2004

GEOMETRIC AND KINEMATIC EVOLUTION OF THE BESSEMER TRANSVERSE ZONE, ALABAMA ALLEGHANIAN THRUST BELT

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ABSTRACT OF DISSERTATION

Margaret Colette Brewer

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University of Kentucky
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ABSTRACT OF DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Arts and Sciences
at the University of Kentucky

By
Margaret Colette Brewer
Warwick, New York

Director: Dr. William A. Thomas, Professor of Geological Sciences
Lexington, Kentucky

2004

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ABSTRACT OF DISSERTATION

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ALABAMA ALLEGHANIAN THRUST BELT

Transverse zones are important syn-kinematic components of thrust belt development. Various scales of data were utilized to develop three-dimensional geometric and kinematic models for the Bessemer transverse zone (BTZ) of the Alabama Alleghanian thrust belt.

Regional analysis of the BTZ began with the examination of geologic maps (1:250,000, 1:48,000, and 1:24,000 scales), seismic reflection profiles, well data, and previous stratigraphic research. All Paleozoic-age stratigraphic contacts, major thrust faults and associated folds, and various unnamed minor structures were compiled to create two strike-perpendicular, and five-strike parallel, cross sections transecting the extent of the BTZ at a scale of 1:100,000. The balanced and viable cross sections were used to create palinspastic maps of the BTZ. The deformed cross sections and geologic maps, and the restored cross sections and palinspastic maps, model the post- and pre-kinematic geometry of the transverse zone, respectively.

Additional geological fieldwork in the northwestern part of the BTZ permitted the construction of geologic maps (1:24,000 scale) documenting cross-strike links (the fundamental unit of transverse zones) exposed at the present erosional surface (Concord and McCalla 7.5’ quadrangles). Balanced and viable geologic cross sections (1:24,000 scale) were constructed from these data and placed parallel and perpendicular to strike of cross-strike links. The cross sections were restored and used to create 1:24,000-scale
palinspastic maps of the cross-strike links in this part of the BTZ. The cross sections and maps model the three-dimensional geometry of the cross-strike links comprising the BTZ.

Sub-allochthon basement structures are present beneath the thrust transport vectors of cross-strike links in the BTZ, indicating genetic relationships between transverse zone structures and underlying basement structures. Basement-graben related changes in the stratigraphic thickness of the decollement-host horizon are interpreted as having localized and facilitated growth of the Bessemer mushwad, a ductile duplex in the allochthon. The muswad localized the structural position of two thrust sheets and several cross-strike links in the BTZ. Geologic map patterns of the transverse zone indicate a break-back deformation sequence for the BTZ, interpreted as a response to decollement propagation through an allochthon-spanning weak decollement-host horizon, which had large stratigraphic thickness variations in basement grabens.

KEYWORDS: Transverse zones, cross-strike discontinuities, cross-strike link, lateral connector, Alabama Alleghanian thrust belt

Margaret Colette Brewer
April 13, 2004
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DISSERTATION

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Lexington, Kentucky

2004

Copyright © Margaret Colette Brewer, 2004
This dissertation is dedicated to

My mother, Mary Walsh Brewer

and to

My soul mate, Philip Charles LaPorta.
ACKNOWLEDGEMENTS

This dissertation represents the blossoming of a dream and the beginning of a lifetime of new possibilities! Life-defining goal achievement only comes to fruition with the help of a great number of loving and caring people, only a few of whom are mentioned below.

Most especially, I would like to express my soulfelt gratitude to my dissertation advisor, Dr. William A. Thomas. Through my trials of trying to balance a consulting career with an academic career, Dr. Thomas consistently maintained his faith in my ability to bring this project to a successful conclusion. Dr. Thomas provided me with scientific support, mentoring support, and a wry sense of humor to help me with all of my dissertation endeavors. Dr. Thomas never permitted me to make excuses and pushed me to be more than I ever thought I could be. I have achieved more than I have ever dreamed of because of his belief in my abilities. There is no greater gift that a teacher can give to a student. Thank you Dr. Thomas! Thank you so very much! Many thanks are also due to the other half of what I have already dubbed the “Thomas team”. Mrs. Rachel Thomas has always been a “Mom away from home” for me. Her caring and support through the long years have been a lifeline for all of Dr. Thomas’ students, myself included. Many thanks for the taco stacks, the cookies and the brownies, and the life lessons that you have passed on to us!

Additionally, I would also like to express my gratitude to a patient, supportive and understanding committee. Jim Drahovzal expressed exuberance for this project back in the days of my master’s program, before this dissertation project even began. Jim’s enthusiasm was an integral reason for my taking on this project in the first place, and a critical reason for its completion. Kieran O’Hara provided invaluable assistance in helping me to understand advanced structural geology concepts. John Watkins, my outside committee member from the Department of Geography, encouraged me to view my project outside of its geological framework and provided me with invaluable
advice on balancing an academic with a consulting career. Alan Fryar was brought on board in the final stages of my project to fill the shoes of the late Nicholas Rast. Anyone in the geological community would have to agree on Alan’s bravery for assuming Nick’s post as a committee member. I asked Alan to be a committee member because, despite of his non-tectonic background, I absolutely trusted his science and had faith that he would make Nick proud. My apologies Alan for making you read “War and Peace, with better illustrations”! The late John Ferm was an unofficial committee member who passed away at the beginning stages of my project. A kinder and gentler man I will never meet again. I truly miss him! He was my friend and my mentor. He will never be forgotten!

The mapping stages of this project were made possible by the support of the Alabama Geological Survey, especially with the guidance and assistance of W. Edward Osborne and Dan “Curvin” Irvin. Both gentlemen assisted me in the field with mapping and provided me with many Bar-B-Q lunches where the geology of the Concord-McCalla area was tackled with unabashed, greasy, enthusiasm. Many great geological ideas were discussed at the outside cafe of Dreamland’s Bar-B-Q! Many others at the Alabama Geological Survey also assisted me in various ways, including Dorothy Raymond, Jack Pashin and Andrew Rindsberg! Thank you all!

The geological community at the Department of Geological Sciences at the University of Kentucky has served as my extended family for the past 10 years. Debra Smith, Pam Stevens and Mary Sue Johnson provided me with many hours of sisterly and administrative support. They were always concerned that I keep a balance between “Maggie, the person” and “Maggie, the scientist” and did a tremendous job. Their help and assistance allowed me peace of mind, which any scientist knows is crucial to keep a project moving. The faculty at the University of Kentucky, particularly Drs. Ettonshon, Howell, and Moecher always lended a helping hand where they could. Of the newer faculty that arrived after my tenure in the department, particularly Harry Rowe and Ed Woolery, thank you for making my return “home” feel welcoming. The students at the department were always my life blood, particularly Steve Jucszik (the other New Yorker), Drew Andrews, the remaining Alabama team
(Greg Graham, Brian Cook, Brent Garry and German Bayona), and the “new guys” Matt Surles, Mike Solis, and Tom Becker, who moved over and shared their space and research lives with me when I popped back onto the scene. Many thanks to Matt Surles and Walter Johnson for the “coffee walks” and power lunches where all sorts of non-geological discussion topics helped to keep me grounded. Thank you to the non-Thomas students, Big Dan Brown, Rachel Galvin, Todd Aseltyne, and Kristen Toth for being kind enough to make me feel at home.

Completion of this dissertation was impossible without the help and support of the scientific staff at LaPorta and Associates, L.L.C., Geological Consultants. I cannot repay the debt I owe to Philip LaPorta, who provided me with the research time, office space, and the funding necessary in order to finish this dissertation. Scott Minchak and Alyssa Werner provided me with their friendship and their technical skills and helped me finish many computer-drafted illustrations that were needed for this dissertation. Linda Sohl provided me with friendship and the “woman-scientist” perspective. She assured me that there was indeed life after a dissertation program. Tina Hutchinson has provided me with much needed assistance in everyday business tasks, and like the administrative staff at Kentucky, provided me with the peace of mind needed in order to finish my degree. Anthony LaPorta and Peter Ponzini provided me with the “legal peace of mind” necessary in order to manage a growing business and helped keep Uncle Sam off my back as I balanced corporate tax deadlines with dissertation deadlines. Thank you all so very much!

I wish to thank my mother, Mary Walsh Brewer, and my sister and her family, the Brewer-O’Connor clan. I also wish to thank the LaPorta additions to my family, Philip’s mom Vivian, Aunt Maureen, Cousin Phil and all of the kids. Thank you all for your love, patience and understanding. The Walsh family members are immigrants to this country, who came to these shores looking for a better life. It is a credit to them that a young woman, raised partly in New York City and partly in rural western Ireland, could achieve such elite goals. They are living testimony to the fulfillment of the “American Dream”. My mother, in particular, is witness to the power a woman has in shaping her children’s lives. A single mother, she defied a
long-term, very painful, illness to balance work and school. She challenged herself to rise above the limitations set by her shortened primary school education. My mother gained her GED, put herself through college, held down a full-time job, and raised two young girls in the world’s largest city. She set an example for her two daughters on how hard work, and believing in a dream, can lead to a better life. All of my successes are rightfully hers. Thank you Mom for all of your sacrifices, for your undying love, and for your great Irish heritage! Your gifts have been my strength during difficult times.

Finally, but not least, I would again like to thank Philip LaPorta, this time on an intimate level. Philip you have been my inspiration and my joy for a third of my life. For the past six years, in particular, you have given me all of the love and happiness that only a soul mate can provide. It is because of you that I went to grad school in the first place, it is because of you that I finished my program. You are God’s greatest gift to me. I love you so very much!

Funding for this project was provided through grants awarded by the United State Geological Survey Edmap Division, the Brown-McFarlan Fund of the Department of Geological Sciences at the University of Kentucky, and the research fund of LaPorta and Associates, L.L.C., Geological Consultants.
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Chapter 1: Introduction

Statement of Problem

Thrust systems in orogenic belts are composed of imbricate thrust sheets bounded by a three-dimensional system of interconnected fault surfaces; thrust flats, frontal ramps, lateral and oblique ramps, and transverse faults (Figure 1.1) (Rich, 1934; Dahlstrom, 1970; Boyer and Elliott, 1982; Butler, 1982; Thomas, 1990). Thrust flats are thrust faults parallel to stratigraphic bedding at the time of displacement (Figure 1.1) (Butler, 1982). Frontal ramps cut obliquely up through the stratigraphic succession in the direction of thrust displacement (Figure 1.1). Lateral and/or oblique ramps are the strike-perpendicular and strike-oblique equivalents, respectively, of frontal ramps (Figure 1.1) (Rich, 1934; Laubscher, 1965; Dahlstrom, 1970; Suppe, 1983; Thomas, 1990). The positions of thrust flats and ramps within the stratigraphic succession are controlled by contrasts in the mechanical properties of the strata being deformed (Woodward, 1988; Hatcher et al., 1989), by sub-decollement basement structures that modify the stress field responsible for allochthon formation (Kulik and Schmidt, 1988; Wiltschko and Eastman, 1988), or by some combination thereof.

Frontal ramps, with associated fault-bend folds, persist along structural strike for considerable distances; however, they terminate abruptly, rather than gradually along strike (Wilson and Stearns, 1958; Laubscher, 1965, 1981; Dahlstrom, 1969; Thomas, 1990). At a frontal-ramp termination, fault displacement is transferred across strike to another frontal ramp. Displacement transfer is accommodated via cross-strike links that are transverse or oblique to the strike of the allochthon (Wilson and Stearns, 1958; Dahlstrom, 1970; Harris, 1970; Laubscher, 1981; O’Keefe and Stearns, 1982; Mitra, 1988; Thomas, 1990, 2001; Thomas and Bayona, 2002). Types of cross-strike links include lateral and/or oblique ramps, displacement-transfer zones, and transverse faults (Figure 1.2) (Thomas, 1990).

Some cross-strike links are randomly distributed within the allochthon; however, many cross-strike links are aligned into kilometers-wide zones termed cross-strike structural discontinuities (CSD) (Drahovzal and Thomas, 1976; Wheeler, 1978, 1980; Wheeler et al., 1979). CSD’s are the surface expressions of transverse zones (Thomas,
Transverse zones are the three-dimensional extension of CSD’s at depth, but they terminate at the base of the allochthon.

The systematic alignment of cross-strike links into transverse zones suggests some primary control on location within the allochthon. Controls on locations of cross-strike links and transverse zones are complex. Alternative hypotheses focus on controls external to the allochthon (sub-decollement basement structures), controls within the allochthon (basement-rooted faults in the cover strata; drape-folds in the cover strata over basement faults; stratigraphic variations in the cover strata, especially in the decollement horizon), and combinations of stratigraphic variations and sub-decollement basement structures (Thomas, 1990).

