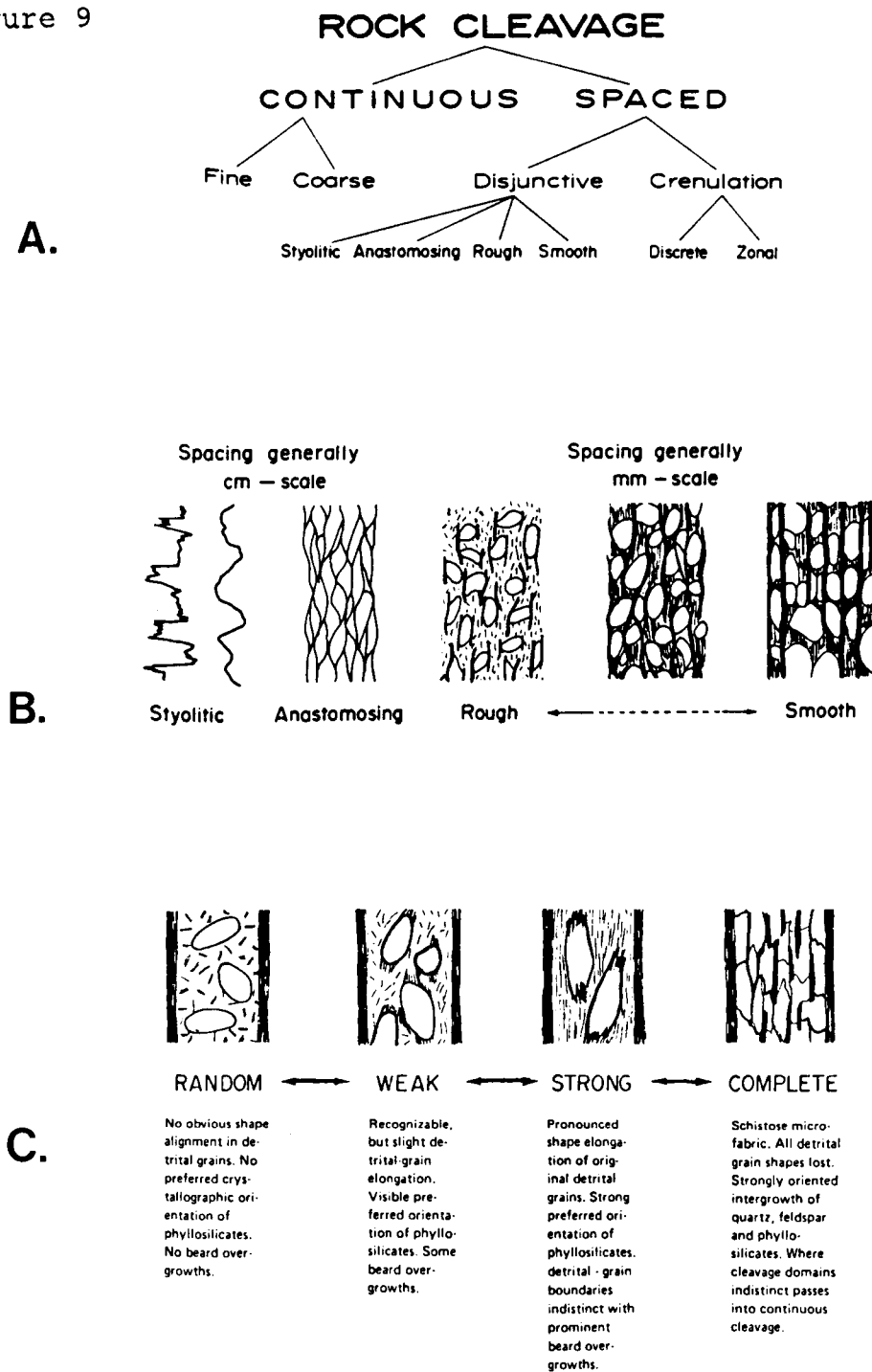


Table 1. Detailed classification of cleavage in collected samples according to Powell (1978).

Sample	Lithology	Ave. Spacing	Domain	Microlithon	%Cl
2	Sh	<0.001 mm	In-Sm	Str-C	25
4	Ls, D	0.5 cm	St-An	Rn	30
5	Ls, D	0.001 cm	R-St	W	25
6	Sh	0.05 mm	In-Sm	W-Str	30
7	Sh, Slt	<0.001 cm	Sm	C	20
8	D, Ls, Sh	0.05 cm	R-St	R-W	<5
9	Ls, Slt, D	0.5 cm	R-A	Rn	<5
10	Ls, Qtz	1 cm	R	Rn	<5
11	Ls, Qtz	0.5 cm	S-R	Rn	<5
12	Ls, D, Qtz	>0.5 cm	An	R	<5
13	Slt, Sh	0.1 cm	In-S	S-C	25

Columns listed in the table are; sample number, lithology, average cleavage spacing, cleavage domain type, degree of microlithon realignment, and percent of the rock occupied by cleavage selvages.

Abbreviations used are as follows: for lithology, Ls-limestone, D-dolostone, Sh-shale, Slt-silt, Qtz-sand sized quartz; for domain type, St-stylolitic, An-anastomosing, R-rough, Sm-smooth, In-intermediate; and for degree of microlithon realignment, Rn-random, W-weak, Str-strong, C-complete.

The location of all samples is given on Plate 1.

Figure 10. Photomicrographs of cleaved samples 4, 6, 8, and 9 as listed in Table 1. (A) Sample 4 is a dolomitic limestone of the Knox Group. The cleavage is stylolitic to anastomosing and has an average spacing of about 0.5 cm. Microlithon realignment is non-existent. (B) Sample 6 is a shale from the Sevier Shale near the Great Smoky fault. The cleavage is smooth to intermediate and very closely spaced ($< .001$). Microlithon realignment is weak to strong. (C) Sample 8 is a shaley, limey, dolostone from the Wilhite Formation. The cleavage is rough to stylolitic with an average spacing of 0.05 cm. Microlithon fabric is random to weakly realigned. (D) Sample 9 is a silty, dolomitic, limestone of the Wilhite Formation. The cleavage is rough to anastomosing with an average spacing of 0.5 cm. Microlithon fabric is random.

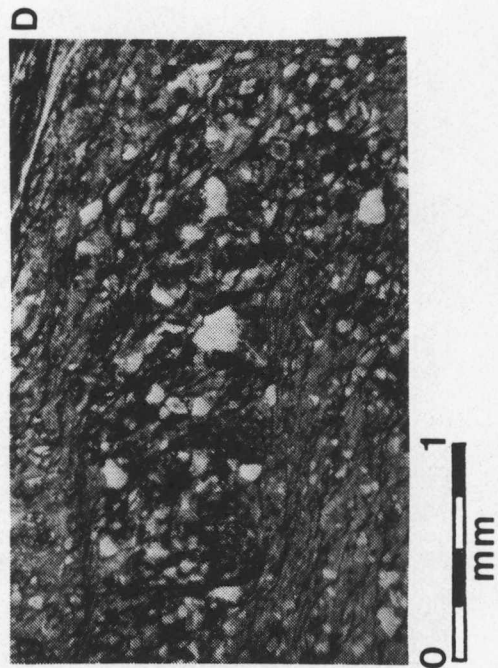
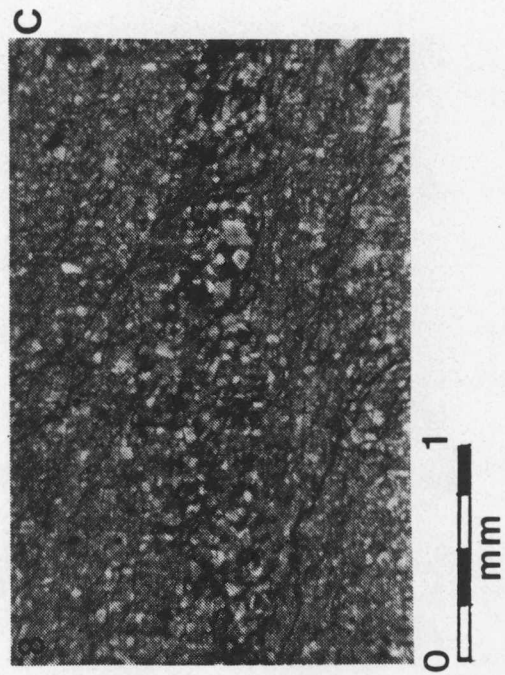
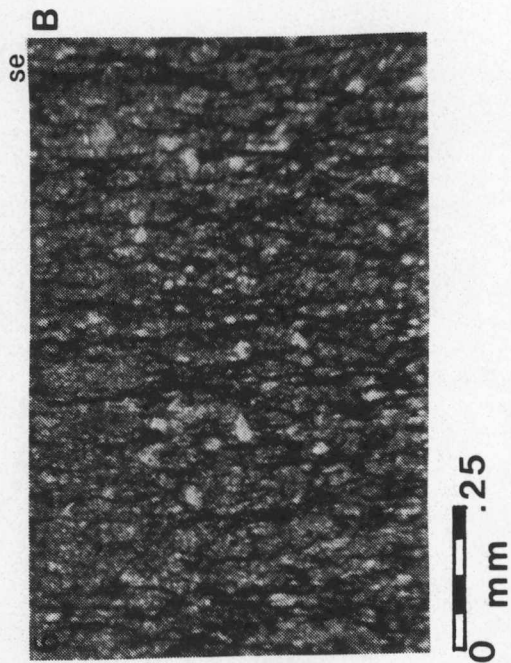
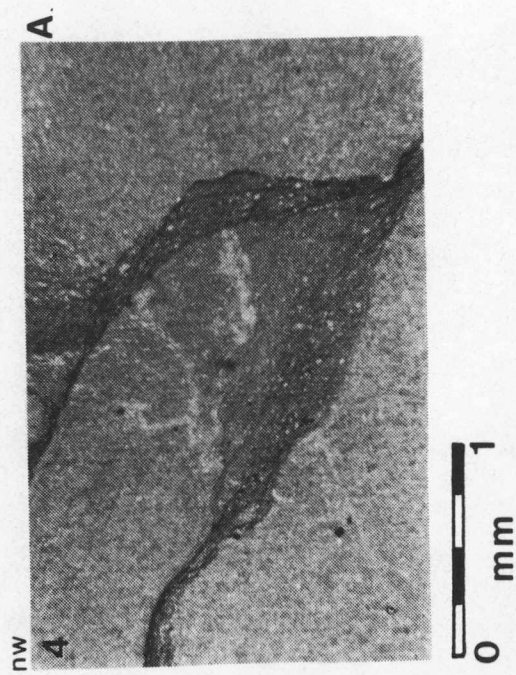


Figure 11. Photomicrographs of cleaved samples 10, 11, and 12 (A and B) as listed in Table 1. (A) Sample 10 is a sandy limestone of the Wilhite Formation. The cleavage is rough and has an average spacing of 1 cm. Microlithon fabric is random. (B) Sample 11 is a sandy limestone from the Wilhite Formation similar in lithology to sample 10. The cleavage, however, is noticeably stronger. It is stylolitic to rough with an average spacing of 0.5 cm. The microlithon fabric is random. (C) Sample 12A is a silty, dolomitic, limestone from the Wilhite Formation. The cleavage is anastomosing and has an average spacing of about 0.5 cm. Microlithon fabric is random. (D) Sample 12B is from the thin-section as 12A. The lithology of this portion of the sample has changed to dominantly microcrystalline calcite with some shale. The cleavage here has changed morphology to where it is almost invisible except as thin, anastomosing, white lines. Due to the fine-grained nature of the sample and the weakness of the cleavage, no further description of the cleavage is possible.



Figure 12. Photomicrograph of cleaved sample 11 as listed in Table 1. The sample is a shaley siltstone-slate from the Wilhite Formation. The cleavage is intermediate to smooth and has an average spacing of 0.1 cm. Microlithon realignment is strong to complete.

ALBERT
14532-13
LANCASTER BOND
100% COTTON FIBRE

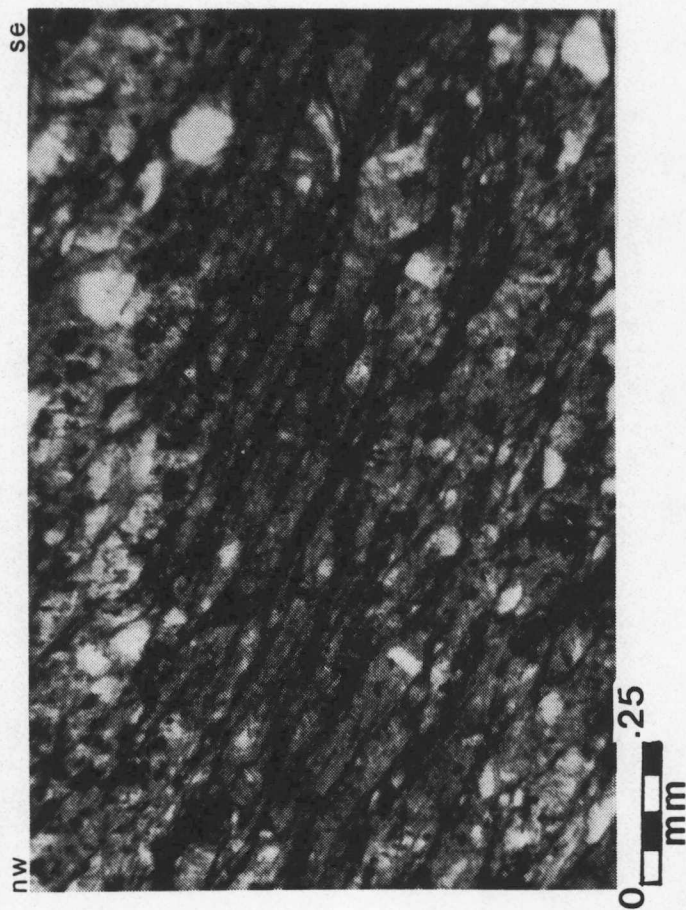
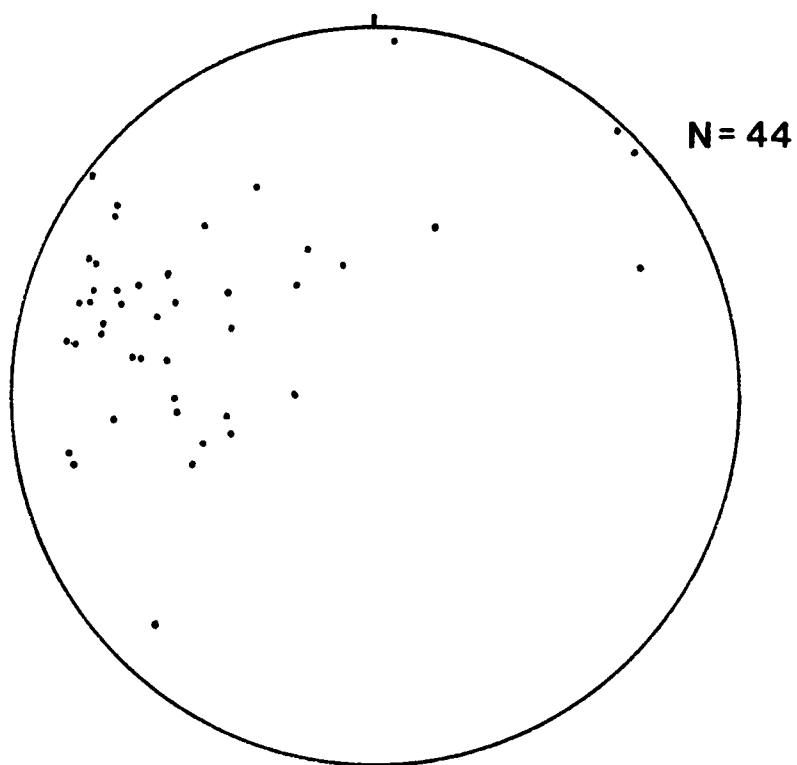


Figure 13. Equal-area net plot of poles to cleavage in both the Denton duplex (A) and the Great Smoky thrust sheet (B).