Transverse zones are important synkinematic components of thrust-belt evolution. Further investigation of transverse zones permits understanding of how pre- and/or synkinematic structures and stratigraphic variations affect the synkinematic plan of thrust belts. This dissertation considers which of these factors control the origin and location of the Bessemer transverse zone (BTZ) in the Alleghanian allochthon.

Study of the BTZ was accomplished with two tiers of observation. Initial discovery was conducted by generating cross sections and maps at a scale of 1:100,000, thus permitting geometric and kinematic analysis of all major thrust faults and thrust-related folds transecting the transverse zone. The second tier of observation was conducted through the generation of 1:24,000-scale maps and cross sections of cross-strike links exposed in the northwestern part of the transverse zone. The relationship between the exposed cross-strike links and three major thrust sheets, in this part of the BTZ, was accomplished by analyzing the finer scale maps and cross sections. This two-tiered investigation permitted the development of a genetic model for the BTZ in this part of the Alleghanian allochthon.

**Location of Study Area**

Numerous transverse zones have been mapped in the Appalachian Mountains of eastern North America (Figure 1.3) (Rodgers, 1963; Gwinn, 1964; Wheeler et al., 1979; Wheeler, 1980; Wheeler and Dixon, 1980; Lavin et al., 1982; Coleman, 1988a). Six transverse zones have been mapped in Georgia and Alabama; the Rome, Clinchport,
Rising Fawn, Anniston, Harpersville, and Bessemer transverse zones in Alabama (Figure 1.3) (Drahovzal and Thomas, 1976; Coleman, 1988b; Groshong, 1988; Thomas, 1985B, 1990; Thomas and Osborne, 1994; Bayona, 2003).

The BTZ is the southernmost transverse zone exposed in the Appalachian Mountains in Alabama. Structural changes in northeast-striking thrust faults and fault-related folds mark the areal distribution of the BTZ where these structures cross the transverse zone (Figures 1.3, 1.4) (1:250,000-scale maps: Szabo et al., 1988; Osborne et al., 1988). Small-scale north- to northwest-striking reverse and normal faults, as well as tight folds, mark the surficial expression of cross-strike links offsetting the major thrust-belt structures (1:48,000-scale map, Kidd and Shannon, 1977; Kidd, 1979). The northwest-southeast-trending transverse zone encompasses an area approximately 16 km wide by 77 km long. The transverse zone extends from the leading (northwestern) edge of the thrust belt in the Appalachian Plateau physiographic province (Oak Grove and Concord 7.5’ quadrangles, Jefferson County) southeastward into metamorphic rocks in the Piedmont physiographic province (Ozan, Shelby, and Talladega Springs 7.5’ quadrangles, Shelby, Chilton, and Coosa counties) (Figure 1.4).

Description of Analytical Techniques

Analysis of the geometric and kinematic evolution of the BTZ was conducted utilizing two scales of observation; a regional (1:100,000) resolution enabling analysis of the BTZ as a whole and a local resolution (1:24,000) permitting analysis of finer scale transverse zone structures, such as cross-strike links.

Regional Analysis of the Bessemer Transverse Zone

Regional analysis of the BTZ started with determining the areal extent of the Bessemer CSD by examining geologic maps at various scales (1:250,000-scale maps: Szabo et al., 1988; Osborne et al., 1988; 1:48,000-scale maps: Kidd and Shannon, 1977; Kidd, 1979; 1:24,000-scale maps: Guthrie, 1994 a, b, c, d; Osborne and Ward, 1996; Osborne et al., 1998; Rindsberg and Osborne, 2001) (Figure 1.5). Changes in stratigraphic and structural strike orientations, dip and plunge angles, and displacement of major thrust faults and related folds outline the extent of the Bessemer CSD in map view (Figure 1.4). The various scales of geologic maps were compiled on a 1:250,000-
scale geologic base map (Plate 1). All Paleozoic-age stratigraphic contacts, major thrust faults (Blue Creek, Opossum Valley, Jones Valley, Helena, Yellowleaf, Dry Creek and Talladega faults), major folds (Blue Creek, Coosa and Cahaba synclines; Birmingham and Kelley Mountain anticlines), and various unnamed minor folds and faults were transferred to the 1:250,000-scale map. Additionally, measurements such as strike, dip, trend, and plunge orientations of various structures were transferred from the 1:48,000-scale (Kidd and Shannon, 1977; Kidd, 1979) and 1:24,000-scale maps (Guthrie, 1994 a, b, c, d; Osborne and Ward, 1996; Osborne et al., 1998; Rindsberg and Osborne, 2001) and plotted on the 1:250,000-scale transverse zone map.

Stratigraphic thickness and facies changes in the BTZ were collated from eighty-nine data points located in the transverse zone. The stratigraphic data were compiled from measured sections and well data from numerous published and non-published (academic and state survey) sources. The locations of these data points were plotted on the 1:250,000 scale map and shown in conjunction with the transcribed structural and stratigraphic contact data.

Two industry seismic lines constrained subsurface stratigraphy and structure in the BTZ. Depth of buried lithologic contacts and thrust sheets were converted from two-way travel time using a pre-established velocity profile. Velocity of each lithotectonic unit was calculated by correlating deep-well stratigraphy to seismic reflectors (Thomas, 2001). Seismic reflectors were correlated with the surficial geology and with data from wells located on or near the seismic line. This correlation permitted the identification of stratigraphic units at depth. Thrust faults were identified in the seismic profiles by tracing the linear expression of cutoff reflectors up dip to the ground surface, to fault traces mapped at the surface.

Two strike-perpendicular geologic cross sections were constructed from the 1:100,000 compilations (Plates 3 and 4). The cross sections are located on either side of the BTZ and are parallel to the northwest-southwest trend of the transverse zone, extending from the Appalachian Plateau (foreland basin) to the Appalachian Piedmont (orogenic hinterland). Additionally, five transverse-zone-perpendicular (strike-parallel) geologic cross sections (Plates 5, 6, 7, 8, and 9) were placed to intersect variations in thrust belt structures crossing the transverse zone.
The two strike-perpendicular cross sections were bed-length and/or area balanced and restored (Plates 3A and 4A) using the techniques of Dahlstrom (1969) and Marshak and Woodward (1988). The five strike-parallel cross sections, in theory, cannot be balanced and restored (Dahlstrom, 1969; Marshak and Woodward, 1988). The restored strike-perpendicular cross sections were used to create a 1:100,000-scale palinspastic map of the BTZ part of the Alleghanian allochthon (Appendix 1). Three restored stratigraphic horizons (the base of the Cambrian-Ordovician Knox Group (Plate 10), the top of the Cambrian-Ordovician Knox Group (Plate 11), and the top of the Mississippian Tuscumbia-Fort Payne Formations (Plate 12) were used to construct the palinspastic map of the BTZ. The traces of bedding cutoffs at major thrust faults were plotted on the palinspastic map. Any discrepancies between the displacement magnitudes and vectors of thrust blocks on the palinspastic map were interpreted as being incorrect interpretations on the balanced geological cross sections. The cross sections were subsequently revised and the palinspastic map re-drafted until the data between the cross sections and palinspastic map were consistent. This iterative, cross checking technique of using both cross sections and palinspastic maps to correct geometric and kinematic assumptions permitted tighter constraints of the genetic model developed for the BTZ (Thomas, 2001).

**Local Analysis of the Bessemer Transverse Zone**

Large-scale analysis of the northwestern part of the BTZ began with geologic mapping (1:24,000 scale) in the field of cross-strike links exposed in the Concord and McCalla 7.5’ quadrangles (Brewer, 2000) (Plate 13). Paleozoic stratigraphic contacts were mapped in the Concord and McCalla 7.5’ quadrangles using standard field mapping techniques, including mapping of float. Bedding orientation and attitude measurements were taken at all outcrops where stratigraphic layering could be identified. Fault surfaces are not exposed in the Concord and McCalla 7.5’ quadrangles and were mapped by interpreting omission or duplication in the stratigraphic section from the contact mapping. Folds were interpreted from the mapping of stratigraphic repetition and limb attitude. Fold hinges were identified by plotting fold limb attitudes on stereonet and transferring the orientation data to the 1:24,000-scale Concord and McCalla maps.
A composite stratigraphic section was measured in the Concord and McCalla 7.5’ quadrangles (Plate 15). The exposed Paleozoic section in the Concord and McCalla 7.5’ quadrangles extends from the Cambrian Conasauga Formation to the Pennsylvanian Pottsville Formation. The base of the composite section, however, is floored in the Silurian Red Mountain Formation because the underlying Cambrian Rome and Conasauga formations, Cambrian-Ordovician Knox Group, and Ordovician Chickamauga Formation are exposed only as float in the Concord and McCalla area.

Eight geologic cross sections (seven strike perpendicular and one strike parallel) were constructed using mapped stratigraphic contacts and structures (Plates 16, 17, 18, 19, 20, 21, 22, and 23). Stratigraphic thicknesses in the cross sections were constrained with measured stratigraphic sections compiled from various published and non-published (academic and state geologic survey) sources, the composite section compiled during mapping, and well data. Cross-section construction during field mapping permitted the testing of multiple-working-map hypotheses regarding the areal exposure of the geology in the Concord and McCalla 7.5’ quadrangles. Stratigraphic thickness interpretations and inferred locations of contacts and structural features were tested through cross-section construction and corrected in the field by revising map interpretations where discrepancies were located. The cross sections were balanced and restored (Plates 16A, 17A, 18A, 19A, 20A, 21A, and 22A) (Dahlstrom, 1969; Marshak and Woodward, 1988).

Two additional geologic cross sections (sections 7 and 8) were constructed after the completion of all fieldwork (Plates 22, 22A, and 23). These cross sections span the Concord and the adjacent Bessemer 7.5’ quadrangle (Figure 1.4). Further elucidation of the subsurface geometry and kinematics was needed for that portion of the transverse zone and the sections were constructed for that purpose.

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Figure 1.1: Footwall structure of thrust sheet showing three-dimensional relationships of thrust flat surfaces, frontal ramp faults, and lateral and/or oblique ramp faults (modified from Wilson and Stearns, 1958).
Figure 1.2: Various types of cross-strike links that comprise a transverse zone.

A: An example of a transverse fault (modified from Stanley, 1986).
B: Lateral ramps, shown in relation to thrust ramps (modified from Wilson and Stearns, 1958).
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Figure 1.5A: Explanation for Figure 1.5 geologic map.
Chapter 2: Research History of Transverse Zones in Thrust Belts

Introduction

During 30 years of research, transverse zones have been identified as lineaments, cross-strike discontinuities, and lateral ramps. Numerous field investigations of CSD’s (cross-strike structural discontinuities) have been conducted worldwide. However, in the Appalachians of the eastern United States, field investigations of CSD’s include studies in western and south-central New York State and north-central Pennsylvania (Kowalik, 1975; Krohn, 1976; Hunter, 1977; Quahh, 1977; Abriel, 1978; Parrish, 1978), West Virginia (Heyl, 1972; Henderson, 1973; Mullennex, 1975; McColloch, 1976; Trumbo, 1976; Kulander and Dean, 1978; LaCaze, 1978; Sites, 1978), and Alabama (Drahovzal, 1974, 1976; Thomas and Drahovzal, 1974; Coleman, 1988; Groshong, 1988; Thomas and Osborne, 1994; Thomas, 2001; Thomas and Bayona, 2002; Bayona, 2003).

Lineaments, Cross-Strike Discontinuities, and Transverse Zones

Initial investigations of lineaments, cross-strike discontinuities, and other types of thrust-belt offsets naturally focused on the modes of occurrence of these phenomena before attention was turned to the causes and controls of these thrust-belt features. Rodgers (1963) concluded that thrust-belt lineaments marked diffuse boundaries between blocks that were partly decoupled during thrusting, so that the blocks moved together, but in part were deformed independently. In his discussion of thin-skinned tectonics of the Plateau and Valley and Ridge of the central Appalachians of Pennsylvania, Gwinn (1964) observed the termination of, or change in trend of, anticlines along lineaments trending perpendicular to the regional northeast strike. Some of the lineaments were interpreted by Gwinn (1964) as transverse faults along the margins of semi-independently advancing thrust blocks. Other lineaments, where no surface faults are recognized, were interpreted as zones where the sole thrusts in the Appalachian allochthon changed stratigraphic level along structural strike. Fold amplitudes that change across lineaments were interpreted as being controlled by changes in along-strike stratigraphic thickness. Kowalik (1975) inferred that decoupling occurred along zones of prethrusting weakness in the thrust sheets and that
fracture zones propagated upward from basement faults underlying the thrust. The first to hypothesize, however, that prethrusting weaknesses in thrust sheets were formed at vertically stacked facies changes was Trumbo (1976). The building interest in thrust-belt lineaments led to the recognition of their being an important class of structures in all thrust belts, not just a random occurrence. This class of thrust-belt structures was first termed cross-strike structural discontinuities (CSD) by Drahovzal and Thomas (1976) in an abstract on regional lineaments that cut across structural strike in the Alabama Alleghanian thrust belt.