A.



B.

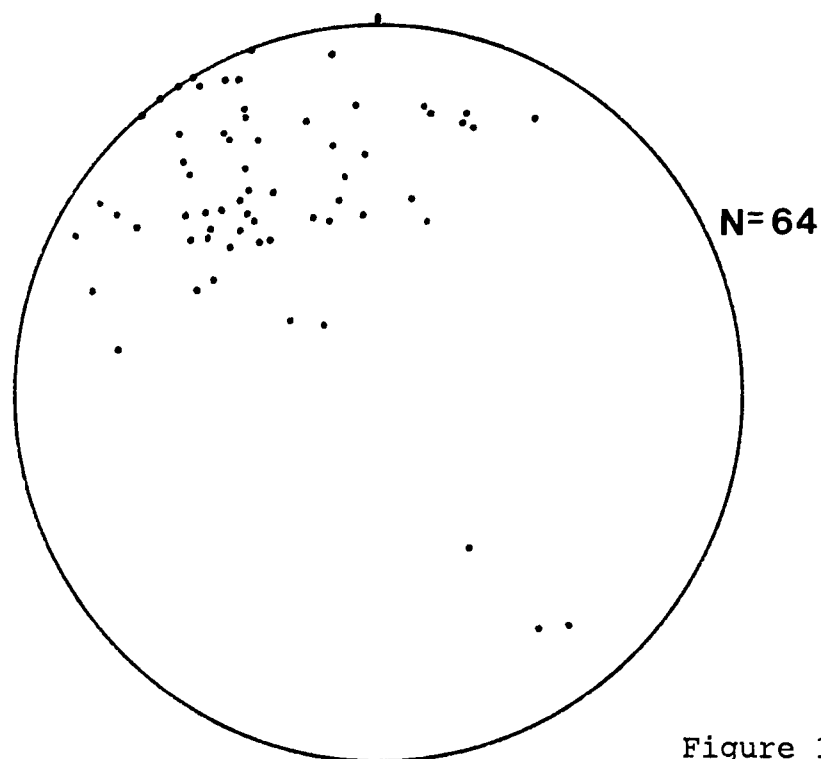


Figure 13

cleavage are a function of lithology and proximity to faults. Both are best developed in shale and shaley carbonate strata of the Sevier Shale and Knox Group that occur near faults (Figure 14) and thus, are a direct result of movement on the faults. Figure 9A and B (p. 52) shows cleavage from samples collected near the Great Smoky fault. (see Plate 1 and Table 1; samples 4 and 6). Sample 1 shows a strong stylolitic to anastomosing type of cleavage with about 30% of the rock occupied by domains. Sample 5 (Table 1; no photograph) shows a weaker, less conspicuous, rough to stylolitic cleavage with weak microlithon realignment in a shaley dolomitic limestone. Cleavage is well-developed in the shale strata of the Sevier Shale near the Great Smoky fault (Figure 9B). This photograph shows an anastomosing to rough cleavage with weak to strong microlithon alignment.

Thrust Block A: This thrust block is composed entirely of Shady Dolomite. The unit is composed of a wide variety of rock types including shale, and it is commonly highly deformed.

In Allen Grove along a small farm road (Plate 1, block A), abundant small wavelength folds (<0.3 meters) were found. The folds have random axial orientations and are probably separated by small faults. Small folds were also observed at the base of Raines Knob (Plate 1, block A) near the Pigeon River. These folds are gentle to open and

Figure 14. Map of the study area showing structural features.

- normal to cleavage
- ↗ anticline
- ↘ syncline
- minor fold
- ↘ fault dip

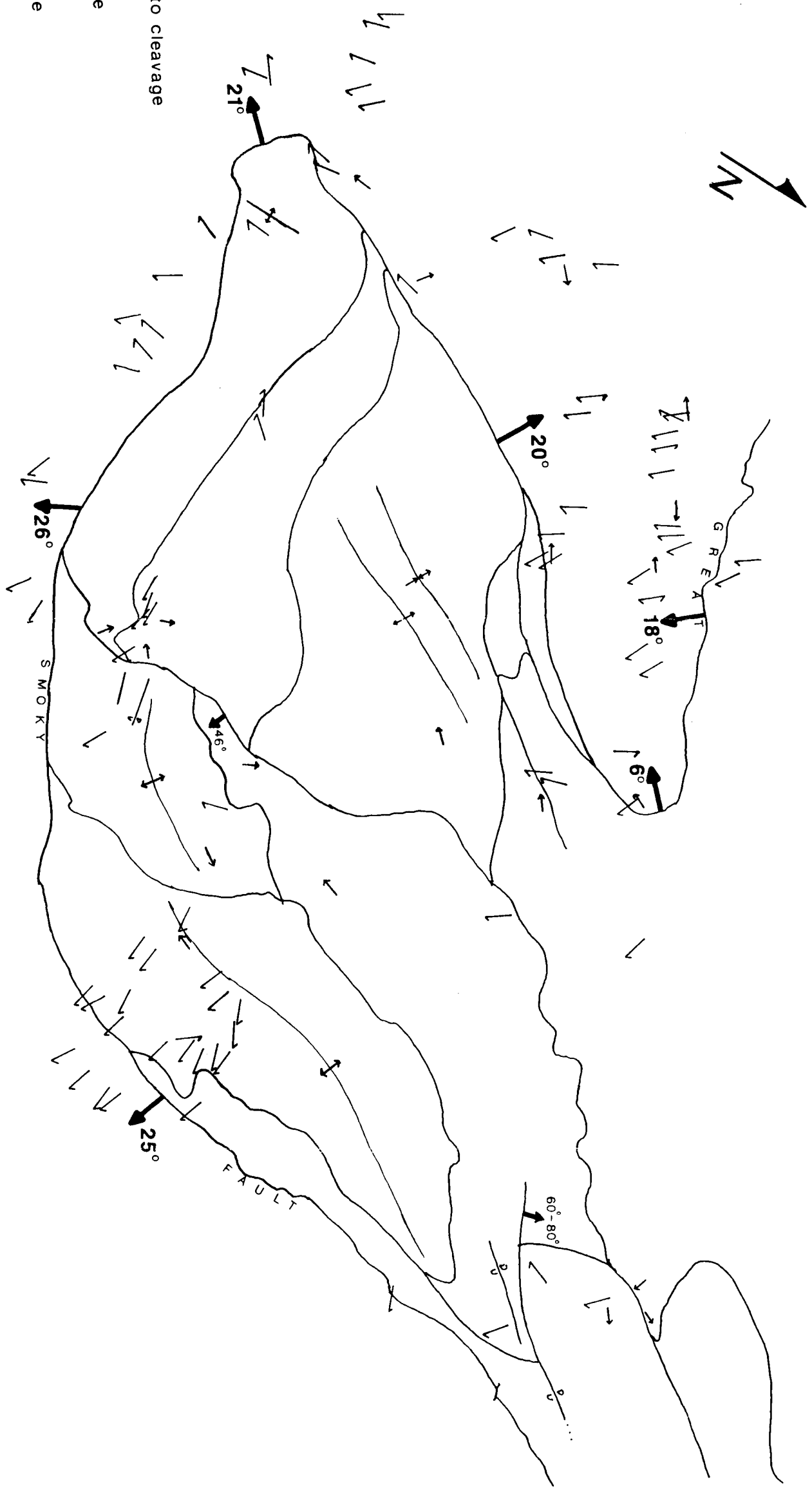


Figure 14

have fold axes that trend about 230° , with a plunge of about eight degrees.

Based on the areal extent of the Shady Dolomite and the rocks exposed along Allen Grove Road (Plate 1, block A), it appears that the stratigraphic section is repeated either by folding or faulting. Due to poor exposure, details found for this block were limited and it is likely that the geology is much more complicated than is shown on the map. No cleavage or systematic array of fractures or veins was observed in this block.

Thrust Block B: Folds in this block occur mostly in the Hampton Formation, which extends easterly from the Pigeon River to the Foothills Parkway (Plate 1). Many small folds are well exposed along the Pigeon River, just below faults C and E (Figure 7A p. 43). At this locality, the average plunge of the fold axes is about 16° , trending 045° (Figure 14 and Plate 1). The folds are mostly open to gentle and have wavelengths of tens of centimeters to tens of meters. A sub-axial planar cleavage (Figure 7B, p. 43; Table 1, sample 2, p. 54) is associated with these folds. Both cleavage and the folds are more intense as the fault is neared, and both are sub-parallel to faults C and E.

On the western side of the Pigeon River in Laurel Hollow (Locality #13; Plate 1), folds similar to those mentioned above were observed. However, their orientations are somewhat different, plunging approximately 36° to the

north (Figure 14). Cleavage associated with these folds is not axial-planar, because the average fold axial plane dips deviate approximately 20° to 30° from cleavage (Plate 1).

Near the sharp bend in the Foothills Parkway (Locality #14; Plate 1), an abrupt change in bedding orientations suggests a fold. On the easternmost part of this bend in the road, an outcrop of shale and quartzite strata is present with steep northeasterly dips, whereas on the southwesternmost part of the outcrop, orientations change to shallow southwesterly dips. Cleavage in this area (Table 1, p. 54, sample 7) appears to have a consistent orientation (Plate 1) and may have been later than the fold. An alternative to placing a fold here is to place a fault somewhere between the dip changes. However, no evidence for a fault was seen.

No folds were observed in the Erwin Formation in this block. However, changes in bedding orientations occur along the ridge south of the Foothills Parkway. This may represent a large fold in the rocks as shown in cross-section (Plate 2), or perhaps a minor fault.

No cleavage was observed in the Erwin Formation, but joints are very common. Along Interstate 40 where the Pigeon River cuts through the Erwin Formation, an apparently systematic set of joints is pervasive throughout much of the section. The majority of these joints strike

about 050° to 080° , with northwesterly dips between 60° and 90° . Just north of Landin Cove along I 40 (Locality #15; Plate 1), a dangerous rock slide is produced where bedding slopes toward the road and rock slabs break along joint surfaces.

Thrust Block C: Fabrics in this block are numerous. Folds ranging from outcrop scale to map scale are present, as are joints and minor cleavage. The largest outcrop-scale fold is exposed along the western side of the Pigeon River near Bluffton (Plate 1). It is a gently inclined fold with one overturned limb (Figure 15: Locality #16; Plate 1). The fold is roughly cylindrical and has undergone significant flexural slip between layers. The exposed portion of this fold is approximately 16 meters high by 10 meters wide. However, it is possible that the fold is much larger. Several smaller folds are present just to the south along the river, where fold orientations are random, and possibly some small faults are present. The orientation of the larger fold also is oblique to any other structures in the area. Possibly the fold has been rotated after its formation. A large anticline on the western end of Green Mountain (Locality #17; Plate 1) north of the Foothills Parkway trends approximately 196° with a plunge of about 16° . As mapped, the fold is a least 120 meters in amplitude and 300 meters in wavelength. The fold appears to be bounded by faults because of sharp

Figure 15. Photograph of a large gentle fold in the Cochran Formation near the Pigeon River in thrust block (C). Exposed portion of the fold is approximately 10 meters high.



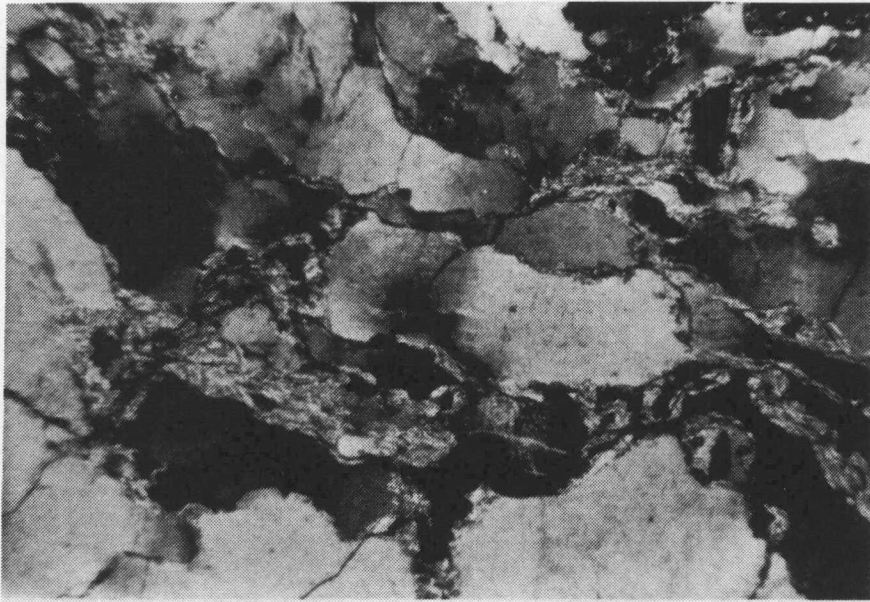
Figure 15

changes in bedding orientations on either side. As seen on cross-section A (Plate 2), the central part of this block is comprised of a large gentle syncline that is oblique to and terminates at fault C.

Joints and fractures are common in the quartzite and dense sandstone sequences. Along the Foothills Parkway (Plate 1) near fault C, a somewhat systematic set of joints trends about 290° to 355° , with steep dips of about 60° to 85° to the southeast. Cleavage was found along the Foothills Parkway (Locality #17; Plate 1); its orientation was measured to be about 090° with an 85° dip to the south. The cleavage is weak, with a spacing on the order of centimeters. Heavily sheared sandstone of the Cochran Formation was observed along the eastern end of Green Mountain (sample #14; Plate 1) near the trace of the Great Smoky fault. The rock at this locality is a mylonite that consists of heavily strained quartz with undulose extinction and subgrain formation (Figure 16). A fine-grained matrix is present as thin zones, which are parallel to the maximum stretching direction of the quartz. The stretching direction is somewhat chaotic, but appears to be northwest-trending with dips of 40° to 60° to the northwest. This material is composed of very fine-grained sericite and iron oxides, which probably represent breakdown of feldspar.