Wheeler et al. (1979) were the first to summarize the sizes and characteristics of CSD’s, or groups of CSD’s, in numerous thrust belts. They introduced the concept of CSD’s as fundamental parts of several thrust belts, stating that CSD’s are, “structural lineaments or alignments of disruptions in structural or geomorphic patterns . . . are complex zones of diverse sizes . . . and have various structural, geophysical, chemical and other characteristics” (Wheeler et al., 1979, p. 193-195). In generalizing the characteristics and differences of CSD’s, Wheeler et al. (1979) noted that CSD’s should not be classed solely as transverse faults or joint zones. Hundreds of cubic kilometers of rock are included in CSD’s; each CSD has distinct physical and chemical properties. The spatial distributions of CSD’s may vary, some are very deep, others are wider rather than deep, and some are highly fractured areas of the allochthon. Subdecollement basement may or may not be involved with the formation of a CSD. Basement involvement may also change from active involvement (basement fault structures disrupting allochthon propagation, syn-sedimentary basement fault reactivation) to passive involvement and back again under any combination of circumstances.

Wheeler (1980) reviews again the characteristics of CSD’s in thrust belts and their potential to yield hydrocarbon-bearing deposits. Combining data from CSD’s in the Appalachians, the Canadian Rockies, Ireland, and Chile, Wheeler (1980) hypothesizes that on average CSD’s “can be estimated to be typically about 3.5 km wide, at least 4 km deep, and at least 70 km long, with a centerline spacing of about 25 km (between adjacent CSD’s) . . . Such CSD’s would each contain at least 980 km$^3$ of rock and therefore, could include 14% of that part of the detached sedimentary prism
that they traverse” (Wheeler, 1980, p. 2167). After examining the orientation and minimum lengths of CSD’s as a class of structures, Wheeler (1980) concluded that the geometry of CSD’s might be influenced by cratonic structures that were activated, or reactivated, under advancing thrust sheets. However, Wheeler (1980) further qualifies his hypothesis by noting that CSD’s are complex structures and may form in different ways. Wheeler (1978) presented a mechanism for “forming aligned tear faults and anticlinal noses without basement involvement, by processes operating entirely within the thrust sheets. Whether a particular part of a specific CSD overlies or once overlay basement faults is a question answerable with only local data.” (Wheeler, 1980, p. 2170-2171). CSD’s are interpreted as being very large volumes of intensely jointed rock, where the joints extend possibly as deep as the basal decollement surface. Further contributions towards the understanding of CSD’s are presented in the listing of criteria that can be used to identify CSD’s in fold and thrust belts, as follows:

“1. Bends, ends, or style changes of detached folds or longitudinal thrust faults…

2. Transverse faults, particularly if movement occurred at more than one time, in more than one direction or both…

3. High joint intensity: large size, close spacing, or both…

4. Presence of some type of small fold or fault that records larger movements

5. Intense cleavage development…

6. Anomalous changes in contours of smoothed values of strike or dip of beds…

7. Changes in orientation of structural grain…

8. Gravity anomalies, particularly with terrane corrections …

9. Magnetic anomalies, particularly with terrane corrections…

10. Disruptions in magnetic or gravity gradients …
11. Abrupt changes in depth to magnetic or seismic basement…

12. Earthquake epicenters …

13. Water and wind gaps …

14. Course changes of major streams …

15. Mineralization: usually abundant, or indicative of deeply penetrating fracture systems…

16. Volcanic centers and intrusions…

17. Long Landsat photolineaments …

18. Unusually dense air photo lineaments …

19. Facies and thickness changes of stratigraphic units…

20. Blocky shapes on isopach maps, indicating abrupt thickness changes across straight lines…

21. Springs: unusual temperatures, chemistries, or yields …

22. Gas or oil seeps…


Applying Wheeler’s criteria to the BTZ, it is evident on the geologic map of the region (Figure 2.1) that the following apply: bends, ends, and style changes in folds and thrust faults in the transverse zone; abrupt changes in the smoothed orientation of bedding; changes in facies and sedimentary thickness; and changes in the orientation of structural grain. The early literature concerning lineaments in Alabama (Drahovzal, 1974; 1976; Drahovzal et al., 1975) discusses the presence of photolineaments for the Anniston and Harpersville transverse zones. Although the BTZ is not discussed in those papers, the Harpersville transverse zone is the next northeastern transverse zone
neighboring the BTZ (Figure 2.2), and the presence of Landsat photolineaments is documented for the Alabama Alleghanian thrust belt.

Thomas (1990) was the first to discuss the finer scale anatomy of transverse zones, proposing that transverse zones are composed of lateral connectors (which were redefined as cross-strike links in Thomas and Bayona (2002)), a variety of which may be aligned orthogonal to regional strike to form the thrust-belt discontinuity. Combinations of structural and stratigraphic variations, both internal and external to the allochthon, are hypothesized by Thomas (1990) as controlling the alignment of these cross-strike links into transverse zones. Thomas (1990) also defined the characteristics of three different types of cross-strike links; the lateral ramp, the displacement transfer zone, and the transverse fault (Figure 2.3).

**Cross-Strike Links in Transverse Zones**

**Lateral Ramps**

A lateral ramp is described as a “transverse fault [that] cuts through the beds between lower- and upper-level detachment horizons, accommodates an along-strike change of stratigraphic level of decollement, and connects the orthogonally offset ends of two frontal ramps.” (Thomas, 1990, p. 729). Two types of lateral ramps, the hanging wall and the footwall, are defined in this paper. In a hanging-wall lateral ramp, the rocks in the hanging wall are thrust onto the upper-level detachment, forward of the intersection between the leading frontal ramp and the backward connecting lateral ramp. The rocks cut off in the hanging-wall lateral ramp form a plunging fold and the thrust fault in the hanging-wall lateral ramp cuts through the stratigraphic succession (Thomas, 1990). In a footwall lateral ramp, the hanging-wall rocks are transported onto the upper-level detachment, forward of the intersection between the trailing frontal ramp and the forward connecting lateral ramp. The hanging-wall rocks form a plunging fold that drapes over the footwall cut off of the lateral ramp and the thrust fault in the footwall lateral ramp remains within one stratigraphic unit at the base of the hanging wall (Thomas, 1990).
Displacement Transfer Zones

Another type of cross-strike link, the displacement transfer zone, is described as “lateral connectors between the en echelon ends of two frontal ramps that rise from the same stratigraphic level of decollement. Translation decreases in opposite directions, and the net translation on the two frontal ramps is approximately constant along strike. Displacement is transferred from one frontal ramp to the other progressively along strike.” (Thomas, 1990, p. 729) (Figure 2.3).

Transverse Faults

The third type of cross-strike link is the transverse fault. Also known as tear faults or compartmental faults, transverse faults are common in thrust sheets because of the mechanical impossibility of displacing very large volumes of rock as a single unit. Large thrust sheets are commonly broken into smaller structural units bounded by leading and trailing ramps and transverse faults. Although a thrust sheet may be broken into smaller structural units, the kinematic history of the smaller units is linked with the translation of the thrust sheet as a whole. Transverse faults also serve as partitions between thrust sheet domains in which a common magnitude of shortening has been achieved in different ways, i.e. a transverse fault might separate a fold-dominated domain from another that is fault-dominated.

Cross-Strike Link Controls

A vital contribution towards the understanding of cross-strike links is the map view, “cross-strike links are expressed . . . by along-strike terminations of thrust faults and ramp anticlines; by curves and offsets in strike; and by along-strike changes in angle and direction of plunge, dip of fold limbs, direction of vergence, stratigraphic level of detachment, and structural style . . . [they] commonly exhibit a range of types, scales, and senses of apparent offset.” (Thomas, 1990, p. 729, 730). These features can be seen in the geologic map of the BTZ (Figure 2.1). Thomas (1990) described the significant aspects of the Anniston transverse zone in the southern Appalachians of Alabama and compared the geologic controls on the formation of transverse zones in the European Alps, the U.S. Rocky Mountains, and the central Appalachians. One of the major conclusions is that the genetic relationship between sub-decollement
basement faults and the location of transverse zones is variable and that the certainty of the correlation is also based on the local geology and the available evidence (Thomas, 1990). If there is a relationship between pre-existing basement faults and transverse zones, the following hypotheses may be viable: thrust faults are deflected over an irregular, faulted, basement surface; a decollement-host stratigraphy that is deformed by pre-existing basement structures that may partition advancing thrust sheets; drape folds in the cover strata may deflect advancing thrust faults; and thrust surfaces may be displaced by a still active, underlying basement fault. Strike-parallel stratigraphic variations in the decollement-host stratigraphy, such as lateral thinning, pinch-outs and facies changes, are also considered as a fundamental control on the placement of transverse zones (Thomas, 1990 and references cited therein). Thomas (1990, p. 740) explained that, “fault-bounded irregularities on the autochthonous basement surface control the location of thrust ramps which are formed at the site of emplacement of the allochthon over basement faults; a lateral connector so formed would remain above the basement fault.” Alternatively, however, cross-strike links initiated by pre-thrusting stratigraphic or structural variations in the allochthon-host strata, will be translated farther cratonward during thrusting. There are some controls on the post-thrusting location of these cross-strike links. A lateral connector formed in cover strata that was deformed by a basement structure that strikes parallel to thrust displacement will be located along the strike-parallel projection of the basement structure; however, where the vector of allochthon displacement is oblique to the orientation of the basement structure, the allochthonous cross-strike link will be translated to a position oblique to the strike of the basement structure (Wheeler, 1986; Thomas, 1990).

**Thrust Ramps: Frontal, Lateral, and Oblique**

Considering that transverse zones are composed of cross-strike links (thrust ramps, displacement transfer zones and transform faults) (Thomas, 1990), it is appropriate to discuss the current knowledge base for these structures. The concept of a thrust ramp was first developed by Rich (1934) in his description of the geometry of the Pine Mountain thrust block in Virginia, Kentucky, and Tennessee. “The thrust plane may be pictured as following some zone of easy gliding such as the lower shale….until frictional resistance became too great; then shearing diagonally up across the bedding to
another shale; following that for several miles, and finally shearing across the bedding to the surface.” (Rich, 1934).

Miller and Fuller (1954) proposed that the frictional resistance in the glide plane of the Pine Mountain thrust, as described by Rich (1934), was increased by the presence of sub-decollement folds that impeded the propagation of the aforementioned Pine Mountain thrust fault. Miller and Fuller (1954) hypothesized that these folds were responsible for the ramping of the thrust fault from the Cambrian Rome Formation to the Devonian-Mississippian Chattanooga Shale. This viewpoint provides a structural mechanism for ramping of the thrust faults. The Pine Mountain thrust fault is thought to propagate into the fold, “until it confronts a downward flexure where the fault can no longer follow the incompetent units. Once the cross-cutting has begun, many or most overthrust faults continue to break across the formations, competent and incompetent alike.” (Miller and Fuller, 1954, p. 258-259).

A departure from the more classical field studies of thrust ramps is provided by Wiltschko (1979), who developed a linearly viscous, plane-strain, mechanical model for the deformation of a thrust sheet at a frontal ramp. The model solves for the state of stress within the thrust sheet as it moves over the thrust ramp. Hanging-wall resistance due to internal deformation is interpreted by Wiltschko (1979) as an important impediment to thrust-sheet movement, as important as fault-zone drag at a ramp. Gravity may be either an important resisting force or a moderate aid in the motion of the thrust sheet, depending on the paleotopography at the time of thrust-sheet propagation. Wiltschko (1981) supplemented his earlier model of thrust-sheet deformation at a ramp by proposing that an increase in hanging-wall viscosity and thickness, and an increase in the dip of the thrust ramp, impedes forward motion of the thrust sheet. Conversely, Wiltschko (1981) concluded that an increase in the dip of the erosional surface in the direction of thrusting and an increase in the proportion of incompetent rocks will aid thrust-sheet movement.

Wiltschko and Eastman (1983) noted that the location of thrust ramps and other structures might not be random. Pre-existing basement folds and faults are interpreted as both playing a role in controlling the locations of thrust ramps. Experiments were conducted using two-dimensional, two-layer, photoelastic models. The results of the
experiments indicate that pre-existing basement folds constitute a rigid surface against which principal stress trajectories bend, hence deflecting propagating faults. Wiltschko and Eastman’s (1983) photoelastic models illustrate maximum stress intensities concentrated just past the crest of the fold, distal from the deformation load, where the stratigraphic section is thinnest (Figure 2.4). Minimum stress intensities were also illustrated on the distal side of the fold, but at the model basement-sediment contact (Figure 2.4). Thrust initiation would occur at the maximum stress loci, the area distal from the deforming load. This fault may propagate from the distal part of the fold crest backwards, toward the detachment level. Also, the photoelastic models predict that faulting will not displace the rocks below the crest of the fold, very low stresses occur in that part of the deformation field (Figure 2.4A).

Pre-existing basement faults (one modeled at a 45° dip and the other at a 90° dip) were also addressed in Wiltschko and Eastman’s (1983) photoelastic model as disturbing the regional stress field, concentrating stress trajectories and facilitating failure. Principal stress trajectories shallow and then steepen beyond the corner of the upthrown basement block of the 45° fault (Figure 2.5). Wiltschko and Eastman (1983) interpret these stress trajectories as being geologically difficult, if not improbable. However, in the vertical fault model, stress trajectories are not as localized as those above the 45° fault. In contrast there are two areas of high stress; one area of high stress is at the sharp upper corner of the fault block, and the other is in front of the steep fault face (Figure 2.6). These two areas of stress concentration are interpreted by Wiltschko and Eastman (1983) as leading to more gently dipping, more geologically realistic, potential fault orientations. In addition, a dead zone is hypothesized where fault motion will be unlikely, because of the proximity of the unyielding basement. Therefore, while the region directly in front of the fault may fracture, motion will only occur on higher level faults; the two lowest potential fault surfaces remain static (Figure 2.6). Wiltschko and Eastman (1983) interpret these experimental results as having important three-dimensional implications. First, if it is correctly assumed that failure occurs within the stratigraphic section above basement faults, thrust faults must propagate down section to join the detachment fault, as well as up section, for significant displacement to occur. Second, once started, a thrust fault may propagate
along strike into regions where there is no apparent mechanical cause for the initial break.

While their paper focuses on pre-existing structural controls on thrust ramps, Wiltschko and Eastman (1983) do discuss stratigraphic controls on fault ramps. Stratigraphic inhomogeneities are interpreted as being prevalent on a local scale, especially where the stratigraphy is discontinuous in nature. Ductile and brittle stratigraphic units alike exhibit thickness changes in space, and when deformed, support stresses in a non-uniform manner. Wiltschko and Eastman (1983) state that in a compressional stress regime, pinch-outs of brittle stratigraphic units will create stress concentrations. Under shear stress, terminations of ductile lithologies will also act as stress concentrators, as more of the stress load is transferred to the surrounding brittle units. Undulatory bedding surfaces are hypothesized as non-uniformly stressing during shear. High-amplitude bedding undulations do not facilitate fault movement, which in turn causes a large stress concentration.

Woodward (1988) presented an alternative hypothesis to Wiltschko and Eastman’s (1983) theory; that stratigraphic changes provide a reasonable origin for localizing thrust ramps in both map pattern (via facies or thickness changes) and in vertical position within the stratigraphic section (via regionally changing stacks of structural lithic units). In general, basement faults seem to exhibit less direct control on thrust ramp location than does stratigraphic variation (Woodward, 1988). The extent of control that basement structures exert on thrust belt geometry is in the effect basement structures have on pre-thrusting sedimentation patterns in cratonal, miogeoclinal, and eugeoclinal basins. “Where basement properties are regionally nonuniform, more abrupt stratigraphic changes should be common. The changes in stratigraphy (loss of a glide horizon for example) and thickness will have a major impact on the origin and evolution of subsequent thrust structures. Areal and vertical locations of ramps and flats in the stratigraphic section are proposed to be controlled more by stratigraphic packaging as structural lithic units than by basement-fault proximity or geometry. The vertical position of ramps within the stratigraphic section is a major part of the question. Commonly there are several major ramps in thrust paths. Although a basement fault might conceivably localize the ramp upward from the lowest glide zone into an
intermediate level flat horizon, it is difficult to use that explanation alone to explain ramps across higher stratigraphic units.” (Woodward, 1988, p. 354). The positions of ramp-flats in thrust sequences is interpreted as being controlled by the critical taper of mechanically dominant parts of the host stratigraphy, such as the major decollement horizons or the massive ramp units (Rutherford, 1985).

A hypothesis was proposed by Petrini and Wiltshoko (1986) stating that hanging-wall strain, as the hanging wall moves over a lateral ramp, is controlled by lateral-ramp height, hanging-wall thickness, and the extent over which strains were accommodated. A theoretical model of a footwall ramp structure was developed (the ramp structure consisted of a frontal ramp bounded by two lateral ramps) in which strain was analyzed during hanging-wall movement over the footwall ramp structure. The model results indicated that, if bedding-normal thinning were permitted, thinning ranged between 2% and 29% for lateral ramps dipping between 10° and 45°, respectively. Line length increase over this range of lateral ramp dips was 2% to 45%. An alternative hypothesis of simple shear deformation was also examined; the results indicate that the amount of shear imposed on footwall rocks not located in the ramp structure is equal to the tangent of the lateral ramp dip. The same shear also results when a hanging-wall block originally cut by the footwall ramp structure is subsequently displaced onto a thrust flat. Petrini and Wiltshko’s (1986) conclusion was that significant shear and/or thinning will occur within the rocks either in or bounding lateral ramps, and they hypothesize that given the large amounts of strain predicted for reasonable lateral ramp dips, such strains should be readily visible in the rock record.

Apotria et al. (1992) developed a kinematic model to understand three-dimensional particle paths over an oblique ramp and the resultant out-of-plane strain that occurs at ramp intersections. The hanging wall is modeled as deforming by layer-parallel shear. The material particle paths in the hanging wall are deflected out of the transport plane during displacement over an oblique ramp (Figure 2.7). The deflection and out-of-plane shear strains are zero for the special cases of pure frontal and lateral ramps, and maximum at an intermediate oblique orientation that depends on oblique-ramp dip. At the trailing intersection zone, which is concave in the direction of transport, divergence of hanging-wall rock results in lateral extension (Figure 2.7). The
predicted extension may be a mechanism for hanging-wall transverse faulting or enhanced fracturing. At the leading intersection zone, which is convex in the direction of transport, displacement paths converge in the hanging wall resulting in lateral shortening intersections, therefore, could be interpreted as the locus of anomalous deformation in the hanging wall and indicate that layer-parallel shear alone cannot accommodate the deformation. If the footwall deforms in a similar manner, out-of-plane deflection of the footwall produces lateral shortening at the trailing intersection (Figure 2.7). The layer-parallel-shear model provides insight into the types of strain expected at ramp intersections, but does not explicitly address stress and strain magnitudes and orientations above the central region of the oblique ramp.

In conclusion, numerous hypotheses regarding the evolution of thrust ramps have been proposed over the years. Thrust ramps evolve from the degeneration of the thrust glide horizon, to the point where frictional resistance is great enough to initiate a change in the vector of the glide path, causing refraction into a different rheologic unit. Pre-existing structures, faults, anticlines, synclines, may present a mechanical obstacle to thrust propagation, initiating an up stratigraphic section change in the orientation of the glide horizon, which according to Miller and Fuller (1954) is irrespective of rheology. Photoelastic experiments (Wiltschko and Eastman, 1983) confirmed Miller and Fuller’s (1954) observations, showing high-stress concentration above the crests of pre-existing anticlines, as well as the crests of pre-existing, upthrown, normal fault blocks, where the stratigraphic section is the thinnest. Fault initiation occurs at the maximum stress loci and thrust propagation is bi-directional. Thrust propagation is forward moving (break forward) to continue cratonward thrust propagation, but is also hinterlandward moving (break back) for short distances. Break-back thrusting occurs to connect forward-breaking thrust segments with the detachment below the maximum stress loci, at the inflection point where flat-lying stratigraphic units intersect the fold and/or fault-block structure. Stratigraphic changes in the allochthon-host horizon also control the location of thrust ramps. Facies pinchouts and high-amplitude bedding undulations become stress concentrators. The extent to which pre-existing structures and/or stratigraphic variations control the location of thrust ramps is still debated. It is not abundantly clear which (structure vs. stratigraphy) exerts the dominant control on
thrust ramp initiation; however, a compromise is accepted where both factors are acknowledged as having an impact, the severity of the impact depending on local factors.

Mechanical models for thrust ramp initiation indicate that deformational resistance in the hanging wall of the thrust fault, in the form of hanging-wall viscosity and thickness, as well as an increase in the height and dip of the thrust ramp, will impede thrust propagation. Gravity and paleotopography during thrust sheet emplacement either impede or facilitate fault movement, depending on the direction of paleoslope vs. thrust propagation direction. Variations in the footwall geometry will also impact the motion of a hanging wall over a thrust ramp. Structural highs in the thrust-fault footwall are modeled as resulting in strike-parallel extensional deformation of the hanging wall; whereas, footwall structural lows result in strike-parallel compressional deformation of the hanging wall. The geometry of the intersection of frontal and oblique ramps also deforms the overriding hanging wall. The intersection of a trailing frontal ramp and a lateral or oblique ramp (structural high), which is concave in the direction of thrust transport, will result in extension of the overriding hanging wall. At the leading frontal ramp intersection with the lateral/oblique ramp (structural low), the hanging wall will deform compressionally. Ramp intersections, therefore, may represent areas of increased strain during thrust propagation over lateral/oblique ramps.

**Displacement Transfer Zones**

In his paper discussing the balancing of structural cross sections, Dahlstrom (1969) also introduces the concept of displacement transfer zones in thrust belts. He introduces the concept by discussing a potential problem in comparing shortening changes along individual thrust faults vs. shortening changes in the entire thrust belt. Shortening percentages are substantially greater in local structures than is the overall shortening amount for the thrust belt as a whole. “Since the whole does not change as rapidly as its component parts, it follows that there must be some sort of compensating mechanism at work whereby displacement is “transferred” from one structure to another.” (Dahlstrom, 1969, p. 751-752). The type of displacement transfer zone introduced by Dahlstrom is a “lap joint”. A fault that is experiencing an along-strike decrease in displacement is replaced by an en-echelon fault experiencing an
along-strike increase in displacement. The two en-echelon faults are by their nature required to be rooted in a common detachment surface, along which the transfer occurs. The importance of displacement transfer zones is summed up in Dahlstrom’s (1969) statement, “Recognition of transfer zones enables correlations to be made between thrust faults. Although one fault terminates, its place is taken by another and the zone of thrusting persists.” (Dahlstrom, 1969, p. 753). Dahlstrom (1969) concludes that the displacement transfer mechanism also works well with en-echelon, fault-related, folding, “…the transfer mechanism operates for folds as it does for faults. En-echelon folds are tied to one another by a sole fault (decollement) and maintain consistent shortening by replacing a dying structure with an en echelon growing equivalent (Wilson 1967).” (Dahlstrom, 1969, p. 753).

O’Keefe and Stearns (1982) combined field studies with laboratory experiments to develop a three-end-member classification of displacement transfer zones in thrust belts. The end members are 1) tear faulted transfer zones; 2) distributed strain transfer zones; and finally 3) localized strain transfer zones. The concept of a tear-fault displacement transfer zone is well documented in the geological literature (Wilson and Sterns, 1958; Price and Mountjoy, 1970, Laubscher, 1981). Displacement transfer zones that do not utilize tear faults are common in thrust belts. Experimental clay and beeswax models (the different materials used in the experiments were meant to model differing lithologic rheologies) were used to constrain the variables responsible for forming displacement transfer zones. The clay models were used to evaluate the effects of four parameters: the surface separation of the thrust faults parallel to thrust propagation direction; the thickness of the rock above the fault surfaces; overlap of the zone where both faults are present; and amount of displacement caused by the implied stresses. O’Keefe and Stearns (1982) postulate, from their experiment with the clay models, that surface separation and overlap between adjacent thrust faults are the most important parameters relative to the transfer zone geometry produced. Within the model dimensions of 10 cm long by 7.5 cm wide (along fault-strike direction) and 5 cm high, when the surface separation between the two model thrust faults was less than 1 cm (10%) and/or overlap between the two thrust faults was less than 2 cm (28%), a tear fault was developed between the two model thrust faults. However, when either of
these quantities was larger, transfer was accomplished through folding, faulting, and distribution of ductile strain in the overlap region, with extension parallel to the overlap leading edge (distributed strain transfer zone). In the beeswax models, strain concentrated near the terminations of the model thrust faults during deformation. The upper and lower transitional material undergoes rigid body rotation and distortion occurs only at the ends (localized strain transfer zone).