The structural orientations in this block appear to

Figure 16. Sheared sandstone of the Cochran
Formation near Green Mountain. Sample 14, Plate 1.



have little coherence. Folds and cleavage have no apparent geometric relationship to each other or to the regional transport direction. Possibly a more detailed study of this block would reveal much more complex structural relationships than is shown on Plate 1.

Thrust Block D: This block is composed almost entirely of Erwin Formation which, because of its massive nature, has few small-scale folds. As indicated by map data, however, large map-scale folds are common. In Landin Cove (Locality #18; Plate 1) between faults D and E, a large map-scale fold occurs in a very thick, massive, dense quartzite sequence. The fold is open and plunges gently to the north. A smaller fold, approximately 0.5 meters in amplitude and about 1 meter in wavelength, is present within this larger fold. It has an interlimb angle of about 150° and plunges 18° to 340° . The small fold is present and mechanical bedding (slip surfaces) are present in the quartzite strata.

In Pigeonroost Branch a somewhat tighter fold with an interlimb angle of 70° to 90° was found. The wavelength and amplitude of this fold are unknown due to limited exposure, but the wavelength is constrained to about 15 meters by observation of bedding at adjacent outcrops. The fold axis trends 195° and plunges 20° . Flexural slip between bedding partings is common and mechanical bedding is produced near the center of the fold. Other large

folds, and possibly faults, are certainly present in this block, as inferred from areal differences in bedding orientations. Orientations of the observed folds are sub-parallel to the general transport direction, thus, it is likely that the folds are related to the emplacement of the block.

Cleavage in this block was observed at only one locality. A closely spaced, penetrative cleavage was found in the easternmost part of this block where the Hampton Formation is exposed (Locality 19; Plate 1). Its orientation (Figure 14, p. 64) suggests that it is related to the emplacement of the block. Joints in this block are common in the Erwin Formation, however, they were not studied in detail.

Fault Block E: This block is part of a large, gentle northeast-trending hanging-wall anticline. Bedding on the southeast limb dips 20° to 50° south, and the northwest limb is very gently north-dipping to horizontal. The general shape of this fold can be seen on the steep west-facing cliffs over the Pigeon River near Bluffton (Plate 2).

A series of broad, gentle, but steeply-plunging folds are present in block E along the trace of the Great Smoky fault. These folds are not shown on the map, but are well exposed along Interstate 40. The only other folds found in

this block occur in the Hampton Formation. One, in Landin Cove, is poorly exposed and composed of quartzite and sandstone. It is a relatively large outcrop-scale fold that is overturned so that both limbs are gently dipping to the northwest. The fold axis trends 035° plunging about 10° (Figure 14, p. 64). The wavelength is estimated to be about 15 meters and the amplitude is poorly constrained, but is probably on the order of 30 meters or less, based upon outcrops above and below. Some smaller folds were found in the Hampton Formation, but exposure was limited.

Cleavage in this block was found in two places. In both instances the cleavage was only locally developed in very fine-grained sandstone, siltstone, and shale. Along the Pigeon River near Locality #5 (Plate 1), two faults of unknown displacement were also found. Near these faults, bedding is masked by abundant fractures and joints. Displacement on these faults is minor because immediately to the east, no stratigraphic separation is evident. In the dense quartzite strata, joints are common, but were not studied in detail.

Along Interstate 40 where the Pigeon River parallels the Great Smoky fault, abundant small faults and fractures are present, and in many cases, bedding is not traceable for significant distances along strike. These small faults are interpreted to be a result of footwall splays of the Great Smoky fault, which cut down-section, producing a

normal offset in bedding; however, they are compressional in nature.

Fault Block F: The most conspicuous of all map-scale folds in the area occurs in this block. It is a large, broad anticline that forms the highest ridge (Hall Mountain). The axial trace of the fold trends roughly 025° and its axis is nearly horizontal (0 to 10° plunge to the northeast). Bedding on the northwest limb of the fold dips from 20° to 50° to the northwest, and the southeast limb is nearly horizontal at the top of Hall Mountain and dips 60° southeast in the Cochran Formation on the south slope (Plate 1). Many smaller folds and faults are present in the Cochran Formation on the southeastern limb of the fold, where the structure is probably more complex than is shown on the map.

Based upon this writer's mapping, the large fold in this block is only slightly separated from the large fold in block E. This interpretation requires that the fold formed prior to the formation of the southernmost segment of fault F.

Cleavage in this block is abundant in the silty sandstone and shale beds of the Cochran Formation south of Hall Mountain (Locality #20; Plate 1). In general, it is a well developed northerly striking cleavage, with moderate to steep (30° to 70°) dips to the east (Figure 14, p. 64).

The orientation of the cleavage is roughly parallel to the Great Smoky fault and fault G. It may well be a result of the emplacement of the block. The intensity of the cleavage is a result of the fine-grained nature of the Cochran Formation in this block.

Fault Block G: This block is continuous with the Yellow Springs Mountain fault block of Hadley and Goldsmith (1951). The only fold observed in this block is the syncline mapped by Ferguson and Jewell (1951). In the easternmost part of the field area, this syncline has gently dipping (20° to 45°) limbs that flatten out in the center. However, as the block continues southerly, the southeastern limb becomes steeper until it is overturned along Panther Mountain. This relationship can also be seen in cross-section C (Plate 3). No small folds were observed within this block, although small-scale footwall splays similar to those of block E were observed near the trace of the Great Smoky fault.

Cleavage was found at only one locality in the southernmost part of the block. It is roughly parallel to the cleavage of block F.

Great Smoky Thrust Sheet: Minor folds are present in this sheet throughout the study area. The fold axes and axial planes of the folds appear to be roughly parallel to regional cleavage (Figure 14, p. 64). Due to limited exposure of the rocks in this sheet, correlation of

separate outcrops is difficult. Using the bedding orientation data on the map (Plate 1), there appears to be little coherence between many outcrops; the writer attributes this to abundant minor folds and faults of different magnitudes which were not mappable.

In addition to folds within the thrust sheet, it will be shown in Chapter 4 that these rocks have been broadly folded from beneath (Plate 2). The re-entrant of the Great Smoky fault in the northwestern part of the field area sits within a synform in its footwall (Figure 14, p. 64). An anticline in the Great Smoky sheet occurs where the Precambrian rocks are folded above Green and Stone Mountains (Plates 2 and 3). In the western part of the field area, both of these folds plunge about 10° to the southwest.

Cleavage in this sheet is abundant. Its presence and classification appears to be largely related to lithology; the coarser the material, the less likely it will be cleaved. It is commonly disjunctive, anastomosing to rough in the shale, silt, and fine-grained sandstone. In the carbonate strata, stylolitic, anastomosing, and rough disjunctive cleavage dominate. Where coarse-grained quartz-rich sandstone is present, no cleavage was observed.

Cleavage in the carbonate beds is commonly weak and widely spaced, or is not at all visible at the outcrop. In

thin-section, however, it is present in most samples collected. Typically, cleavage in these samples includes several different classes (Powell, 1978) within one sample. For instance, samples 8 and 9 in Figure 10 (p. 55) exhibit a combination of stylolitic and anastomosing to rough cleavage (Table 1 p. 54). Sedimentary layering has an effect not only on the type of cleavage but on its orientation. Figure 10D (sample 9, p. 55) shows cleavage refraction due to an increase in the abundance of quartz grains.

Where sand- and pebble-sized grains are present, cleavage tends to be highly variable in type and in intensity. The composition and size of the matrix and clasts is the most important variable. Figure 11 (A and B) exemplify quartz-bearing, intraclastic limestone with highly variable cleavage (Table 1, samples 10 and 11). The shapes of individual cleavage selvages are again largely controlled by the quartz grains. Figure 11A (p. 57) shows individual stylolitic selvages conforming to the quartz grains. Selvages are not rough, but are more continuous than those of Figure 11B. Cleavage in Figure 11B is very weak. Individual selvages are discontinuous (rough) and are often present only on the lower grain boundaries.

Figures 11C and 11D (p. 57) show two photomicrographs from the same thin-section. Figure 11C is a thinly-laminated, shaley, quartz-bearing limestone. Cleavage

selvages (Table 1, p. 54; sample 12) produce small offsets in bedding layers, giving the rock a rippled appearance. In Figure 11D however, the rock is composed of mostly micritic limestone. Cleavage in this portion of the sample shows up only as very dim, discontinuous stripes. The rock is too fine-grained to see the cause of the stripes, however, it appears that the cleavage is due to the preferential twinning of the calcite crystals.

The clastic rocks of the Great Smoky thrust sheet show varying degrees of cleavage. In general, the finer the grain size, the better the cleavage development. However, other factors, such as the proximity to faults and folds, are also important. Typically, rocks with mud-sized grains have a well-developed cleavage that would be classified as slaty cleavage on outcrop scale. In thin-section, however, most of this cleavage is closely spaced anastomosing cleavage (Powell, 1978) that refracts from layer to layer (Figure 12, p. 59 and Table 1, p. 54; sample 13).

In the coarser-grained clastic rocks such as the quartz sandstone and arkose of the Sandsuck Formation, cleavage is commonly not present on the scale of the hand sample. It is possible that some fabric is present on a smaller scale, but no thin-sections of this rock type were made.

(E) Cross-Sections

Four cross-sections (Plates 2 and 3) are used to graphically show the inferred structural relationships, based on map and fabric analysis. All sections were constructed using the methods described by Woodward et al. (1985). Only one of the sections (A-A') was extended to the base of deformation to test how deep surface structures should be. Cross-section orientations were chosen to be at right angles to the transport direction. Folds, cleavage, and average orientation of major faults were used as indicators of transport direction. The orientation of section A (Plate 2) was also chosen to be perpendicular to the folded Great Smoky fault to show its true shape. Section D (Plate 3) was drawn using data from Ferguson and Jewell (1951) and Keller (1980), as a comparison to their interpretations. Depth and slope of the base of deformation were taken from Tegland (1978) who interpreted the Geophysical Services Inc. seismic line #TC-2 (depth section) approximately 20 km to the northeast. The base of deformation is not necessarily assumed to be the bottom of the stratigraphic section.

Folds in cross-section were drawn following the shape of folds observed in the field. Stratigraphic thicknesses were calculated from map patterns or estimated where complete sections were not exposed. In places where faults

follow bedding (decollements), thicknesses used were calculated from map outcrop patterns in the field area (150 m in the Sevier Shale) or were merely estimated from regional outcrop patterns as for the Rome Formation (185 m).

After construction of balanced cross-sections, it is useful to retro-deform the fault blocks to show the relationship of one block to another prior to deformation. Plates 2 and 3 show each cross-section along with its restored section.

Cross-section A: This section extends from southeast of the Denton duplex northwestward to just beyond the Fair Garden anticline. Major surficial features (the Denton duplex, the unnamed syncline to the northeast of the Denton duplex, the Newport Anticline, the English Mountain syncline, and the Fair Garden anticline) reflect broad folds in the subsurface. This is shown by the fact that a single Sevier Shale detachment appears to underlie all major thrust sheets on the map. Thus, these surficial folds were caused by movement of the underlying sheets.

The Denton duplex, which consists of three separate thrust blocks in this section, is shown to fold the overlying Great Smoky thrust sheet by successive stacking of the horse blocks. This anticlinal fold continues to the northwest where its northwestern limb becomes the southeastern limb of a broad syncline. This synclinal fold, which involves the Great Smoky thrust sheet, must

have its origin in the underlying Valley and Ridge rocks. This is also shown by the fact that the folds in the Great Smoky sheet continue beyond the leading branch-line of the Denton duplex.

The English Mountain syncline is shown to have been gently folded between the underlying Newport anticline (Witherspoon, 1982) and the Fair Garden anticline (Bumgarner, 1956). The Fair Garden anticline is a relatively tight fold that probably formed in the hanging wall of an unnamed thrust fault (Witherspoon, 1982). This thrust fault has not been mapped at the surface, but was shown to be necessary by Witherspoon (1982) because of the shallow depth at which the Rome Formation must occur. He argued that because the Rome Formation marks the base of the stratigraphic section, a fault must be present. In his cross-sections he showed the fault (an extension of the Guess Creek fault) appearing at the surface in the midst of a large belt of Sevier Shale. The Fair Garden anticline is slightly modified by the Middle Creek thrust as mapped by Bumgarner (1956). Weitz (1983) also mapped two unnamed thrusts within the Sevier Shale region along Douglas Lake, northwest of the Fair Garden anticline.

The Newport anticline is inferred to be caused by a hangingwall ramp-anticline in thrust block 5 (Plate 2) beneath the Fair Garden thrust sheet. It is one of two

duplex horse blocks drawn beneath the sheet to create the necessary structural relief above basement. This follows Witherspoon (1982) who suggested that a duplex is necessary to fill in space to the base of deformation. Below the Fair Garden thrust sheet, the cross-section was completed using the same four stratigraphic units as in higher Valley and Ridge sheets. The faults in the lower part of the section probably continue upwards as part of the Dumplin Valley thrust system. Surface geology and depth to the base of deformation suggest a tripled stratigraphic section.

The restored section (Plate 2) shows that each higher thrust sheet, in the deformed state, restores to the southeast of the sheet below it. Thus, all Valley and Ridge rocks, prior to deformation, were northwest of both the Denton duplex and the Great Smoky thrust sheet (including the English Mountain thrust block). Similarly, within the Denton duplex each higher thrust block, in the deformed state, restores to the southeast of the one below it. The distance between blocks A and B in the duplex is not certain because of a lack of stratigraphic constraints.

Prior to this study, Witherspoon (1982) showed the "Denton structure" as a single structural unit that extended approximately 4000 feet into the subsurface. Because the fault blocks of the Denton duplex are limited in lateral extent and do not contain Ocoee Supergroup rocks

at the surface, the writer believes a shallower geometry is more reasonable. In addition, the broad-gentle shape of the surface folds probably extends into the subsurface.

English Mountain is part of the Great Smoky thrust sheet which overrode the rocks of the Denton duplex and thus restores to the southeast. All of the Ocoee Supergroup rocks restore to the southeast of the English Mountain block. Reasons for this interpretation will be discussed in greater detail in Chapter 4.