In summary, Dahlstrom (1969) points out the existence of displacement transfer zones, albeit a very simple variety, the lap joint, to explain the apparent discrepancy between shortening changes in individual thrust faults vs. the entire fold and thrust belt. Dahlstrom (1969) elaborates that displacement transferred on en-echelon faults may only occur if the two faults are rooted in the same detachment. Displacement transfer may also occur between two en-echelon folds, provided they are cored by faults that branch at depth along the same detachment. O’Keefe and Stearns (1982) developed a three-end-member classification for displacement transfer zones and established, via laboratory experiments, the parameters responsible for formation of a displacement transfer zone. The surface separation between thrust faults transferring their displacement, and the overlap of the surface separation where both faults are present, are the most important factors affecting displacement transfer zone formation. When the surface and overlap distance between two postulated thrust faults was relatively small (<10% and <28%, respectively), tear fault transfer zones formed in their beeswax models; however, when the map (>10% and >28%, respectively) and overlap distance between the two thrust faults increased, distributed and localized strain transfer zones developed.

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Figure 2.1: Geologic map of the Bessemer transverse zone (modified from Szabo et al., 1988), showing the extent of the Bessemer transverse zone (between cross sections A and B).
Figure 2.1A: Explanation for Figure 2.1 geologic map.
Figure 2.2: Schematic map of Alleghanian thrust belt in Alabama and Georgia, showing the locations of four transverse zones (modified from Thomas, 1990). The Bessemer transverse zone is shaded in the blue-purple domain gradient.
Figure 2.3: Various types of cross-strike links that comprise a transverse zone.

A). An example of a transverse fault (modified from Stanley, 1986).

B). Lateral ramps, shown in relation to frontal ramps (modified from Wilson and Stearns, 1958).

C). An example of a simple (lap joint type) displacement-transfer zone (modified form O'Keefe and Stearns, 1982).
Figure 2.4: Basement fold model based on photoelastic experiments conducted by Wiltschko and Eastman (1988).

A). Configuration of fold model with arrows representing uniform displacement from a riding plunger to the left of the model.

B). Stress magnitudes plotted as fringe orders, the load is to 0.65 order. Principal stress trajectories refract near crest of fold, with greatest stress on the distal side of the fold crest.
Figure 2.4A: Continuation of basement fold model developed by Wiltschko and Eastman (1988).

C). Principal stress directions with relation to the crest of the basement fold.
D). Potential fault orientations that would form only under the following assumptions; faults form at an angle of 30° to the maximum principal stress directions, thrust propagation is instantaneous, a fault does not alter the stress field controlling the propagation direction, and antithetic faults do not form.
Figure 2.5: Model developed by Wiltscho and Eastman (1988) under the same assumptions as outline in Figure 2.4.

A). Configuration of photoelastic model with displacement being applied from the left.

B). Stress magnitudes increase at the crest of the upthrown block, with the least stress magnitude in front of the fault face.

C). Principal stress directions for this model.

D). Predicted fault orientations, if using the same assumptions as outlined in Figure 2.4.
Figure 2.6: Model developed by Wiltschko and Eastman (1988) under the same assumptions as outlined in Figure 2.4.

A). Configuration of photoelastic model with displacement being applied from the left.

B). Stress magnitudes increase at the crest of the upthrown vertical fault block.

C). Principal stress directions for this model.

D). Predicted fault orientations, if using the same assumption as outlined in Figure 2.4.
Figure 2.7: Models of hanging wall and footwall translation over lateral and oblique ramps (modified from Apotria, 1995).

A). During hanging wall translation over a fault ramp, extension in the hanging wall will occur at an intersection between a trailing frontal ramp and lateral/oblique ramp, which is concave toward the direction of thrust transport. Hanging wall compression occurs at a topographic low and/or leading frontal ramp and lateral/oblique ramp intersection, which is convex towards the direction of thrust transport.

B). During footwall translation under a fault ramp, footwall extension occurs at a topographic low and/or a leading frontal ramp and lateral/oblique ramp intersection. Footwall compression occurs at a topographic high and a trailing frontal ramp and lateral/oblique ramp intersection. Leading and trailing ramp definitions are defined by the direction of thrust transport, not footwall translation.
Chapter 3: Tectonic History of the Alabama Alleghanian Thrust Belt

Introduction

Proterozoic Deformation

Grenvillian Orogen

The oldest rocks associated with the BTZ are amphibolite to granulite-grade orthogneisses and paragneisses. Radiometric data of granites and gneisses from the Pine Mountain window of Georgia and Alabama yield Rb-Sr whole rock ages of 1055 +/- 20 Ma and U-Pb upper intercepts of 1078 to 1165 Ma (Odom et al., 1985). These data have been used to support interpretations that the rocks were formed during the Grenvillian amalgamation of the Rodinian supercontinent (Rankin et al., 1993). The Rodinian craton of specific importance to the Appalachian thrust belt is Laurentia, which began separation from Rodinia at approximately 770 Ma to 550 Ma during Iapetan rifting (Aleinikoff et al., 1995; Hogan and Gilbert, 1998). The rifted Laurentian margin is the basement of the Alleghanian allochthon throughout the Appalachian Mountains in general, and for the BTZ in particular.

Iapetos Rift

The Laurentian craton of Rodinia was tectonically quiescent for a time span of 250 to 200 m.y. after the Grenville orogeny. Continental rifting of Laurentia from Rodinia occurred in numerous pulses; an aborted pulse at 758 ± 12 Ma (Neoproterozoic-Sturtian), a second rift pulse from 572 ± 5 to 564 ± 9 Ma (Cambrian-Mortenses) (Aleinikoff et al., 1995), and a third pulse activated by a spreading-center jump (Thomas, 1991) farther cratonward from 539 to 530 Ma (Cambrian-Mortenses to Adtabanian) (Hogan and Gilbert, 1998). Iapetos rifting occurred along trends that eventually became present day Appalachian stratigraphic and structural trends (Figure 3.1) (Rankin, 1976; Thomas, 1977). Embayments (concave-oceanward) and promontories (convex-oceanward) of rifted continental crust were the result of sublinear rift zones offset by orthogonal transform faults (Thomas, 1977). During Iapetos rifting, the Alabama promontory was framed by the southern Blue Ridge and Pine Mountain rift zones on the southeast and the Alabama-Oklahoma transform fault on the south-southwest (Figure 3.2) (Thomas, 1991). Very thick accumulations of Neoproterozoic-
Cambrian rift-fill clastic and volcanic detritus are preserved in the Blue Ridge rift, but pinch out abruptly where they overlap southwestward along strike onto the Alabama promontory, presumably at the rifted edge of the continental crust (Thomas, 1977; 1991; 1993). Sandstones of the Chilhowee Group rest nonconformably on basement rocks and conformably on syn-rift rocks along the Blue Ridge rift. The post-rift unconformity is interpreted as being the basal contact of the Chilhowee, and the Chilhowee has been interpreted as marking the rift to passive-margin succession (Thomas, 1977; Wehr and Glover, 1985; Fichter and Diecchio, 1986). Chilhowee Group metaequivalents are present in the Talladega thrust sheet in the BTZ (Tull, 1982). A carbonate platform in a passive-margin setting (Shady and Knox carbonates) was deposited over the Blue Ridge rift system from Early Cambrian through Early Ordovician time (Rankin, 1976; Thomas, 1977; 1991). However, southwest of the Alabama-Oklahoma transform fault, continental rifting had shifted cratonward from the Blue Ridge and Pine Mountain rifts to the Ouachita rift at the beginning of the Cambrian (Figure 3.2) (Thomas, 1991). Extension from the Ouachita mid-ocean rift extended northeastward across the Alabama-Oklahoma transform as the Ouachita rift drifted with time. Extension is interpreted as creating the Birmingham basement fault system that is part of the sub-allochthonous basement complex for the Alleghanian thrust belt (Thomas, 1991). The basement fault system includes several northeast-striking faults that are interpreted as being active during Chilhowee to Conasauga deposition (on the basis of thickness and facies variations) (Ferrill, 1989; Thomas, 1985a, 1986, 1991). The youngest sedimentary rocks of the Birmingham fault system are early Late Cambrian (Dresbachian) age (530 Ma) (Resser, 1938; Grohskopf, 1955; Palmer, 1962), indicating that a passive margin succession was not established on the Ouachita rift until the Late Cambrian (Thomas, 1991). The Birmingham graben-fill rocks and rift faults are overlapped by passive-margin carbonate-shelf rocks of middle Late Cambrian (Franconian) age (Ham, et al., 1964; Thomas and Astini, 1996). In contrast to the Appalachians east and northeast of Alabama, the passive-margin deposition persisted in the Ouachita embayment until the Mississippian (Thomas, 1991; Thomas and Osborne, 1995). Local truncation of the upper Knox, in conjunction with stratigraphic variations in post-Knox rocks, indicate episodic reactivation of the
Paleozoic Deformation

Taconian Orogen

The cause of the Taconian orogen is currently debated as westward subduction of the Iapetos oceanic plate beneath the Laurentian continental margin or eastward subduction of the Laurentian margin and the proximal ocean basin beneath an oceanic island arc (Hatcher, 1972; Drake et al., 1989). Occurring from Middle Ordovician to Late Silurian in the southern Appalachians, the Taconian orogeny is the first major compressional event to affect the southern Laurentian margin (northeast of the Alabama promontory) since Iapetos rifting (Drake et al., 1989; Hibbard and Samson, 1995). Granitoid plutons in the Alabama Piedmont have been dated using U-Pb zircon and Rb-Sr whole-rock methods and have been interpreted as Taconian intrusives (Russell, 1978). U/Pb zircon ages range from 516 to 458 Ma (Russell, 1978). Scatterchrons of the Rb-Sr data give ages ranging from 490 ± 26 to 395 ± 112 Ma (Russell, 1978). U-Pb zircon and K-Ar dates from the Hillabee Greenstone, which crops out in the Piedmont across the BTZ, range from 454 to 380 Ma (Russell, 1978; Tull et al., 1978).

Taconian metamorphism is not strongly evidenced in the Alabama thrust belt, despite being interpreted as the highest metamorphic peak to affect the remainder of the southern Appalachians (Drake et al., 1989). Metamorphism that is recorded in the Alabama allochthon is interpreted as having locally occurred during the Acadian or early Alleghanian orogenies (Figure 3.3) (Tull, 1978; Osberg et al., 1989; Quinn and Wright, 1993; Dennis and Wright, 1997; Miller et al., 1998).

The onset of the Taconian orogeny in the southern Appalachians is primarily evidenced in the sedimentary rock record. A lower Middle to Upper Ordovician foreland-basin deposit, the Blount clastic wedge, is centered in the Tennessee embayment and extends to the southwest onto the Alabama promontory (Figure 3.4) (Kay, 1942; Rodgers, 1953; Kellberg and Grant, 1956; Thomas, 1977; Shanmugan and Walker, 1980; Shanmugan and Lash, 1982). Near the BTZ, the Blount clastic wedge is indicated by the Sequatchie Formation northwest of, and within, the Birmingham fault system from the Middle Ordovician to the Pennsylvanian (Thomas, 1986; Ferrill, 1989; Bayona, 2003).
basement fault system and the Athens Shale southeast of the Birmingham fault system (Bayona, 2003). The clastic wedge succession, in general, thins to the northwest and south from the depocenter in the Tennessee embayment (Thomas and Neathery, 1980; Thomas et al., 2000). Graptolite faunal correlations, however, have been used to show that basal clastic wedge deposition in Alabama predates basal clastic wedge deposition in the Tennessee depocenter (Bradley, 1989; Finney et al., 1996; Bayona, 2003). Ordovician and Silurian Sequatchie-Red Mountain clastic facies pinch out southeastward between the post-Ordovician and post-Silurian unconformities in southeastern thrust sheets of the Alleghanian allochthon. The Sequatchie and Red Mountain facies are interpreted as being either the distal part of the Martinsburg-Shawangunk (Queenston) clastic wedge of the Pennsylvania salient (Figure 3.4) (Rodgers, 1971; Chowns, 1972; Dennison and Wheeler, 1975), or the distal upper part of the Blount clastic wedge of the Tennessee salient (Thomas, 1977). No stratigraphic record of the Taconic orogeny is recognized west of the Alabama promontory (Thomas, 1989).

Acadian Orogen

The Acadian orogen is hypothesized as being the result of an arc-continent collision occurring from early Devonian to Mississippian (Osberg et al., 1989). Evidence for the Acadian orogen in the southern Appalachians east of the Alabama promontory is equivocal. The foreland sedimentary succession in the BTZ contains no synorogenic clastic wedge (Figure 3.5) (Osberg et al., 1989). Silurian or Devonian-age diamictite in the Talladega thrust sheet containing basement-derived clasts, arkosic sandstone, Lower Devonian chert, and greenstone are overprinted by Devonian metamorphism (Tull, 1982; Tull et al., 1988). The Frog Mountain Sandstone, in the Valley and Ridge part of the thrust belt, is a discontinuous unit of feldspathic sandstone, shale, chert and carbonate (Ferrill and Thomas, 1988). These stratigraphic units are interpreted as detritus from transpressional basement structures that may have been the local representation of the Acadian orogeny along the eastern side of the Alabama promontory (Ferrill and Thomas, 1988). No stratigraphic record of Acadian orogenic events is recognizable west of the Alabama promontory. Distal siliciclastic and carbonate platform sedimentary rocks (Mississippian Maury Formation, Tuscumbia
Limestone, and Fort Payne Chert) are interpreted as evidence of Appalachian basin inundation in areas distal from clastic wedge deposition. These sedimentary rocks, deposited synchronously during Acadian tectonism, are part of the BTZ stratigraphic framework. Plutonic rocks within the Piedmont and the eastern Blue Ridge of North Carolina have been dated between 490 Ma to 460 Ma, using ion probe zircon geochronology (Thomas et al., 2000). The ages of plutons are interpreted alternatively as Acadian in age or as reset Taconian uplift ages (Osberg et al., 1989). Ion microprobe U/Pb dating of zircons collected from Appalachian plutons constrains the age even further from 400 to 350 Ma (Miller et al., 1998; Miller et al., 1999).

**Ouachita Orogen**

The initial progradation of Ouachita synorogenic clastic-wedge sediments from southwest of the Alabama promontory onto the continental shelf into the Black Warrior basin, in mid-Mississippian (late Meramecian) time, is interpreted as the beginning event of the Ouachita orogeny (Thomas, 1989). The post-Fort Payne stratigraphy in the BTZ is interpreted as part of the distal Ouachita clastic wedge deposit (Mississippian Floyd Shale, Pride Mountain Formation, and Hartselle Sandstone; Mississippian-Pennsylvanian Parkwood Formation; and Pennsylvanian Pottsville Sandstone) and/or foreland basin, carbonate platform facies equivalent (Bangor Limestone). Composition of the Ouachita clastic-wedge sediments indicates an arc-continent collision resulting from southward subduction of Laurentian continental crust (Mack et al., 1983). Thrusting associated with the Ouachita orogen began in the Middle Mississippian along the southwest side of the Alabama promontory (Thomas and Osborne, 1995). Emplacement of the Ouachita fold and thrust belt initiated down-to-southwest subsidence of the Black Warrior foreland basin and progradation of a synorogenic clastic wedge toward the northeast (Figure 3.6) (Thomas, 1989; Whiting and Thomas, 1994; Thomas and Osborne, 1995).

**Alleghanian Orogen**

The Alleghanian orogen is the result of the collision between Laurentia and Gondwanaland during late Mississippian to Late Permian time (Hatcher et al., 1989). The timing of the Alleghanian orogeny is diachronous. Zircon and Rb-Sr whole-rock
and 40Ar/39Ar cooling ages on Alleghanian plutons in the southern Appalachians range between 330 and 265 Ma (Dallmeyer et al., 1986; Secor et al., 1986).

The Alleghanian orogen in the southern Appalachians is characterized by frontal fold-and-thrust belts and composite crystalline thrust sheets that were transported cratonward. The BTZ was formed during the emplacement of the Alabama Alleghanian thrust belt. Several thrust sheets were emplaced during the orogeny. From the orogenic hinterland cratonward, these thrust sheets are identified as the Talladega, Yellowleaf, Dry Creek, Elliottsville, Helena, Jones Valley, Opossum Valley and Blue Creek. Ramp folds associated with thrust emplacement include the Columbiana syncline, the Kelley Mountain anticline, the Coosa synclinorium, the Cahaba synclinorium, the Birmingham anticlinorium spanning both the Jones Valley and Opossum Valley sheets and the Blue Creek syncline in the thrust sheet of the same name.

Stratigraphic evidence for the Alleghanian orogen in Alabama is present in the Mississippian-Pennsylvanian system that is at the fringe of the Pennington-Lee clastic wedge centered to the northeast in the Tennessee salient (Figure 3.8) (Thomas, 1972, 1974, 1977; Thomas and Neathery, 1980). The clastic wedge prograded from the northeast over the Mississippian carbonate facies (Bangor Limestone) on the Alabama promontory to the northeast of the BTZ. The Pennsylvanian components of the northeastward-prograding Ouachita clastic wedge in the Black Warrior basin merge with components of the southwestward-prograding Pennington-Lee clastic wedge northeast of the BTZ (Figure 3.8) (Thomas, 1989). Coarse-grained sediments prograding northwestward into central Alabama, during the late Early Pennsylvanian, are interpreted as being derived from northwestward-directed thrust sheets being emplaced onto the Alabama promontory subsequent to Ouachita and Pennington-Lee deposition (Horsey, 1981; Sestak, 1984; Thomas, 1989).

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Figure 3.1: Diagram showing how embayments and promontories on the Laurentian continental margin would evolve into salients and recesses in the Appalachian-Ouachita thrust belt (modified from Thomas, 1988).
Figure 3.2: Configuration of the Alabama promontory during Iapetos rifting. The Blue Ridge rift and Alabama-Oklahoma transform fault are the northern and southern borders of the Alabama promontory, respectively (modified from Thomas, 1993).
Figure 3.3: Taconic isograd map for the southern Appalachians (Osberg et al., 1988). The western limit of the Taconian isograds is eastern Tennessee and western Georgia. The rocks of the Alabama Piedmont (e.g., the Talladega belt) were not affected by metamorphism.
Figure 3.4: Late Ordovician paleocontinental reconstruction (modified from Stanley, 1986). The distribution of the Taconic Mountains and the Queenston delta, the distal equivalents of which were the Sequatchie and Red Mountain formations of Alabama (Blount clastic wedge).
Figure 3.5: Distribution of the foreland sedimentary succession during the Acadian orogeny. Note that there are no sedimentary rocks representing the Acadian event in central-southern Alabama. The distal parts of the Acadian clastic wedge pinch out in northern Alabama (modified from Stanley, 1986).
Figure 3.6: The Appalachian-Pennington-Lee clastic wedge overlaps with the Ouachita clastic wedge in northeastern Alabama (Thomas, in Hatcher et al., 1989). The presence of the Pennington-Lee clastic wedge provides stratigraphic evidence for the Alleghanian orogeny in Alabama.
Chapter 4: Regional Thrust Belt Geology of the Bessemer Transverse Zone

Introduction

The original map expression of the rifted Laurentian continental margin, expressed as embayments (concave oceanward bends in the rifted continental margin) and promontories (convex oceanward bends in the rifted continental margin), was inherited by subsequent, synorogenic tectonic outlines in the form of salients (convex cratonward bends in the Paleozoic thrust belts) and recesses (concave cratonward bends in the Paleozoic thrust belts) (Figure 4.1) (Rankin, 1976; Thomas, 1977). The United States part of the Alleghanian-Ouachita orogenic belt is characterized by large-scale sinuous curves that include three regional salients and intervening recesses (Figure 4.1) (Thomas, 1977). The BTZ is located in the Alabama recess, which is defined by an abrupt change in structural strike in northwest Georgia and by a large curve in strike beneath the Gulf Coastal Plain in western Alabama and eastern Mississippi.

Six transverse zones have been mapped in the Alabama recess; the Rising Fawn, Anniston, Harpersville, and Bessemer transverse zones extend across the entire Alleghanian allochthon; and the Clinchport and Rome transverse zones transect the intermediate to trailing allochthon structures in Georgia (Drahovzal and Thomas, 1976; Coleman 1988B; Groshong, 1988; Thomas, 1985B, 1990; Thomas and Osborne, 1995; Bayona, 2003). The BTZ is the southwestermost transverse zone exposed in the Alleghanian allochthon, extending from the Appalachian Plateau in the northwest to the Piedmont in the southeast.

Domains within the Alleghanian Allochthon

Introduction

The Appalachian thrust belt in Alabama is composed of internally coherent thrust sheets detached near the base (Cambrian Rome-Consasauga Formations) of the Paleozoic succession (Thomas, 1985B). Most of the frontal ramps within the Alabama thrust belt cut upward from the basal decollement through the entire Paleozoic succession to the surface (Thomas, 1985B; Thomas and Osborne, 1995). A few thrust ramps, however, do connect to upper-level detachment surfaces (top of the Knox Group, top of the Mississippian Fort Payne Chert-Tuscumbia Limestone and within the
Floyd Shale, and Mississippian-Pennsylvanian Parkwood Formation) (Thomas and Osborne, 1995). The strut of the stratigraphic succession is the carbonate succession of the Cambrian-Ordovician Knox Group; this unit controls the structural style of the Alabama Appalachians. The sequence of thrusting in the Alabama thrust belt is generally from southeast to northwest, a typical break-forward sequence (Thomas and Osborne, 1995). Some thrust faults in the BTZ, however, cut faulted and folded strata in the footwall (Jones Valley, Helena, Yellowleaf, Dry Creek, and Talladega faults) indicating break-back thrusting sequences (Thomas and Osborne, 1995).

The Alabama Alleghanian allochthon is divisible into four structural domains; the northwestern, central, southeastern, and Piedmont metamorphic domains (Figure 4.2) (Thomas, 1982). Domain subdivision is based on mappable structural styles and metamorphic grade of allochtonous stratigraphy.

**Northwestern Domain**

The frontal part of the thrust belt, in the Appalachian Plateau (northwestern domain), consists of broad, flat-bottomed synclines (Coalburg, Blue Creek) and elongate, narrow, asymmetric ramp anticlines (Sequatchie, Blue Creek) having relief of less than 10,000 ft (3,048 m) (Thomas and Osborne, 1995). The Coalburg syncline and Sequatchie anticline are structures in the footwall of the Opossum Valley thrust sheet (Figure 4.3). The Blue Creek thrust sheet terminates into the Blue Creek anticline at depth and contains the Blue Creek syncline in the hanging wall (Figure 4.3).

**Central Domain**

In the Valley and Ridge Province, the central domain, which borders the northwestern domain on the southeast, is characterized by folds associated with large thrust ramps (Birmingham anticlinorium, Cahaba synclinorium) that have relief greater (>13,000 ft/ >3,962.3 m) than the folds in the northwestern domain (Thomas, 1982; 1985B). The Birmingham anticlinorium spans the hanging walls of two thrust sheets, the Opossum Valley and the Jones Valley (Figure 4.3). The northwestern anticline and medial syncline of the Birmingham anticlinorium comprise the hanging wall of the Opossum Valley thrust sheet. The trailing southeastern anticline is in the hanging wall of the Jones Valley thrust sheet. The Cahaba synclinorium is the trailing structure of
the Jones Valley thrust sheet, forming part of a fold pair with the southeastern anticline of the Birmingham anticlinorium (Figure 4.3).

The Proterozoic basement beneath the central domain is downfaulted in the Birmingham basement fault system by more than 9,500 ft (2,895.6 m) in a down-to-southeast displacement (Thomas, 1982, 1985B). The Birmingham basement fault system is an extensional structure interpreted as having formed during Cambrian Ouachita rifting to the southeast (Thomas, 1991). The Cambrian Rome and Conasauga Formations increase in thickness in the downthrown block of the basement fault system, comprising the graben fill and confirming a Cambrian-age for the Birmingham graben system.

**Southeastern Domain**

The southeastern domain, bordering the central domain on the southeast, is comprised of low-angle, broad, multiple-level thrust sheets. The forelandmost thrust sheet is the Helena thrust, with the Coosa synclinorium in its hanging wall (Figure 4.3). The Dry Creek-Yellowleaf thrust sheet is the trailing thrust in this domain containing the Columbiana syncline and Kelley Mountain anticline in the hanging wall (Figure 4.3) (Thomas and Osborne, 1995).