Cross-section B: This section crosses the Denton duplex at its widest point. The duplex here consists of four horse blocks which vary in their stratigraphy from lower Cochran Formation to lower Rome Formation. As in the previous cross-section, the stacking of the horse blocks, combined with structures in the lower Valley and Ridge sheets, fold the overlying Great Smoky thrust sheet. The roof fault of the duplex in this section has a relief of near 4000 feet.

Surficial features, as in the previous section, reflect broad folds in the underlying Valley and Ridge rocks. At the rear of the duplex, an anticlinal fold in the floor fault is inferred because thrust blocks E and F have their trailing branch line in the Cochran Formation, and thus must be drawn shallowly. This space is inferred to be filled by imbrication in the underlying sheet. This

fold imbrication modified an already anticlinal fold over the duplex. Similarly, at the front of the duplex, a small exposure of the Knox Group is created by a fault in the underlying sheet.

The Great Smoky sheet is exposed in only two places in this section. One, to the southeast, is composed of the Wilhite Formation. The second exposure, to the northwest, is composed of the Sandsuck Formation. This exposure is the northeasternmost extent of the synclinal re-entrant (Plate 1) of the Great Smoky fault.

A small imbricate fault in block A is inferred to place Shady Dolomite over a small horse of Rome Formation (see Plate 1). Other exposures of Rome Formation occur in the lower part of the Denton duplex further to the east (Plate 1).

Restoration of this cross-section is similar to that of section A, however, only the rocks of the Denton duplex are shown. Each higher thrust block restores to the southeast of the block below. The lateral distance between blocks D and E is not certain. Again, this is due to a lack of stratigraphic constraints on exactly where the faults occur in the section.

Cross-section C: This section crosses the easternmost extent of the study area. However, the Denton duplex continues for about 15 km to the northeast (Figure 2, p. 5). Along this line, the duplex consists of three

relatively small horse blocks. The Cochran Formation exposed in block G has been overturned beneath the Great Smoky fault. Farther to the northeast, however, block G is probably continuous with the syncline along Stone Mountain (Plate 1), as mapped by Ferguson and Jewell (1951).

A set of steep, northwesterly dipping normal faults, as described in section C of this chapter, displace faults F and G. A similar set of extensional faults is present in the Great Smoky sheet in the southeastern portion of the section in the Waterville Quadrangle, as mapped by Keller (1980). One fault is a thrust, and the other a listric normal fault. Both faults, however, are probably extensional in nature because of their steep dips and limited lateral extent.

As shown in the previous cross-sections, the horse blocks of the duplex combined with structures in the lower Valley and Ridge sheets folded the Great Smoky thrust sheet, which now has a relief of over 4000 feet. Fault block G is interpreted to have moved far enough for its trailing branch to be on top of block F. This represents a transition from a hindward-dipping duplex to an antiformal stack. The difference in the two types of duplexes is the amount of slip on each imbricate fault relative to the length of the horse block (Boyer and Elliot, 1982).

Restoration of this section is similar to that of the

previous sections; each higher thrust block in the deformed state restores to the southeast of the one below.

Cross-section D: This cross-section is located approximately 8 km to the northeast of the study area. It is drawn, based on data from Ferguson and Jewell (1951) and Keller (1980), as a comparison to their hypotheses for the structural evolution of the area. It uses the structural geometries established in this study as its starting point. The location of the section is given in Figure 2 (p. 5) and in Chapter 4.

Block 1 in this section represents the Denton duplex. It contains block G, an unnamed block, and a slice of Rome Formation (not shown in restored section). At this point, the duplex is a true antiformal stack in which each horse block is stacked on top of the other.

Block 2 is a thrust block that is nowhere preserved. Its presence is inferred to explain slices of Erwin and Rome Formations along the Great Smoky fault. Blocks 3 and 4 are both part of the Great Smoky thrust sheet that have been separated by the East Meyer normal fault as mapped by Hadley and Goldsmith (1951). This fault in part, coincides with the Great Smoky fault. Thus, blocks 3 and 4 were once continuous over block 2.

Restoration of the cross-section begins with blocks 3 and 4. Because they are separated by a normal fault, these blocks restore to the southeast as one unit. Next, block 2

restores to the southeast of the Denton duplex. The back (southeast) of block 2 was originally a thrust fault but later experienced normal movement when the East Meyer fault merged with the lower Great Smoky thrust surface. The two small circles shown in the restored section mark the point where the normal fault connects in the deformed state.

Restoration of the Denton duplex horse blocks is the same as in previous sections. Block G restores to the southeast of the unnamed block. The slice of Rome Formation is the northwesternmost part of the Denton duplex.

CHAPTER IV

Discussion

(A) Introduction

Thoughts on styles of deformation, progression of deformation, and mechanics of thrust belts have received much attention over the past several decades. Of particular interest to the present study is the sequence of progression of deformation (forward vs. hindward progression; Boyer and Elliot, 1982).

Many early workers believed that deformation progressed from the foreland to the hinterland or "hindward". Ferguson and Jewell (1951), Hamilton (1961) Bearce (1966), Rodgers (1970), Harris and Milici (1977) among others, believed that younger-higher faults cut across earlier-lower faults. However, Douglas (1950), Verrall (1968), Dahlstrom (1970), Jones (1971), Boyer and Elliott (1982), and Diegel (1985) documented examples where thrusting had a regional "forward sequence" or progressed towards the foreland. Jones (1971,p 304) showed that folded fault structures are "formed by the development of new thrusts and associated structures beneath them". He further stated the local "hindward" development can be explained by "forward" progression, assuming that the duration of movement of each fault can differ greatly.

Thus, a larger thrust could cut a smaller, younger thrust below, regardless of which was started first.

Based on graphic experiments, Boyer and Elliot (1982) explained fault progression in duplex formation. Their model called for "forward progression" of faults in which each thrust sheet is folded from below by movement on a lower, younger thrust fault. Similarly, Diegel (1985 p. 16) showed that structures (cleavage) in the Mountain City Window area of the Blue Ridge front (about 97 km to the northeast) are broadly folded by a lower-younger duplex. He stated that "cleavage formed during the thrusting of each slice and was then rigidly rotated toward the foreland by successive slices" (Figure 17A). He stated that both a polyphase and hinterland progression model (Figure 17B) may show a later upwards-facing cleavage (S2) for which there is no evidence. The writer will present evidence for a "foreland progression" as the simplest explanation for the structure observed in the study area. However, there is the possibility that local out-of-sequence faulting may also have occurred, without much transport to reorder earlier thrust blocks.

(B) Previous Interpretations

The interpretations given in this report are quite different from previous ones for immediately adjacent

Figure 17. Models for fabric development in single and polyphase deformation. (A). Rotation of cleavage in the Mountain City window after Diegel (1985). His model calls for a single phase of deformation. (B). A polyphase of deformation calls for a second fabric (S2) to be overprinted onto the earlier formed cleavage (S1) (Diegel, 1985).

A.



B.

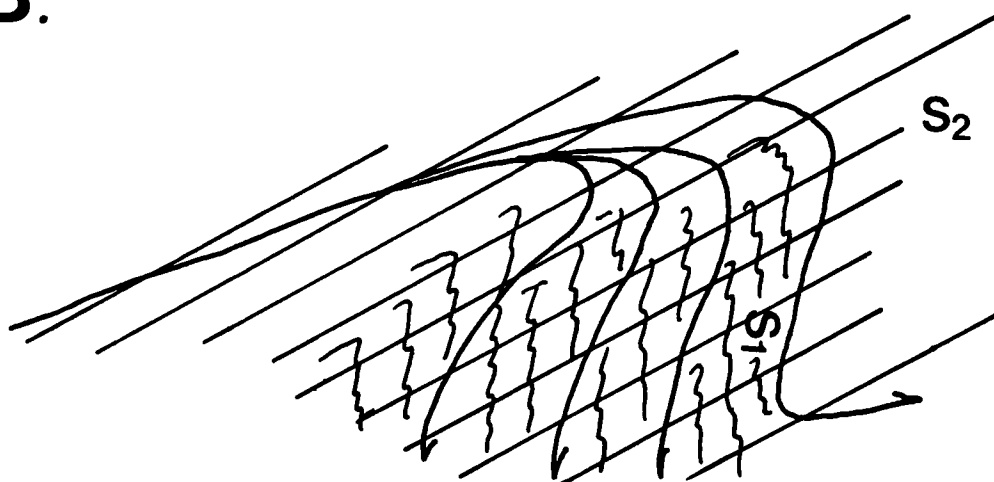


Figure 17

areas. It is therefore necessary to briefly discuss these previous hypotheses before presenting my interpretations. I feel that the reasons for differences between this report and previous reports are a result of: (1) the lack of detailed mapping in the present field area prior to this study; and in the case of older reports, (2) lack of published data on thrust mechanics.

In general, two grossly different interpretations of the structural history of the area have been given. They are: (1) that thrust progression was "hindward" ; and (2) that thrust progression was "forward" but that late-major faults cut through and replicated earlier thrust sheets. The first of these ideas, that thrust progression was "hindward", was suggested by Ferguson and Jewell (1951), Hamilton (1961), and Bearce (1966). Hamilton (1961) showed that the Great Smoky fault overrode the English Mountain fault, thus separating English Mountain and the Denton duplex, which he believed were once joined. His map pattern shows that the Great Smoky fault intersects the "English Mountain" fault at two points. (Figure 2; p. 5). Hamilton interpreted the contact of these two faults as the intersection of a late thrust cutting an earlier-formed one.

Ferguson and Jewell (1951) explained their map patterns by a hindward progression of faulting, followed by a later period of deformation that folded the faults. They

showed the Stone Mountain fault (Great Smoky fault of this report) merging with the Yellow Springs Mountain fault (Figure 18) near the French Broad River just 10 km to the east of the study area. They explained the younger-on-older relationships near the branch of these two faults by a normal fault called the East Meyer fault.

A second interpretation of the structural history of the area to the east was given by Keller (1980). His interpretations of fault relationships were complex. He re-interpreted the map patterns of Ferguson and Jewell (1951), renaming the Stone Mountain-East Meyer fault trace the Great Smoky fault (Figure 19). His reasons for this change were the younger-on-older stratigraphic relationships shown on the map (Figure 19), coupled with stratigraphic facies inconsistencies, which he felt were not easily explicable with any other model. As the writer understands it, Keller's interpretation is summarized as follows:

- (1) Three major thrust sheets existed; Hot Springs (lowest), Del Rio (intermediate; Great Smoky sheet of this report), and Buffalo Mountain (highest) (Figure 20).

- (2) The Del Rio thrust sheet was emplaced first by movement on the "pre-metamorphic" Dunn Creek-Yellow Springs Mountain fault (Figure 20).

Figure 18. Map patterns of the area immediately to the east of the study area according to Ferguson and Jewell (1951). MCM - Meadow Creek Mountain fault. NM - Neddy Mountain fault. YSM - Yellow Springs Mountain fault. SM - Stone Mountain fault. EM - East Meyer fault. BB - Bear Branch fault.

Lines with barbs represent thrust faults and the hatched line represents a normal fault. Cross-section D-D' is presented on Plate 3 of this report.

PCO - Precambrian Ocoee Supergroup undivided, Cc - Cochran Formation, Ce - Erwin Formation, Ch - Hampton Formation, Cs - Shady Dolomite, Cr - Rome Formation, Chk - Honaker Dolomite, C-Ok - Knox Group undivided.

Figure 19. Map patterns of the area immediately to the east of the study area according to Keller (1980). MCM - Meadow Creek Mountain fault. NM - Neddy Mountain fault. YSM - Yellow Springs Mountain fault. GSM - Great Smoky fault. DC - Dunn Creek fault.

Colors are used to differentiate thrust sheets. Blue represents the Del Rio sheet and red represents the Hot Springs sheet. Cross-section is given in Figure 20. Barbs represent thrust faults. Formation symbols are the same as those used in Figure 18.

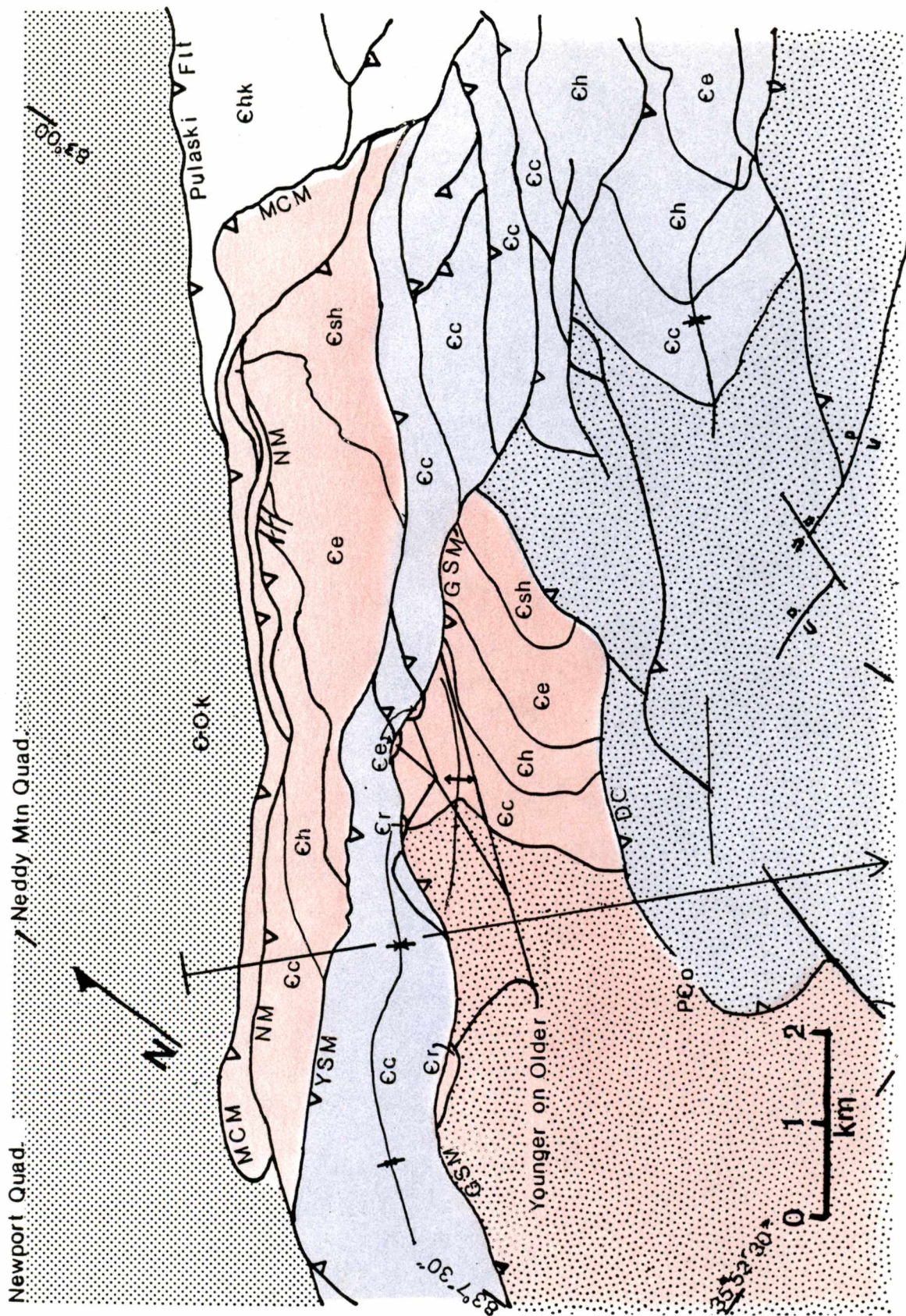


Figure 20. Cross-section showing the major structures and thrust sheets immediately to the east of the study area according to Keller (1980). See Figure 19 for location of the section.

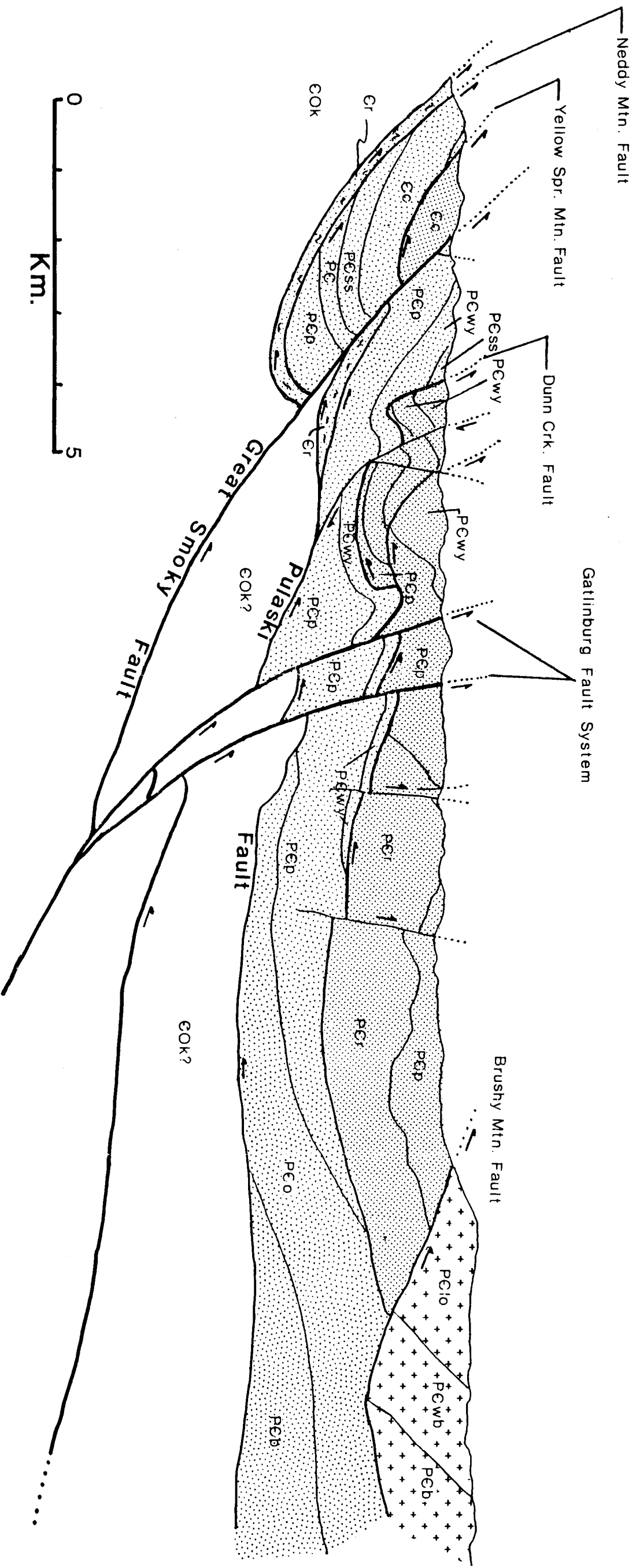


Figure 20

(3) The highest Buffalo Mountain sheet (not shown on map) and the lower- Hot Springs sheet were both emplaced later than the Del Rio sheet, but the Hot Springs sheet was youngest. Both the Buffalo Mountain and Del Rio sheet rode "piggyback on the Hot Springs sheet".

(4) After Hot Springs sheet emplacement, "continued thrusting and uplift from an even deeper level produced the Great Smoky fault [Stone Mountain and East Meyer faults of Hadley and Goldsmith, 1951], which folded and also cut through the older, structurally higher nappes." (Figures 19 and 20).

(5) After the Great Smoky thrust, emplacement of the Gatlinburg thrusts occurred, also truncating earlier thrusts.

(C) Present Interpretations

By combining this mapping project with data from surrounding areas, I suggest that: (1) the map geometries of the area can be explained by a forward progressive-hindward dipping duplex similar to that described by Boyer and Elliot (1982); (2) further folding, but not faulting of this structure, has taken place from younger-lower thrusts in the Valley and Ridge; (3) younger-on-older fault relationships require late, extensional faults rather than an out of sequence major thrust fault; and (4) that English

Mountain is part of the Great Smoky sheet and restores to the southeast of the Denton duplex.

(1) Mapping of the study area and construction of balanced cross-sections show that the Denton duplex is geometrically and mechanically similar to the hindward-dipping duplex model of Boyer and Elliot (1980). Construction of fault contour maps (Figure 21) show that the Great Smoky fault (the roof fault of the duplex) is a single continuous fault that was folded with a relief near 1500 meters. As expected in a duplex, cross-sections (Plates 2 and 3) show that each imbricate fault, from northwest to southeast respectively, places older rocks on younger ones.

This geometric relationship cannot be explained by models proposed by Ferguson and Jewell (1951), Hamilton (1961), or Keller (1980). Ferguson and Jewell and Hamilton used a hindward progression of faulting (southeast to northwest) in their models. Their models required that the Great Smoky fault travel over a curved surface with over 5000 feet of relief and cut across earlier formed thrusts. As shown by Boyer and Elliot (1982, p. 1209), the resulting geometry would show that the top of the Denton duplex had been cut off by the Great Smoky fault and that the Great Smoky fault should cut down-section through each imbricate. Thus, the cut-off part of the Denton duplex would be somewhere in the hanging-wall of the Great Smoky fault that

Figure 21. Structure contour map of the Great Smoky fault in the vicinity of the Denton duplex and English Mountain. Circles mark the intersection of the two imbricates of the Great Smoky fault.

Contour interval is 1000 feet. Dashed line represents 500-foot interval. Thin-light lines are other faults used for reference.

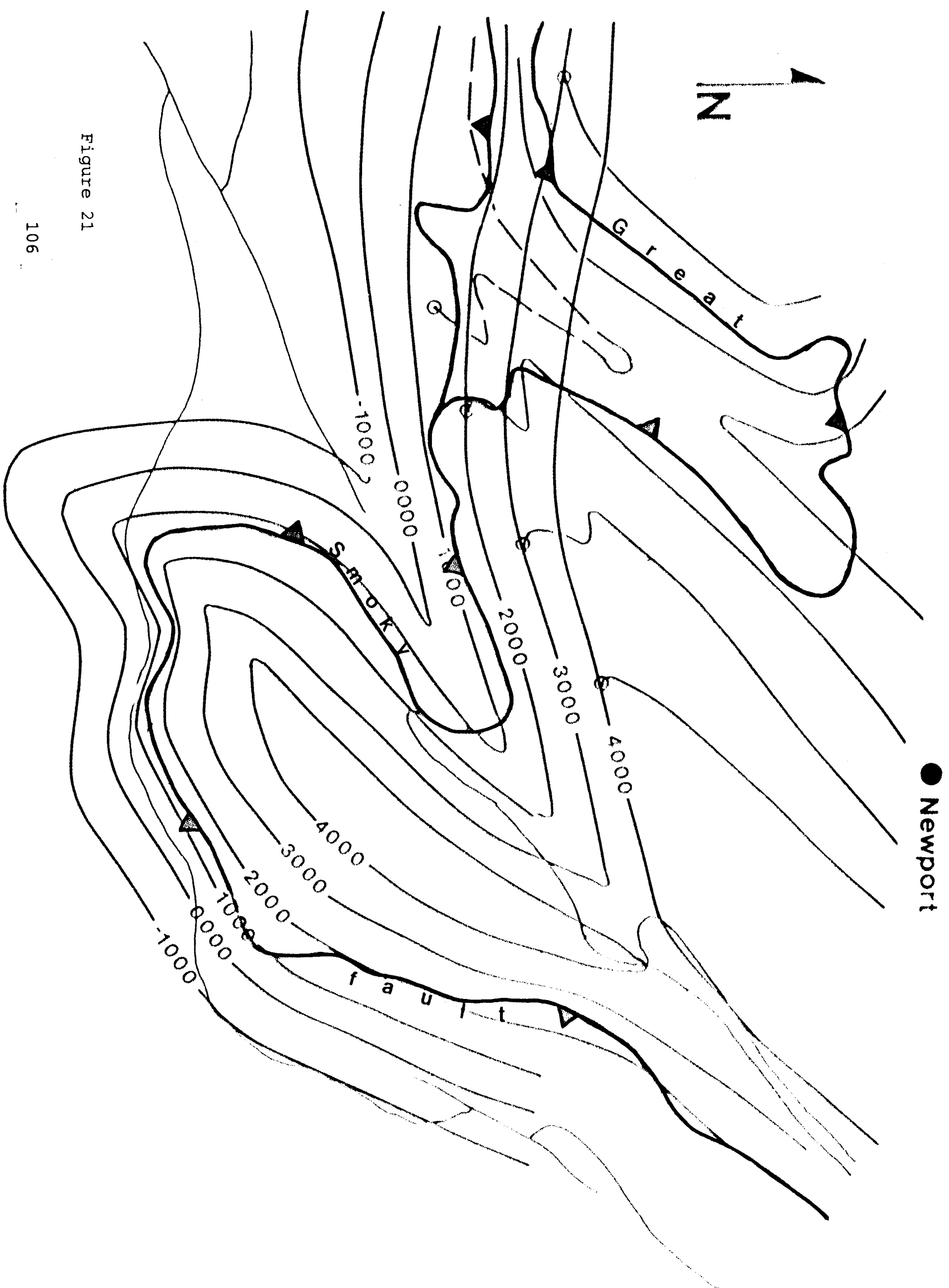


Figure 21

is now eroded. Not only do these geometries not exist, but it is unlikely, from an energy standpoint, for a thrust to travel over such a surface. Development of a new fault would take significantly less energy (Mitra and Boyer, 1986).

Keller's model (1980), which called on the Great Smoky fault to be a late cross-cutting fault, is also proven unlikely by the fault contour map (Figure 21) and map patterns (Figure 2, p. 5). Because the Great Smoky fault of Keller (1980) has been shown to be continuous with the folded Great Smoky fault of this report, it could not have been a late structure.

In addition, Keller (1980) based his structural interpretations on the assumption that "fundamental changes in stratigraphic succession allow the differentiation of thrust sheets." He used thickness and lithologic character of the Chilhowee Group and Walden Creek Group rocks to correlate one thrust sheet to another. This method relies on the assumption that stratigraphic units uniformly thicken and become more shaley from northwest to southeast. Restoration of the English Mountain block (see p. 110) in this report brings up inconsistencies in this argument because the stratigraphic section on English Mountain is about 1250 meters thick, whereas that of the Denton duplex is about 1850 meters thick. This indicates that the

Chilhowee has thinned and is not significantly more shaley to the southeast. This relationship is well shown in the restored part of cross-section A (Plate 2).

(2) Although the Great Smoky thrust sheet is folded over the Denton duplex locally, examination of a larger area shows that both the sheet and the Denton duplex are folded by Valley and Ridge structures underlying them. As shown in Plate 2, the syncline in the Great Smoky sheet immediately to the northwest of the Denton duplex extends beyond the leading branch line of the duplex itself. This geometry is not possible if folding were a result of faulting in the Denton duplex alone.

Other folds created by Valley and Ridge structures are the Newport Anticline (Witherspoon, 1982), the English Mountain Syncline, and the Fair Garden Anticline (Plate 2). At the rear of the Denton duplex, a broad fold in the underlying sheet is probably caused by a Valley and Ridge thrust block.

(3) Younger-on-older stratigraphic relationships (Figure 2, p. 6), which partly led to Keller's (1980) interpretation of the Great Smoky fault, can be explained by late cross-cutting normal faults. Keller (1980) interpreted the East Meyer fault (Figure 18, p. 97) of Ferguson and Jewell (1951) to be a thrust fault that was continuous with his Great Smoky fault (Stone Mountain fault of Ferguson and Jewell). He stated that the "apparent

throw along strike of their [Ferguson and Jewell] Stone Mountain fault is too variable by the geometry they suggest". His reasons for this statement are that along the southwestern portion of the Stone Mountain fault, the lower Precambrian section (Ocoee Supergroup rocks) is thrust over basal Cambrian (Cochran Formation), indicating a throw of less than 700 meters.

I suggest that the map patterns of Ferguson and Jewell (1951) are correct and that the East Meyer fault is part of a system of late extensional faults that happens to merge with the Great Smoky thrust fault. Thus, a portion of the Great Smoky fault, west of the East Meyer fault, has experienced two separate, opposing senses of movement (cross-section D, Plate 2). This explains not only the younger-on-older relationships along the East Meyer fault, but also the presence of small slivers of Rome and Erwin Formations along the trace of the Great Smoky fault.

Similar extensional faults exist throughout the area. Near the northeastern boundary of the study area (Figure 6 and Plate 1) normal faults offset the trace of fault G and probably extend further to the northeast. Hamilton (1961) and Keller (1980) mapped numerous high-angle normal faults, some of which offset thrust faults and place younger rocks on older ones.

The orientations of most of these extensional faults

are parallel to the folding trend of the Great Smoky thrust sheet over the Denton duplex. I suggest that the folding of these sheets from below created the extensional regimes in which these normal faults formed. Similarly, Woodward (1986) argued that the extensional faults and the Gatlinburg fault family (also extensional) are aligned parallel to the folding trends and windows of the Great Smoky thrust sheet.

(4) The English Mountain syncline is a part of the Great Smoky thrust sheet and thus restores to the southeast of the Denton duplex. This interpretation is substantiated not only by the map patterns, but also by a simple diagram showing the two possible restoration schemes.

Map patterns and cross-sections (Figure 2, p. 5; Plate 2) show that English Mountain is a hanging-wall imbricate of the Great Smoky fault. Because the Great Smoky fault was the youngest thrust fault in the duplex, then it, along with English Mountain, must be pulled back first during restoration.