**Piedmont Metamorphic Domain**

The Appalachian Piedmont borders the southeastern domain on the southeast (Figure 4.2) and is composed of three provinces separated by major faults; the Northern, Inner, and Southern Piedmont (Thomas and Neathery, 1980). The Northern Piedmont crosses the BTZ and is separated from the Valley and Ridge province by the Talladega fault (Thomas and Neathery, 1980). A sinuous outcrop trace across the BTZ indicates that the Talladega fault is locally folded (Osborne et al., 1988). The Talladega thrust sheet consists of a single, southeast-dipping panel of metasedimentary and metavolcanic rocks that are metamorphosed to a greenschist facies (Thomas and Neathery, 1980). The schists, gneisses, quartzites, amphibolites, and plutonic assemblages of the Piedmont have uncertain relationships to the Paleozoic succession in the thrust belt (Thomas, 1989).

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Figure 4.1: Diagram showing how embayments and promontories on the Laurentian continental margin would evolve into salients and recesses in the Alleghanian-Ouachita thrust belt (modified from Thomas, 1988).
Figure 4.2: Schematic map of Alleghanian thrust belt in Alabama and Georgia, showing the locations of four transverse zones (modified from Thomas, 1990). The Bessemer transverse zone is shaded in the blue-purple domain gradient.
Figure 4.3: Geologic map of the Bessemer transverse zone (modified from Szabo et al., 1988), showing the extent of the Bessemer transverse zone (between cross sections A and B).
Figure 4.3A: Explanation for Figure 4.3 geologic map.
Chapter 5: Regional Stratigraphy

Introduction

The BTZ spans most of the Alleghanian thrust belt as a northwest-southeast trending structural discontinuity (Figure 5.1). The stratigraphy at the BTZ is divided into two successions, on the basis of differences in metamorphic grade: the stratigraphy of the Valley and Ridge Physiographic Province and the stratigraphy of the Piedmont Physiographic Province. In the Valley and Ridge Physiographic Province, the stratigraphy is contained within three structural domains, each of which contains differing numbers of thrust sheets. The Black Warrior foreland basin and the Blue Creek thrust sheet are in the northwestern domain. Contained within the central domain is the Opossum Valley and Jones Valley thrust sheet. The Helena, Yellowleaf and Dry Creek thrust sheets are in the southeastern domain. The stratigraphy in the Piedmont Physiographic Province of the BTZ is contained in one structural domain, the Piedmont metamorphic domain. The Talladega thrust sheet, which contains the Talladega slate belt, is the only thrust sheet within the Piedmont metamorphic domain (Figure 5.1).

This chapter is organized into two parts: (1) a synthesis of tectonic depositional settings of stratigraphic units within the BTZ, and (2) a summary of the lithostratigraphy within the BTZ. All units in the BTZ are described in terms of lithology, thickness, areal distribution, and age relations.

Tectonic Stratigraphy of the Bessemer Transverse Zone

Introduction

The stratigraphic succession in the BTZ consists of a basal, Neoproterozoic-Cambrian, rifted-margin, siliciclastic succession overlain by a Cambrian-Lower Ordovician passive-margin, carbonate-bank facies. Overlying the carbonate-bank succession are relatively thin and laterally variable packages of Middle Ordovician to Lower Mississippian interbedded, interfingering clastic and carbonate rocks (Figure 5.2). The Middle Ordovician to Lower Mississippian succession includes Taconic and Acadian synorogenic clastic wedges, as well as carbonate shelf strata (Thomas and Neathery, 1980; Thomas, 1995). Mississippian-Pennsylvanian Ouachita-Alleghanian clastic-wedge rocks overlie a Mississippian carbonate shelf (Thomas, 1995).
The stratigraphic succession in Alabama contains four regional unconformities, the hiatus of the three upper unconformities increases to the south (Thomas and Osborne, 1995). From oldest to youngest, the unconformities are located at the base of the Middle Ordovician (post-Knox unconformity), the base of the Silurian, the base of the Lower Devonian, and the base of the Upper Devonian or Lower Mississippian (Thomas and Neathery, 1980).

**Syn-Iapetan Rift to Early Post-Rift and Passive Margin Stratigraphy**

The basal Kahatchee Mountain Group (Waxahatchee Slate), in the Piedmont metamorphic domain of the BTZ, contains syn-Iapetan rift sedimentary rocks associated with the Blue Ridge rift zone of the Alabama promontory (Guthrie, 1983, 1985; Tull and Guthrie, 1985; Tull et al., 1988; Thomas, 1991). Blue Ridge rift-zone rocks grade up section into late syn-rift to early post-rift sedimentary units mapped as the Chilhowee Group and Shady Dolomite, respectively (Thomas, 1991; Thomas and Osborne, 1995). In Alabama, the Chilhowee Group is exposed in only a few thrust sheets of the Valley and Ridge province and it is not exposed in the BTZ. In the Piedmont province, Chilhowee Group equivalents have been mapped in the BTZ as the Brewer, Stumps Creek, and Wash Creek Formations (Guthrie, 1994A,B,C,D). The Chilhowee Group is approximately 2,460 ft (750 m) thick in the southeastern thrust sheets, but northwest of the Birmingham basement fault system the Chilhowee is absent, where post-Chilhowee strata rest unconformably upon Proterozoic basement (Kidd and Neathery, 1976; Mack, 1980; Thomas and Osborne, 1995).

The Chilhowee Group grades up section into shallow-water carbonates of the Shady Dolomite. The deposition of the Shady Dolomite marks the beginning of passive-margin stabilization and tectonic quiescence along the Blue Ridge rift margin (Butts, 1926; Thomas, 1991). The Shady is the lowest part of a regionally extensive, shallow-marine, carbonate-bank facies of Cambrian and Ordovician age along the eastern margin of North America (Palmer, 1971; Thomas and Neathery, 1980). The Cambrian-Ordovician, carbonate-bank, facies in Alabama extends from the thrust belt into the Piedmont as the Sylacauga Marble Group (Thomas and Neathery, 1980; Tull et al., 1998; Tull, 1998).

The Rome-Conasauga clastic facies thins northwestward from greater than 7,500 ft (2,290 m) in the southeastern part of the thrust belt to approximately 3,000 ft (915 m) northwest of the Birmingham basement fault system (Kidd and Neathery, 1976; Thomas and Osborne, 1995; Thomas, 2001). Local thickness increase of the Rome and Conasauga formations is evidenced on seismic profiles and from well data. In the northwestern and central parts of the BTZ, the Rome and Conasauga formations thicken to approximately 10,000 ft (3,050 m) in a basement fault graben underlying the Alleghanian allochthon (Thomas, 2001).

The carbonate, chert, and minor amounts of quartz sandstone and sandy carbonate of the Knox Group are part of a Late Cambrian-Early Ordovician passive margin succession. The base of the Knox Group comprises the rift to drift transition in the Ouachita rift. The Knox Group oversteps the faults of the Birmingham basement fault system and extends entirely across the Alabama promontory, indicating the evolution of the passive margin along the entire Laurentian margin by the Late Cambrian (Thomas, 1991; Thomas and Osborne, 1995).

The Chilhowee through Knox lithologies record a major transgressive event on the Alabama promontory recording early post-rift subsidence of the passive margin along the Blue Ridge rift (Thomas et al., 2000). However, continuous deposition of the passive-margin sequence was interrupted by progradation of the Rome, Conasauga, and Knox quartz sand units from the Laurentian craton and Ouachita rift zone (Palmer, 1971; Thomas and Neathery, 1980; Thomas, 1991; Thomas et al., 2000). Thickness and
facies changes in the Rome through Conasauga succession in Alabama are interpreted as a result of opening of the Birmingham basement fault system during Ouachita rifting along the southwestern edge of the Alabama-Ouachita transform fault (Thomas, 1991; Thomas and Osborne, 1995). Carbonate successions within the Conasauga Formation suggest initiation of a passive margin shelf on elevated basement horsts (Thomas et al., 2000). Silicilastic rocks within the Rome and Conasauga formations indicate deposition in graben structures receiving syn-rift sediments. The irregular distribution of the carbonate and siliciclastic sedimentary rocks of the Rome and Conasauga formations indicates synsedimentary faulting along the Birmingham basement fault system (Thomas et al, 2000).

A major regression in the Ordovician is recorded by a major regional unconformity, the post-Knox unconformity. Because of this erosional episode, the Cambrian-Ordovician sequence is not preserved intact in any thrust sheet in the Alabama Appalachians (Thomas and Neathery, 1980).

**Upper Part of Passive-Margin Succession and Taconic/Acadian Foreland Basin Deposits**

The Middle and Upper Ordovician rocks of the Little Oak-Lenoir-Athens-Chickamauga assemblage are interpreted as a shallow- to deep-marine carbonate and siliciclastic facies unconformably overlying the Cambrian-Ordovician Knox Group (Thomas and Neathery, 1980). Locally, the base of the Middle Ordovician is marked by a chert-clast conglomerate, the Attalla Chert Conglomerate Member, which is an erosional remnant of the Knox Group (Thomas and Neathery, 1980). In the southeastern part of the BTZ, the Athens Shale, a black, graptolitic shale facies, is exposed (Thomas and Neathery, 1980). Regionally extensive bentonite beds are present in the carbonates and shales of part of the Middle-Upper Ordovician (Thomas and Neathery, 1980). All of the Middle-Upper Ordovician facies are truncated by a post-Ordovician unconformity. The unconformity is overstepped by different post-Ordovician units in different places in the Alleghanian thrust belt (Thomas and Neathery, 1980).

The Silurian Red Mountain Formation is a shallow-marine clastic sequence of sandstone, siltstone, shale, and sedimentary hematite that grades northwestward into a
carbonate facies in the Black Warrior basin (Thomas and Neathery, 1980). The Lower and Middle Silurian Red Mountain Formation unconformably overlies the Middle-Upper Ordovician rocks in the northwestern part of the Alleghanian thrust belt (Thomas and Neathery, 1980). The Red Mountain Formation, in turn, is truncated by a post-Silurian unconformity (Thomas and Neathery, 1980). The Silurian unit pinches out southeastward between the two bounding unconformities, along a line that trends more westerly than Appalachian structural strike. This group of formations (Athens to Red Mountain) is interpreted as being the distal part of the Taconic Blount clastic wedge centered in the Tennessee salient (Thomas, 1977; Chowns and McKinney, 1980).

The Lower and Middle Devonian, shallow-marine, Frog Mountain Sandstone unconformably overlies the Silurian Red Mountain Formation and, in turn, is unconformably overlain by post-Middle Devonian strata (Thomas and Neathery, 1980). To the southeast, the Frog Mountain Sandstone oversteps the Red Mountain Formation and rests unconformably upon Ordovician units (Thomas and Neathery, 1980). The Frog Mountain also pinches out to the southeast between the two bounding unconformities, and where it is absent the post-Middle Devonian unconformity rests upon Silurian or older strata (Thomas and Neathery, 1980). Lateral variation in both thickness and facies distribution is the rule for the Frog Mountain Sandstone (Thomas and Neathery, 1980).

The regionally extensive Mississippian Fort Payne Chert and Tuscumbia Limestone unconformably overlie the Frog Mountain Formation in the BTZ (Osborne et al., 1988). The units are interpreted as extensive, shallow-marine, shelf deposits post-dating the distal Acadian clastic wedge (Thomas, 1988; Thomas and Osborne, 1995).

**Mississippian-Pennsylvanian Syn-orogenic Clastic Wedge**

Mississippian siliciclastic rocks overlying the Mississippian Tuscumbia/Fort Payne carbonates mark the progradation of Ouachita clastic wedge sediments (Pride Mountain/Hartselle/Floyd/Parkwood formations) into the Black Warrior basin and Cahaba and Coosa synclinoria. The clastic wedge rocks interfinger with shallow, marine, distal foreland-basin carbonates (Monteagle and Bangor limestone) (Thomas, 1972, 1974, 1995; Thomas and Neathery, 1980). The shallow-marine to lagoonal mudstones of the Floyd Shale and the deltaic sandstones and mudstones of the
overlying Parkwood Formation are the Mississippian clastic wedge facies that form the southwest boundary of the distal foreland-basin Bangor carbonate facies (Thomas, 1972).

Linear Pride Mountain and Hartselle sandstones trend northwestward, parallel with the regional clastic-carbonate facies boundary, but perpendicular to Appalachian structural strike (Thomas, 1972; Thomas and Neathery, 1980; Thomas, 1995). The Bangor limestone of north-central Alabama (Jefferson County) (Thomas and Neathery, 1980) is bounded by two separate, regionally extensive clastic facies, one on the southwest, and the other on the northeast north of the BTZ (Thomas and Neathery, 1980).