A simple schematic diagram of the two possible ways to restore English Mountain with respect to the Denton duplex is presented in Figure 22. The first section (A) shows English Mountain (which has a flat geometry, where fault/bedding angle is less than 5°) being restored to the northwest, or in front of, the Denton duplex which has a ramp geometry, where the fault/bedding angle is greater

Figure 22. Schematic diagram of two possible restoration relationships between the Denton duplex and English Mountain. (A) Restoration of English Mountain to the northwest of the Denton duplex requires that the Great Smoky fault cut down-section from the Rome Formation to the base of the Chilhowee Group. This results in a ramp behind a flat. (B) The English Mountain structure restores to the southeast of the Denton duplex. The fault at the base of English Mountain connects with the fault at the base of the Denton duplex. This results in a flat behind a ramp; the expected geometry.

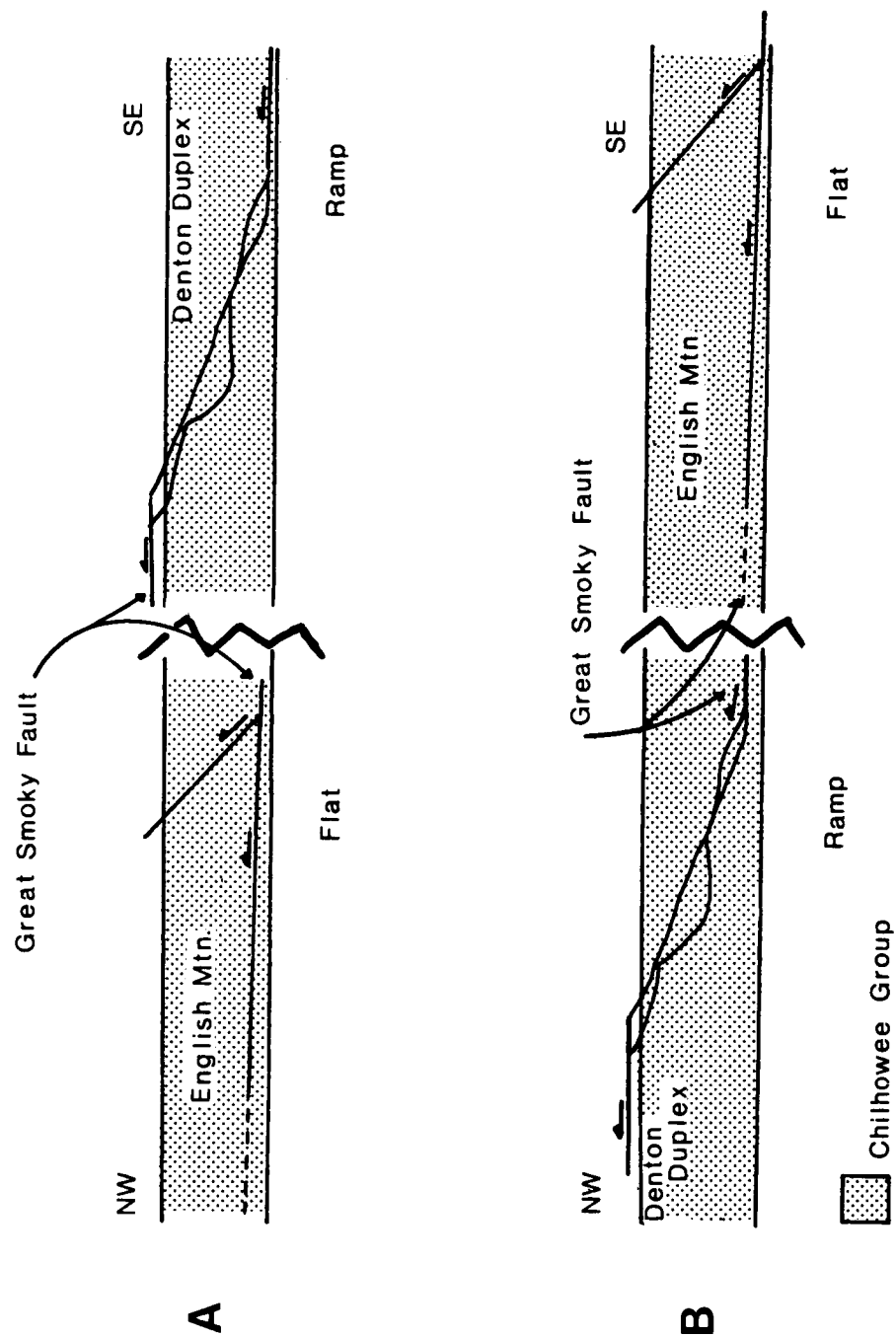


Figure 22

than 15° . In this arrangement, the major thrust would have had to cut up-section through the Chilhowee Group and have picked up the Denton duplex horses, then cut back down-section through the Chilhowee Group to pick up the English Mountain block. This would result in a flat (English Mountain) in front of a ramp (Denton duplex).

A simpler interpretation is presented in Figure 22B and on cross-section A, Plate 2. In this arrangement, the English Mountain block was faulted off of a flat in the Great Smoky fault. With further movement, the block was carried over a ramp in the Chilhowee Group while intermittently picking up footwall horse-blocks, which were later stacked in their present position to form the Denton duplex. Thus, a flat on the hinterland side of, or behind, a ramp appears to be a more likely arrangement.

Based on data from Ferguson and Jewell (1951) and Keller (1980), Section D, Plate 2 presents the inferred structural relationships east of the study area. Map patterns were taken from Ferguson and Jewell (1951) and Keller (1980) as shown in Figures 18 and 19 (pp. 97, 99) of this report. To fully show the relationships inferred, the map geometries have been projected above the erosional surface. The location of this cross-section shown in Figure 19 (p. 99).

As explained in Chapter 3, the last event to occur was the normal faulting, which locally places younger rocks on

older ones. This fault (East Meyer fault of Ferguson and Jewell, 1951) intersects and partially coincides with the Great Smoky fault. Thus, along part of the Great Smoky fault, both reverse and normal movement has occurred. Because the normal fault was post-thrusting and cut thrust sheets, it is separated into two parts in the restored section. As seen in Plate 3, blocks 2, 3, and 4 are nowhere exposed, but are interpreted to be part of the hanging wall of the Great Smoky thrust sheet. They restore in order, with block 1 farthest to the southeast. The East Meyer fault, as mentioned, is only one of many recognized normal faults in the general area by Ferguson and Jewell (1951), Keller (1980), and Woodward (1986).

Block 4 is the northeasternmost extent of the Denton duplex and contains block G of the present study as seen in cross-section C. It is in the footwall of the Great Smoky fault, as is the rest of the Denton duplex.

(D) Conclusions

- The Denton duplex is a hindward dipping duplex that was created by footwall imbrication of the Great Smoky fault.
- With continued deformation, movement on younger faults in the lower Valley and Ridge rocks broadly folded the structures in the Great Smoky thrust

sheet and Denton duplex.

- Late-normal faults, possibly a result of the Valley and Ridge folding, cross-cut pre-existing fabrics and locally place younger rocks over older ones.
- The Great Smoky fault is not a late major thrust fault that cross-cuts previously formed thrust sheets.
- The most reasonable interpretation shows the English Mountain block restoring to the southeast of the Denton duplex. The English Mountain has a "flat" geometry whereas the Denton duplex was created by stacking of horses, which were plucked from the footwall of the Great Smoky fault as it ramped through the Chilhowee Group.

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APPENDICES

APPENDIX 1

DETAILED STRATIGRAPHIC DESCRIPTIONS

OCOEE SUPERGROUP

Great Smoky Group

Roaring Fork Sandstone

Pigeon Siltstone

No detailed descriptions of the Roaring Fork Sandstone and Pigeon Siltstone are given herein. The reader is referred to Hadley and Goldsmith (1963) and Keller (1980).

Walden Creek Group

Wilhite Formation

Rocks assigned to the Wilhite Formation occur only in the south and southwestern portions of the field area. Stratigraphic contacts in this area were established by or extrapolated from previous authors. No obvious stratigraphic contacts were observed so those extrapolated may be subject to some re-interpretation.

Wilhite between the Great Smoky fault and Dunn Creek fault, south of Green Mountain: Wilhite at this locality (Plate 1) forms a narrow valley roughly 1000 feet across at its widest point. It consists of a wide variety of clastic, and mixed clastic and carbonate rocks. Limited exposure and proximity to two thrust faults adds to the difficulty in understanding the relationships of these different rock types. Clastic rock types consist of shale and slate, to coarse-grained quartz sandstone. The most abundant rock type in this group is laminated shale to slate depending upon the degree of cleavage formation. Commonly, these shale-slate rocks are light brown to greenish or grey. Laminations are commonly less than one millimeter thick and vary in color from light tan to dark green or black. A few sandstone beds were found intercalated with the shale-slate. These sandstones range from fine- to coarse-grained quartzose sandstone and occur as thin beds among the shale-slate. At one locality, sandstone beds up to 0.6 meters thick were found. Mixed clastic-carbonate rock types were only observed at a few localities but the author thinks that they are probably more widespread. The most common type of rock found consists of a mixture of thinly bedded grey, micritic, limestone interbedded or laminated with dark shaley,

carbonaceous(?) material (similar to Keller's banded micrite shale). Rounded quartz sand was found in the limestone at a few localities and at one location, limestone clasts up to 2.5 centimeters in length were found. The matrix between these clasts is composed of limestone with abundant rounded quartz sand grains (Figures 11 A and B p. 57).

Wilhite west of Green Mountain: The rocks in this group have been divided into clastic rocks and limestone, because little intermixing of the two was observed. Clastic rock types consist mostly of dark grey and grey shale-slate with thin, light-colored laminations. Laminations are silty, commonly discontinuous, and can be seen to scour the shaley beds at their base. At one location, thinly bedded black and dark grey pyritic metasiltstone and mudstone was found. Also present at a few locations are fine-grained sandstone beds intercalated with the shale-slate beds described before. The sands tend to be lighter in color than the finer grained rocks.

Limestone rock types were observed only at three localities. All occurrences were near the Great Smoky fault. In the creek bed near Larges Church, dark grey to black pyritic, microcrystalline limestone with thin, light grey laminations was found. The nature of the black color in this rock is uncertain. It appears to be shaley or carbonaceous. About 2000 feet north of Proffitt Springs on the western side of Green Mountain, boulder-sized erosional remnants(?) of matrix-supported limestone boulder-cobble conglomerate was found. Immediately in front of this locality, several of these boulders can be seen as ornaments in the yard of Camper's Paradise. Some of these large blocks are weathered out of recent brownish soils. The matrix in these blocks is composed of micritic limestone with abundant rounded quartz sand and pebble-sized grains. The limestone clasts are composed of micritic limestone with or without quartz sand. Grey micrite limestone was found in place at the base of these boulders. Hamilton (1961, p. 23) described rocks similar to these less than 0.5 miles to the east, north of Holder Grove Church near Chavis Creek. He describes limestone boulder conglomerate with clasts up to five feet in length.

Sandsuck Formation

The Sandsuck in the study area occurs in a large re-entrant of the hanging wall of Great Smoky fault. The rocks in this area have tentatively been assigned to the

upper and middle members of the Formation by merely following the divisions of Hamilton (1961).

Middle member: This unit is well exposed along Middle Creek road in the westernmost part of the re-entrant. Erosion by the creek, enhanced by road construction, has exposed a section of coarse sandstone to gravel conglomerate interbedded with shale and slate. The dominant lithology is orangish-tan coarse-grained sandstone with scattered gravel and pebbles of quartz. Sorting is generally medium to poor and rounding is moderate to good. Shale chips and feldspar are present in the coarser units. Commonly intercalated with these sandstone beds are darker black to grey shale or slate, fine-grained micaceous sandstone, and siltstone. Typically these darker materials form laminations within the lighter-colored coarser material. Cross-beds are common in the sandstones and lenticular beds are found in a few conglomerate. Also found in this member are a few thin beds of limestone and calcite-cemented siltstone. These limestone units are thinly bedded to thickly laminated and are intricately mixed with the dark shaley rock types.

Upper Member: The remainder of the Formation is tentatively placed in this member. It is doubtful that these rocks represent a complete or continuous sequence because of many faults and folds. The dominate rock type observed is an intricate mixture of sandstone, shale-slate, siltstone, and feldspathic (and in some cases conglomeratic) sandstone. The sandstone and siltstone beds are commonly brownish-tan, whereas the shale and slate beds are olive green, grey, or black. Where the sandstone dominates, there are often thin beds or laminations of the darker shale or slate. Where the dark shale or slate is sandy, laminations are commonly present. Also present are thinly bedded limestone, calcite-cemented quartz sandstones, dense quartzite, and metasiltstone. Near the eastern-most extent of this re-entrant near Wood's Island (Plate 1) in the Pigeon River, a large outcrop of grey limestone similar to that found in the Wilhite Formation was observed. This limestone is grey with black and light-grey to white laminations. The darker laminations (reaching 0.5cm) are thicker than the lighter ones. The color of these rocks appears to be related to the shale content. It is possible that these rocks do indeed belong to the Wilhite Formation.

The Chilhowee Group

Cochran Formation

The Cochran Formation in the study area crops out in four separate thrust blocks and in one small horse block. Nowhere in the area was the base of the Formation found, and the top of the Formation is inferred to be present in only one place. Thus, any correlation of the Cochran within the area and with other areas is difficult.

The most distinct and abundant rock type of the Cochran in the study area is white, coarse-grained, conglomeratic, feldspathic sandstone with white feldspar and abundant hematite stains. This rock type was observed to some extent in all thrust blocks.

Thrust Block (C): Stratigraphically, this is probably the lowest occurrence of Cochran. It is well-exposed along the Foothills Parkway. It consists primarily of white to bluish-red, coarse-grained, arkosic, conglomeratic sandstone and orthoquartzite. Most of the feldspar in this section has the characteristic white color and is commonly coarse sand- to fine pebble-sized. The orthoquartzite commonly contains scattered shale chips up to five centimeters in length. Cross-bedding in these units is widespread; individual foresets measure 30 centimeters or more in thickness. Also exposed along the Parkway just below this unit is a poorly exposed, yellow-green, micaceous unit of shaley siltstone and coarse-grained sandstone grading into pebbly conglomerate. The siltstone beds are thickly laminated with uneven layers of fine sandstone. The unit was found at only a few locations along the road but in one case, near the last large bend in the west end of the parkway, these siltstone and sandstone beds coarsen upward. Finally, they contain lenses of coarse conglomeratic feldspathic sandstone and grade into the white conglomeratic feldspathic sandstone described before.

Thrust Block (E): This thrust block contains much of the same rocks of thrust block (C), although it probably includes rocks stratigraphically both below and above. As in the previous thrust block, the most conspicuous rock type is white, coarse-grained feldspathic, conglomeratic sandstone and quartzite. This block, however, contains a thick section of dense, white quartzite not seen in the former section.

The lowest part of this section is well exposed along the Pigeon River near Bluffton. Here, the Formation consists of white-grey to bluish, feldspathic, conglomeratic coarse-grained quartz sandstone, coarse-grained feldspathic orthoquartzite, and lesser amounts of

fine- to medium-grained feldspathic quartz sandstone. In general, sorting is poor, cross-bedding is common, and much of the feldspar is white. Farther up section poorly sorted orthoquartzite becomes more abundant, although arkosic sandstone still dominates. Several thin beds of maroon, micaceous, shale, siltstone, and cross-bedded coarse-grained sandstone and black shale occur between the coarse whitish-yellow sandstone. At one interval, scattered pebbles (up to 3cm) of milky-white, rounded quartz occur in the coarse sandstone lithologies. These pebbles are commonly matrix-supported, and their occurrence appears to be laterally inconsistent. The uppermost part of the section observed in this block consists of well-indurated sandstone and orthoquartzite, most of which are poorly sorted and more or less feldspathic. It may be laterally equivalent to the Moccasin Gap member.

Thrust Block (F): This thrust block is the largest individual block containing the Cochran Formation. It contains rocks similar to and possibly above those of block (E), and is interpreted to be only slightly separated from it. The rocks in this block, however, appear to be very structurally complex, making stratigraphic relationships difficult to interpret.

The bulk of the Formation in this block consists of a highly varied mixture of shale or slate, orthoquartzite, and coarse sandstone. Stratigraphically, the lowest part occurs in the center of the large, breached anticline south of Devil's Backbone (Plate 1). Here, it consists of greenish-grey micaceous, laminated shale and slate interbedded with lighter-colored siltstone and poorly sorted, coarse-grained sandstone and orthoquartzite. Near Interstate 40, coarse sandstone and conglomerate more typical of the Formation are exposed. Medium- to very coarse-graded, pebbly, white to tan, poorly sorted conglomeratic quartz sandstone is the most conspicuous rock type. Most of the feldspar is white and the quartz pebbles (reaching 2 cm) are largely milky-white vein quartz. Large- and small-scale cross-beds are common in the coarse sandstone sequences, as are ripple cross-laminations in the silty beds. A minor amount of maroon, micaceous, cross-laminated, very fine-grained silty sandstone was observed.

Stratigraphically, the typical white, feldspathic, coarse-grained sandstone becomes absent, and interbedded shale, tan and maroon micaceous coarse sandstone, and orthoquartzite are present near the top of the Formation. The uppermost part of the section consists of silvery-grey, thinly laminated shale to slate with minor interbedded coarse sandstone. Many of the shale units are fissile, and have thin, discontinuous, white silty laminations.

The upper part of the Formation is well exposed on a road that parallels Mill Creek and winds up to the top of

Rich Top Mountain. The upper contact is placed at the boundary between the silvery shale and sandstone of the Cochran and the lower, green silty shale strata of the Hampton formation.

Thrust Block (G): This thrust block consists entirely of Cochran Formation. Rodgers (1953) first mapped his area as a slice of Unicoi that was continuous with the Stone Mountain thrust block of Ferguson and Jewell (1951). Although coverage of this area was limited, the rocks observed in this block appear to be equivalent to the middle and upper Unicoi of Ferguson and Jewell (1953) in their Stone Mountain block. The lowest part of the Formation observed consists of maroon and tan cross-bedded, interbedded feldspathic conglomerate, sandstone, and shale. Sorting is very poor in the conglomerate and sandstone, and vein quartz pebbles up to 2 cm in length are common. The uppermost part of the section exposed here is probably equivalent to the Moccasin Gap member of Ferguson and Jewell (1951). It consists of pinkish-white to light grey, moderately sorted, fine- to coarse-grained orthoquartzite. Thickness is greater than 50 to 60 feet.

In the northeastern part of this block, the Cochran is exposed in a large gentle syncline that extends several miles to the northeast (Ferguson and Jewell, 1951). In the present study area, only the northwestern limb of the fold is completely preserved due to a normal fault that separates it from the southeastern limb. In agreement with Ferguson and Jewell (1951), these rocks consist of abundant pink, to maroon and yellow coarse-grained sandstone. The Moccasin Gap member is present near the center of this section. Below this member, the Formation is only partially exposed due to its lack of resistance to weathering. Mostly coarse-grained, poorly sorted quartz sandstone and conglomerate beds with minor orthoquartzite are exposed intermittently up the northwest side of Stone Mountain. The Moccasin Gap member is well-exposed in the steep valleys, and consists of over 15 meters of dense, moderately- to poorly-sorted, medium-bedded orthoquartzite. Above this, poorly-sorted, feldspathic maroon quartz sandstone and conglomerate dominate, although yellow sandstone and conglomerate are present.

Hampton Formation

The Hampton Formation in the study area is present in three thrust blocks, none of which contain a complete section. Following Keller (1980) and Ferguson and Jewell (1951), the Formation is divided into three members. There

is some question, however, about the upper member because it is not found to be in contact with the middle orthoquartzite member. The base of the Formation is interpreted to be present in two thrust blocks but was only observed in block (F).

The most characteristic rock types of the Hampton in the study area are green and tan micaceous shale and siltstone for the upper and middle members, and medium-bedded, moderately-sorted white orthoquartzite and interbedded grey to brown shale for the middle quartzite member.

Thrust Block (B): A narrow section of the upper member is present in Laurel Hollow between Interstate 40 and the Foothills Parkway. It can be observed to be in stratigraphic contact with the overlying Erwin orthoquartzite strata. The Formation consists of dark green to grey-black shale or slate and light brown silty sandstone and sandy siltstone. Many of the sandstone beds have dark shale chips, and exhibit graded bedding. Green sand- and silt-sized orthoquartzite sequences occur in a few places.

Along the Foothills Parkway, a few beds of maroon orthoquartzite and poorly-sorted sandstone are exposed with interbedded grey-silver shale. The orthoquartzite is fine- to medium-grained and well sorted, whereas the sandstone is moderately- to poorly-sorted and micaceous. The shale is grey with thin, white laminations, and some small black shale chips.

Thrust Block (E): Only the lower and middle quartzite members are exposed in this block. The lower member consists of green and brown shale with thin light-brown siltstone laminations. Exposure of this member was limited and much was mapped by shale chip which commonly occur in the soil.

The upper quartzite member caps a thin ridge in this block. It consists of clear, white to grey, medium-grained, moderately-sorted quartzite. Scolithus is common and bedding is 0.1 to 0.6 meters thick.

Thrust Block (F): The lower and middle quartzite members are exposed in this block along an anticline that forms Hall Top Mountain. The lower member consists of green and grey shale or slate, commonly with thin, light-colored silty laminations. This unit is exposed on the county road that runs to the top of Hall Mountain. The middle quartzite member is a thick sequence of white, cross-bedded, medium-grained mature orthoquartzite. Commonly, bedding is 0.3 to 1.0 meters thick and has Scolithus at 90 degrees to bedding. Sandstone and micaceous shale occur intermittently in the member, as does quartz pebble conglomerate. A significant amount of shale was found along Hall Top Road near the crest of the

mountain and thus, may be the lower-most upper member. Exposure, however, was not adequate to determine this. Excellent exposures of the middle quartzite member occur all along Hall Top Road from just below Low Gap to near the crest of Hall Mountain.

Erwin Formation

The Erwin Formation in the study area crops out in thrust blocks (B) and (D). A nearly complete section is well exposed along Interstate 40 in thrust block (B). This section is approximately 866 meters thick and is apparently missing only part of the Helenmode member. Along the Interstate on both sides of the Pigeon River, the four-fold subdivision used by others can be recognized; however, it was not possible to differentiate the Formation elsewhere.

The most characteristic rock type in the Erwin is medium- to thickly-bedded, white or grey orthoquartzite. Beds in the middle member are thinner, and contain thin intercalated shale sequences. Brown and green, poorly-sorted sandstone, siltstone, and metasiltstone are also quite common. The Erwin is mostly feldspar-free; however, a few beds of orthoquartzite and sandstone with very fine-grained pink feldspar were found.

All rocks exposed in the field area that were assigned to the Erwin were done so based upon the section exposed along Interstate-40. For this reason, a brief description of this section will be given as representative of the whole Formation in the study area.

The lower quartzite unit consists largely of white to grey and brown, fine-to medium-grained mature orthoquartzite. Bedding partings are 0.3 to 1.5 meters thick (or less where thin, interbedded silts and shales occur). Scolithus are present throughout the member, although in places, they are difficult to see due to the recrystallization of the orthoquartzite.

The middle unit consists of thinly-bedded sandstone, orthoquartzite, siltstone, and shale. The lower part consists of bluish orthoquartzite with abundant Scolithus, capped by brown, micaceous, laminated, moderately sorted sandstone. Beds rarely exceed 0.3 meters in thickness and only a few contain minor pink feldspar. The upper part of this unit is thinly-bedded grey and brownish sandstone and siltstone. Mica and heavy minerals were abundant, but no feldspar is present. A few beds of brown orthoquartzite are present. Cross-bedding is rare as, are Scolithus.

The upper unit consists of medium-bedded, dense grey, green, and white orthoquartzite with minor interbedded

sandstone, siltstone, and shale. Orthoquartzite commonly forms beds less than 0.6 meters thick, and varies in color depending on type of quartz or matrix material. Smoky quartz appears to be responsible for the dark-grey orthoquartzite lithology, whereas a chlorite matrix is responsible for the green lithology. Blue and maroon shades are also present, presumably from iron in various states of oxidation. In places, small rust spots (presumably from oxidized glauconite) give the orthoquartzite a "speckled" appearance.

In the uppermost part of the Erwin exposed here is a thin section of interbedded fine-grained quartz conglomerate and dirty, poorly-sorted glauconitic sandstone and siltstone. Most of the sandstone and siltstone are brownish-green, whereas the orthoquartzite is white or grey with maroon stains. It is possible that these beds mark the bottom of the Helenmode member. No Scolithus was observed in Helenmode member.

Shady Dolomite

The Shady Dolomite in the study area only crops out in thrust block (A). The Shady was not found to be in stratigraphic contact with either the Erwin Formation below or the Rome Formation above. Due to poor exposure, stratigraphic and lithologic interpretations are limited. It is probable that the section along Greasy Cove Road is doubled. On the geologic map (Plate 1), two folds are shown to repeat the section, but it can also be explained by a fault.

The most commonly observed rock type is white, massive saccharoidal dolostone. Probably due to the recrystallization from limestone to dolomite, bedding features are very difficult, if not impossible to see in this rock type. In a few samples, bedding-parallel(?) stylolites were found. It is more common for these rocks to be heavily fractured. This rock type is well exposed along Interstate 40 about a half of a mile north of the Foothills Parkway exit, on the east side of the road.

Also assigned to the Shady are beds of blue-grey dolostone, yellowish silty shale and minor sandstone, grey algal laminated limestone-dolostone, and dark-grey chert. At the base of Raines Knob near the Pigeon River is a relatively good exposure of dark blue-grey dolostone with a few beds of chert. Bedding here is commonly 0.3 to 1.0 meters thick with chert and pink dolomite filled vugs.

Very thin silty shale and sandstone beds were found along Greasy Cove Road east of Cosby School. Chert nodules

and lenses(?) of white saccharoidal dolomite were found within these clastic rocks. Most of the rock type observed is saprolite, with the dolostone and chert weathering out. At two locations along Greasy Grove road (Plate 1), grey algal laminated dolostone with minor limestone was found. The surface of the rock has been weathered, revealing the "wispy" very thin laminations. Very sparse, medium sand-sized, rounded quartz grains are present, as is pyrite.

By comparing this section with these of King et al. (1944) at the Stony Creek District, it appears that it represents the upper white member and part of the upper blue member. Shaly dolomite, chert beds, blue dolomite, and white dolomite all occur in the upper 152 meters of their section (Figure 3, King et al., 1944).

Rome Formation

The Rome Formation in the study area is present north of the valley created by Shady Dolomite. It consists of thinly bedded maroon micaceous silty shale and siltstone with some tan and green shaley beds. Much of the Formation here is structurally deformed, thus it could not be described. Normally, the Rome lies on top of the Shady Dolomite, but here it is interpreted as being separated by a minor thrust fault.

The Knox Group

The dominant rock type in the area is grey, micritic, thinly laminated (< 1mm) in 0.3 to 1 meter beds. Scattered sand-sized quartz grains are common, and in a few places, beds with up to about 40 percent quartz sand were found. Where quartz is abundant, cross-beds, limestone intraclasts, and scour surfaces are common. Dolomite is also sporadically present as laminations, thin beds or as spotty areas in mottled limestone.

It must be noted that some of the Knox limestone strata are quite similar to some of the Wilhite limestone. Carbonate conglomerate with abundant quartz sand similar to that described in the Wilhite, also occurs in the Knox. The difficulty in distinguishing these two rock types, however, should be resolved if their relationship to the surrounding rocks can be deciphered. The Wilhite carbonate sequences are not laterally persistent and are commonly in association with fine-grained clastic rocks. Knox

carbonate sequences, however, rarely have associated clastic rocks, except for the overlying Sevier Shale.

Sevier Shale

The Sevier Shale in the study area was shown by Rodgers (1953) to occur in a series of fault slivers that branch from the footwall of the Great Smoky fault. His interpretation has not been changed herein as they seem reasonable from what the author has observed.

The only rock type observed was light-to dark-brown, faintly-bedded mudstone or slate. A thin-section of this formation shows a clayey siltstone with anastomosing micron-spaced cleavage selvages. Near the Great Smoky fault, cleavage commonly obscures bedding (Figure 10b p. 55).

APPENDIX II

ROAD LOG AND DESCRIPTION OF STOPS



Geologic map of the field area showing field trip stops.

Map on preceding page shows field trip stops (red) as discussed in this appendix.

MILEAGE		DESCRIPTION
Cumulative	Interval	
0.0	0.0	Depart from Geology building on "The Hill". Turn right on Cumberland/W. Main. Keep straight onto I-40E entrance ramp. Take I-40E to Ashville.
35.2	35.2	I-40E separates from I-81N. Stay on I-40E toward Ashville.
43.0	7.8	English Mountain's large knobby hills are visible to the west and south (Chilhowee group rocks).
52.5	9.5	Panoramic view of Denton duplex. Bumpy knobs to left are Cochran, Hall Top Mountain ahead.
54.6	2.1	Exit 440 to 321-S.
00.0	0.0	Turn right on 321-S (stop sign). Reset mileage to zero for those not traveling from Knoxville
	.2	
.1	.1	Turn right 321-S (Wilton Springs Road.)
.6	.5	Exposures of Knox Group carbonates to the right.
2.0	1.4	Exposure of Sevier shale soils on left.
2.4	.4	Left on 321-S.
2.5	.1	Cross Great Smoky fault.
3.5	1.0	Pull off on gravel road to left beside building. Stop 1.

Exposure of Sandsuck Formation behind building. Rock consists of thin beds of shale and siltstone and thicker (< 1 meter) beds of coarse grained, poorly-sorted, pebbly feldspathic sandstone and quartzite. Bedding strikes N55°

and dips about 65° SE. Cleavage in the finer grained silts and shale is nearly vertical with a strike of about $N50^{\circ}E$. Graded bedding suggests that bedding is upright.

This stop is one of only a few in the Precambrian age rocks. The rocks are in the hanging wall of the Great Smoky fault and are, in general, structurally complex. The rocks at this outcrop are unusually coarse-grained and could be correlative with the section just to the northwest near Locality #21 (Plate 1).

- | | | |
|-----|----|--|
| 3.9 | .4 | Pull off on gravel road to left. Walk south along the road to large exposure of the Cochran Formation. Stop 2. |
|-----|----|--|

Large, gentle fold in the Cochran Formation very near the Great Smoky fault. This slice of Cochran is a small horse block that is bound by the Great Smoky fault and a small footwall imbricate. The block has traveled farther than the other thrust blocks in the duplex so that it is now foreland-dipping. The fold is inclined such that the upper limb has an orientation of $N88^{\circ}W/78^{\circ}SW$ and the lower $N58^{\circ}W/55^{\circ}N$. The orientation of the fold axis as determined from a stereonet plot of poles to bedding is $N65^{\circ}W/29^{\circ}$. The axial plane dips to the southeast.

The rock at this outcrop consists of thick (< 1 meter) beds of poorly-sorted, feldspathic, fine- to coarse-grained, pebbly orthoquartzite. Bedding features are not easily discernable due to the massive nature. Stratigraphic up is to the northeast (left) as suggested by graded bedding in a cut hand-sample.

- | | | |
|-----|-----|---|
| 4.2 | .3 | Maroon and orange soils of the Rome Formation are visible on the left side of the road. |
| 6.7 | 2.5 | Take gravel road (Green Mountain Road) to the left. |
| 6.9 | .2 | Large weathered boulders of Wilhite Formation carbonate strata. Stop 3. (After Stop 3, turn around and proceed southward on 321.) |

Large boulders (?) of carbonate cobble conglomerate. It is difficult to tell how far (if at all) this rock has been removed from its original position. It probably has not moved far because some in-place outcrops were found in the woods nearby. The rock consists of micritic and calcarenitic clasts in a matrix of quartz sandy limestone. The clasts range in size from several millimeters to tens

of centimeters, and are commonly supported by the matrix. The quartz grains in both the matrix and clasts is commonly coarse-grained, sub-rounded, and moderately to well sorted. A thin-section shows that the quartz is entirely monocrystalline.

Bedding at the outcrop can be seen in a few places by a change in the size and abundance of clasts. No obvious structural features are present and the thin-section shows only weak, discontinuous stylolites.

7.7	.8	Turn left onto Foothills Parkway.
7.9	.2	Cross Great Smoky fault.
8.9	1.0	Heavily fractured outcrops of Cochran Formation.
9.1	.2	Rest stop.
9.4	.3	Orange shale grading upward into poorly sorted, lenticular sand bodies.
9.8	.4	Begin continuous outcrops of Cochran Formation.
10.0	.2	Pull over into rest stop on right. Stop 4.

Large outcrop of Cochran Formation on the left side of the road consists of heavily fractured and faulted, poorly-sorted sandstone and orthoquartzite. Bedding is oriented nearly parallel to the road (N40°-70°E) and dips are generally 50° to 70° to the northwest (into outcrop). Although bedding here is very difficult to see, it can be easily seen about 100 yards to the west and then followed into this part of the outcrop.

The rock here consists largely of poorly-sorted, pebbly, feldspathic, white to maroon orthoquartzite. Cross-bedding is common, as are lenticular beds. At the eastern end of the outcrop (right), abundant disharmonic, soft-sediment folds are present. The folds have random orientations and some are refolded.

The many small fractures and small faults here are probably a result of the proximity of this outcrop to the eroded Great Smoky fault overhead (see Plate 2). Blasting fractures, though, add to the complexity.

To the south is a view of Mount Camerer and Mount Guyot of the Great Smoky Mountains National Park. In the foreground, the valley is composed of Wilhite Formation and Pigeon siltstone, which are separated by the Dunn Creek

fault. The Gatlinburg fault, on the far side of the valley, places Roaring Fork Sandstone over Pigeon Siltstone.

10.9	.9	Interbedded sandstone and shale of the upper Hampton Formation.
11.0	.1	Valley created by Hampton shale.
11.1	.1	Hampton-Erwin contact.
11.5	.4	Rest stop on left side of road. English Mountain visible to northwest. Between English Mountain and here are rounded knobby hills of the Sandsuck Formation. To the NNE, is a set of ridges in the Shady Dolomite. The tallest hill to the NNE is the northeasternmost extension of the Cochran horse block that was carried over the duplex by the Great Smoky fault.
12.1	.6	Road parallels fault B.
13.5	1.4	I-40 west and east junction; take I-40 to Knoxville (left).
14.3	.8	Cross Pigeon River.
14.7	.4	Shady Dolomite (large outcrop on right).
16.7	2.0	Exit 321 Wilton Springs Road.
17.0	.3	Left on Wilton Springs Road.
17.2	.2	Straight on road.
19.5	2.3	Intersection; stay left.
19.6	.1	Underpass I-40.
20.4	.8	Probable location of fault B which places Shady Dolomite over Erwin Formation.
20.6	.2	Begin extensive outcrops of northeast-dipping Erwin Formation. Strike of beds can be seen in river to the right.

20.8	.2	Probable contact between upper and middle Erwin members.
21.0	.2	Lower Erwin-middle Erwin contact.
21.5	.5	Very steeply dipping Erwin Formation just below fault E. Heavily fractured.
21.7	.2	Stop 5.

Heavily cleaved shale, siltstone, and fine-grained sandstone. Cleavage is the dominant fabric to the south, near faults C and E, and weakens to the north. Near fault C, the cleavage actually appears to have some shear component. Further away from the fault, cleavage weakens and can only be seen in the shale. Its average strike is to the northeast with dips of about 50° to 80° to the southeast.

Folds vary both in size and shape. Wave length varies from a few centimeters to several meters. Interlimb angles vary from about 70° to 120° . Fold axes generally plunge to the northeast and plunge less than 25° . Figure 7 (p. 43) shows a small fold with associated cleavage. The cleavage is subaxial planar to the folds. Both fold type and cleavage orientation appear to be most affected by changes in lithology.

The photographs on the next page are examples of the folds and their associated cleavage. As seen in the first photo, some movement has occurred along cleavage traces. The fine-grained sandstone layer has been slightly offset. This offset can also be seen in the shale (Figure 7, p. 43) where slickensides along the cleavage are common.

The lower photo shows folding in an interlayered sequence of shale, siltstone, and fine sandstone. Folds die out horizontally and laterally.



21.8	.1	Fault C.
21.85	.05	Fault E. Large outcrops of Cochran Formation on left.
22.0	.15	Large fold in Cochran Formation to right on other side of river.
22.3	.3	Bluffton Bridge to right.
22.6	.3	Bluffs to right are composed of Pigeon Siltstone on top, thrust over the Wilhite Formation on Dunn Creek fault.
28.4	1.8	Left to I-40W.
28.5	.1	Left to enter I-40W.
28.9	.4	Wilhite Formation on right.
29.2	.3	Begin intermittent outcrops of Cochran Formation in footwall of Great Smoky fault.
29.7	.7	Exposures of tuff member of the Cochran Formation along the Great Smoky fault. Stop 6.

Broadly folded feldspathic quartzite interbedded with maroon, fine-grained material. The maroon material occurs as one or several thin beds within the quartzite. Small fractures are common, as are pale-green to white elliptical spots. The spots are less than 2 cm in diameter.

Hadley et al. (1974) quoted John Hosterman (written communication) in saying that the most abundant mineral in this maroon material is illite (60-65%). Hematite makes up most of the remainder, about 30-35%, with a few percent magnetite, TiO_2 , and apatite. He also wrote that a semiquantitative analysis indicated unusually high values of Cu (0.01%), Mo (0.01%), Po (0.01%), V (0.01%), and Zn (0.5%). Several modes of origin were suggested. "These include amygdules in volcanic rocks; hematite concentrations in lateritic soils with the elliptical areas the result of colliform-textured chemical precipitates; alteration of a glauconitic-rich bed with subsequent alteration prior to deposition of the overlying quartzite; and others."

From observation of two thin-sections of this material (Figure 5, p. 27), I suggest that it is most likely a tuff

of some type. As seen in Figure 5A, the material is in conformable contact with cross-bedded sandstone. It appears that the tuff material conforms to the original sandstone surface as would be expected in an air-fall deposit.

The principal mineral identified is chlorite (light material in photo), with thin, elongate, opaque oxide grains. Most likely, the lighter-colored area represents a volcaniclast that has been altered to chlorite. The matrix material (also dominantly chlorite) probably represents some sort of ash material. The origin of the opaque material is unknown. It appears as though it may have relict shard texture, thus, represents volcanic glass. Basalt and tuffaceous rocks have been reported in the Unicoi Formation (Cochran equivalent) farther to the northeast by King et al. (1944, p. 39). "Some of the tuffaceous rocks," they explain, "are green earthy shale and siltstone weathering red, brown, and orange. Others are green, dense indurated rocks with marked conchoidal fracture, forming massive beds."

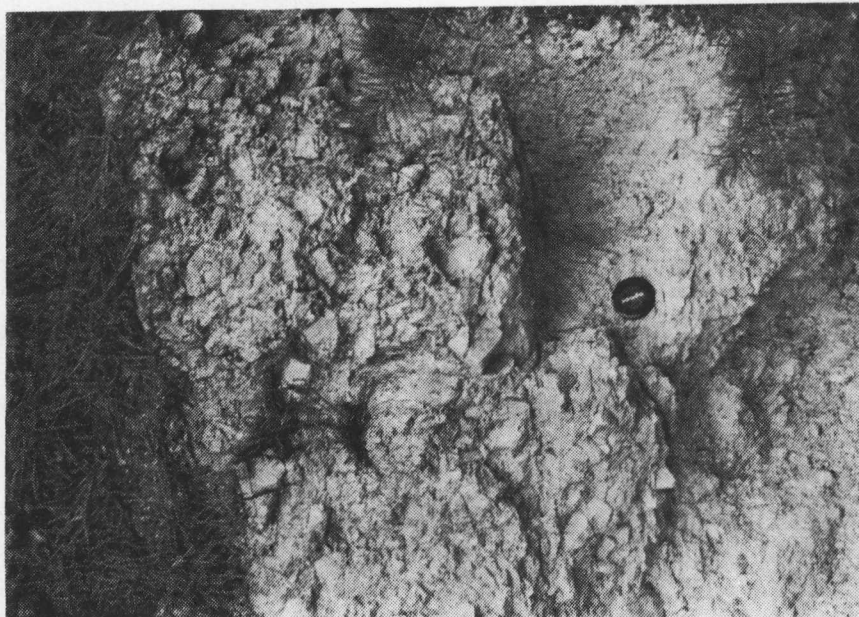
The Great Smoky fault trace is roughly parallel with the highway.

30.4	.5	Cochran Formation on right.
30.9	.5	Cross Pigeon River.
31.6	.7	Rock slide on left and begin continuous outcrop of Erwin Formation on left.
32.4	.8	Fault B.
33.4	1.0	Shady Dolomite on right.
35.4	2.0	Exit #40-Hwy 321; Wilton Springs Road.
35.6	.2	Right on 73N.
36.0	.4	Rock quarry in Knox Group.
37.7	1.7	Turn right on Sweetwater Road.
38.8	1.1	Fork; bear right onto gravel road.
39.3	.5	Fork; bear left.

- | | | |
|------|----|--|
| 39.9 | .6 | Begin intermittent exposures of loose sandstone and shale of the Cochran Formation on right. |
| 40.4 | .5 | Cochran quartzite strata on left. |
| 40.5 | .1 | Stop 7. |

Small outcrop of quartzite breccia formed from steep northwesterly-dipping normal fault. The breccia consists of angular quartzite clasts that range from about 15 cm to several microns. The larger clasts show the original quartzite triple-junction grain boundaries, whereas the smaller material consists of pieces of single quartz grains. As shown in Figure 8 (p. 49), the smaller grains occur in thin deformation bands, where most of the fault movement has taken place.

The photos below show the breccia as exposed along the left side of the road. Large angular clasts of Erwin Formation are easily visible in the matrix of smaller orthoquartzite fragments. Several meters to the southeast, bedding, although heavily fractured, becomes recognizable.





On the opposite side of the road about half-way down the hill, this same breccia zone weathers out as a large ledge up to two meters high and about 1 meter wide. The zone trends about 045° with a dip between 60° to 80° to the northwest.

This normal fault is not only parallel to the trend of many other normal faults in the area, but it is very nearly centered on the folding axis of the Denton duplex (Plate 2). It is suggested that the broad folding of both the Great Smoky sheet and in the Denton duplex by lower Valley and Ridge structures created local extensional regimes. This extension allowed for the movement of many high-angle normal faults.

40.8	.3	Deformed Erwin near normal fault.
41.1	.3	Steeply dipping, Scolithus-bearing quartzite strata of the Erwin Formation. Valley to the right is underlain by Hampton Formation.
41.3	.2	Hampton on left.
41.5	.2	Lowermost Erwin Formation caps the ridge to the left of the road.
41.8	.3	Fork; bear right.
42.2	.4	Possible location of fault F.

42.8	.6	Soil and float of Hampton Formation.
43.3	.5	Dense white quartzite of the middle Hampton Formation. Dips are to the northeast; Scolithus traces.
44.4	1.1	Flat-lying quartzites beds of Hampton in road.
44.6	.2	Possible upper member of Hampton Formation on right.
45.0	.4	Hall Top Mountain lookout tower. Stop 8.

Climb up tower. Excellent view of the Denton duplex and surrounding areas. To the northwest is English Mountain, which is composed of Chilhowee Group rocks. The Great Smoky Mountains are visible from the southwest to the southeast. They are composed of the lower formations of the Ocoee Supergroup. To the northeast are the Chilhowee-capped Mountains of the Del Rio district. The tallest mountain, Neddy Mountain, is composed of Erwin Formation.

In the Denton duplex, to the east, the re-entrant of the Great Smoky fault is visible where the bumpy hills of the Sandsuck Formation stand out above the carbonates around it.

52.2	7.2	Left on 70W to I-40.
54.3	2.1	Right on I-40W to Knoxville.

VITA

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