Along the southeastern part of the thrust belt (Cahaba and Coosa synclinoria), the Pride Mountain/Hartselle succession is equivalent in thickness to the sections in the Black Warrior basin (Thomas, 1995). The Floyd-Parkwood deltaic clastic facies, however, is much thicker and extends much farther to the northeast in the Cahaba and Coosa synclinoria than in the Black Warrior basin (Thomas, 1995). In the Cahaba and Coosa synclinoria, the equivalent Bangor carbonate facies is restricted in extent and thickness. Southwestward transgression of the Bangor limestone over the Pride Mountain-Hartselle siliciclastic facies does not extend as far to the southwest as correlatives in the Black Warrior basin (Thomas, 1972; Osborne, 1985; Leverett, 1987; Osborne et al., 1991; Thomas, 1995).

All of the Mississippian clastic facies in Alabama are overlain by Pennsylvanian clastic-wedge facies (Thomas and Neathery, 1980). The Pottsville Formation is a coal-bearing, sandstone-shale succession that is twice as thick in the Cahaba and Coosa synclinoria as in the Black Warrior basin (Thomas and Neathery, 1980; Pashin, 1997). The section thickens to the southwest and west, across Alabama and Mississippi, toward the Ouachita orogen (Thomas, 1976; Thomas and Neathery, 1980).
Stratigraphy along the Bessemer Transverse Zone

Lithologies of the Valley and Ridge Province

Introduction

The Valley and Ridge Province in the BTZ is underlain by Cambrian to Pennsylvanian strata in six thrust sheets; in order from the Black Warrior foreland basin hinterlandward, the Blue Creek, Opossum Valley, Jones Valley, Helena, Yellowleaf, and Dry Creek thrust sheets. The stratigraphy of the Valley and Ridge Province is described in temporal succession, from oldest to youngest. This summation presents lithology, thickness, and areal distribution of each formation exposed along the BTZ.

Cambrian Rome Formation

The Rome Formation is divided into three unnamed members (Osborne, 1992, 1996, 1998). The lowermost 170 ft (52 m) of the Rome Formation is interbedded, gray-red-purple, pale-olive and olive-gray shale and mudstone containing thin beds of medium-dark-gray, argillaceous, micritic dolomite. The dolomite facies grades upward into gray-red siltstone and sandstone in the upper part of the lower unit. The middle unit is 75 ft (23 m) of interbedded olive-gray shale and mudstone and thin- to thick-bedded, dark-gray, locally laminated dolomite containing three beds of medium-gray, stylo nodular limestone. The upper 135 ft (40 m) of the section is interbedded, light-gray, gray-red-purple, and light-brown sandstone and olive-gray, gray-red-purple and very dark-gray shale. The sandstone is very fine grained, is thin to medium bedded, and contains ripple laminations. The sandstones are at the base and top of the upper unit, sandwiching an olive-gray, fossiliferous, shale-dominated succession. The Rome Formation crops out in the Helena and Talladega thrust sheets in the BTZ (Figure 5.3).

Cambrian Conasauga Interval

The Cambrian Conasauga interval contains all rocks above the Cambrian Rome Formation and below the Cambrian-Ordovician Knox Group (Osborne et al., 2000). Formally identified as the Conasauga Formation, including three dolomitic facies equivalents (Brierfield, Ketona, and Bibb dolomites) (Butts, 1910, 1926, 1927, 1940), the Conasauga interval is so named to encapsulate numerous facies variations across- and along-strike in the Alleghanian allochthon (Osborne et al., 2000). The tri-partite
subdivision of the Brierfield, Ketona, and Bibb dolomites is based on diagenetic variations, namely the presence and/or absence of chert and the dolomitization of limestone (Osborne et al., 2000). The presence of the dolomitic facies varies across the thrust sheets of the BTZ. Only the Ketona facies is present above the Conasauga in the Opossum Valley and Jones Valley thrust sheets (Figure 5.4) (Osborne et al., 2000). In the Helena thrust sheet, all of the Conasauga facies; the Brierfield, the Ketona, and the Bibb dolomites, are present (Osborne, et al., 2002) (Figures 5.4 and 5.5).

The Conasauga Formation varies significantly across the BTZ. The lower Conasauga is a medium to dark gray, thin-bedded, micritic limestone and dark-gray shale (Osborne et al, 2000). The middle and upper Conasauga is a dark gray, stylonodular, bioclastic and oolitic limestone (Osborne et al., 2000).

The Conasauga interval ranges in thickness from 2,000 to 2,600 ft (610 to 800 m) across much of the Alleghanian thrust belt (Thomas and Drahovzal, 1973). The Conasauga crops out in the Opossum Valley, Jones Valley, Helena, and Talladega thrust sheets (Figure 5.5) and has been mapped in the Concord and McCalla 7.5’ quadrangles (Plate 13).

**Cambrian Brierfield Dolomite**

The Brierfield Dolomite is a medium- to medium-dark gray, fine- to medium-crystalline dolomite that is thin- to medium-bedded and contains horizontal to wavy laminations (Osborne, 1992). Dark, nodular, stringer and cavernous chert characterize the unit. The Brierfield is ranges from 150 ft (45 m) to 250 ft (75 m) in the BTZ and crops out in the Helena thrust sheet.

**Cambrian Ketona Dolomite**

The Ketona Dolomite is a very light- to medium-dark-gray, fine- to coarse-crystalline, medium- to massive-bedded dolomite (Osborne, 1992). The lower part of the Ketona contains beds of mottled, light-medium-gray and dark-gray dolomite interbedded with a thin interval of dark-gray to black, thin-bedded, argillaceous shale (Osborne, 1992).

The boundary between the Conasauga and Ketona in the Opossum Valley and Jones Valley thrust sheets is a gradational facies change from dolomitic limestone to a
limey dolomite that is a cross-bedded, ooid grainstone and edgewise conglomerate (Osborne et al., 2000). The Ketona is interpreted as a variably dolomitized facies of the Conasauga limestone (Osborne et al., 2000). Thickness of the Ketona Dolomite is approximately 300 ft (90 m). The Ketona Dolomite crops out in the Opossum Valley, Jones Valley, and Helena thrust sheets and has been mapped in the Concord and McCalla 7.5’ quadrangles (Plate 13).

*Cambrian Bibb Dolomite*

The Bibb Dolomite is exceedingly similar to the Brierfield lithologically; were it not for the presence of the Ketona Dolomite separating the Brierfield and Bibb Dolomites, the two would be indistinguishable (Osborne et al., 1998). The Bibb Dolomite is medium- to medium-dark-gray, fine- to medium-crystalline dolomite that is thin- to medium-bedded and contains horizontal- to wavy laminations (Osborne et al., 1998). Dark, nodular, stringer, and cavernous chert characterize the unit.

The Bibb Dolomite crops out in the Helena thrust sheet in the BTZ.

*Cambrian-Ordovician Knox Group*

The top of the Knox Group is an erosional surface that is mapped as the post-Knox unconformity. The Helena thrust sheet marks a transition in the stratigraphy of the Knox Group in the thrust belt (Figure 5.6) (Osborne and Raymond, 1992). Outcrops of the Knox Group exposed to the east of the Helena thrust fault (i.e., Yellowleaf and Dry Creek thrust sheets) generally include the most complete sections of the Knox stratigraphy preserved beneath the post-Knox unconformity (Upper Cambrian Copper Ridge Dolomite, Lower Ordovician Chepultepec Dolomite, Longview and Newala limestones, Lower Middle Ordovician Odenville Limestone) (Butts, 1926, 1927, 1940; Osborne and Raymond, 1992; Osborne et al., 1998). Alternatively, exposures of the Knox Group to the west of the Helena fault (i.e., Opossum Valley, Blue Creek, and Jones Valley thrust sheets) contain a less complete section of the unit beneath the post-Knox unconformity; generally only the lower part of the Knox (Copper Ridge interval) is preserved (Butts, 1926; Hooks, 1985; Roberson, 1988; Osborne and Raymond, 1992).
**Cambrian Copper Ridge Dolomite**

Generally, the Copper Ridge Dolomite is a light- to medium-gray, fine- to coarse-crystalline, siliceous, thick-bedded dolomite that is vuggy and algal laminated (Butts, 1926; Osborne, 1992). Only the Copper Ridge Dolomite represents the Knox Group in the Concord and McCalla 7.5’ quadrangles (Plate 13), the remainder of the unit is eroded at the post-Knox unconformity. The Copper Ridge is approximately 2,000 ft (610 m) thick in the Opossum Valley, Blue Creek, and Jones Valley thrust sheets.

**Ordovician Chepultepec Dolomite**

The Chepultepec Dolomite ranges from 1,375 ft (420 m) to 1,520 ft (463 m) thick. The lower 350 ft (105 m) of the Chepultepec Dolomite is a light-gray, compact, thick-bedded limestone, with interbedded dolomite (Butts, 1926). Overlying the lowermost limestone of the Chepultepec is a dark-blue, coarse-crystalline, thin- to thick-bedded, siliceous dolomite. The upper 700 to 800 ft (213 to 243 m) of the Chepultepec contains a soft, cavernous and fossiliferous chert in a thin-bedded to shaly limestone sequence (Butts, 1926; Batchelder, 1984; Osborne, 1992).

**Ordovician Longview Limestone**

The Longview Limestone is composed of light-gray, peloidal, quartz-sand-bearing, thick-bedded, cherty limestone with interbedded dolomite (Butts, 1926; Hooks, 1985, Osborne, 1992). Thin-bedded, stromatolitic chert and nodular chert are common in the unit (Osborne and Raymond, 1992). The unit ranges from 200 ft (61 m) to 500 ft (152 m) in thickness.

**Ordovician Newala Limestone**

The Newala Limestone is composed predominantly of a light- to dark-gray, intraclastic, peloidal, thick-bedded limestone with thin interbeds of laminated dolomite (Butts, 1926; Puckett et al., 1990). The unit ranges from 500 ft (152 m) to 1,000 ft (304 m) in thickness, except at Pratt’s Ferry, Bibb County (Butts, 1926; Ferrill, 1989), where the post-Knox unconformity eroded the Newala to a thickness of 200 ft (60 m) (Butts, 1926; Hooks, 1985).
**Ordovician Odenville Limestone**

The Odenville Limestone contains a lower unit that is a thin, burrow-mottled, dolomitic limestone and an upper unit that is astylonodular, chert-nodule-bearing, fossiliferous limestone (Roberson, 1988). Thickness variations are interpreted as being the result of the post-Knox unconformity, the maximum thickness of 366 ft (111 m) is in the Helena thrust sheet (Roberson, 1988).

**Ordovician Lenoir Limestone**

The Lenoir Limestone is divided into the Mosheim Limestone Member, the Lee Branch Member, and the upper Lenoir Limestone (Roberson, 1988). The limestone is a unique marker horizon for mapping the Knox-Lenoir contact, or the post-Knox unconformity (Osborne, 1996). The Lenoir Limestone is mapped as a consolidated unit with the Little Oak and Athens formations in the Helena thrust sheet in the BTZ (Figure 5.7). The formation is not mapped on the other thrust sheets of the transverse zone.

Medium- to dark-gray, thick-bedded, micritic limestone comprises the Mosheim Limestone Member. The Lee Branch Member is a light- to dark-gray, coarse-grained, limestone containing ooids, peloids, intraclasts, and fossil fragments (Roberson, 1988). The upper Lenoir is a medium-dark-gray to dark-gray, fine-grained to fine-crystalline, medium- to thick-bedded, argillaceous, fossiliferous, micritic limestone (Butts, 1926; Thomas and Drahovzal, 1973; Osborne, 1996). The upper and lower contacts of the basal limestone are interpreted as erosional; however, conodont investigations indicate that the unit-bounding unconformities do not span large tracts of time (Roberson, 1988; Osborne, 1996).

**Ordovician Little Oak Limestone**

The Little Oak Limestone is very dark-gray, fine-grained to micritic, thin- to thick-bedded and contains thin irregular and anastomosing partings of clay (Benson, 1986; Osborne, 1992, 1996). Very similar in lithostratigraphy to the underlying Lenoir Limestone, the distinguishing mapping characteristic of the Little Oak is the abundance of fossils and fossil fragments in the unit (Osborne, 1992; 1996). The Little Oak Limestone is mapped with the Lenoir and Athens formations only in the Helena thrust sheet of the BTZ (Figure 5.7).
**Ordovician Athens Shale**

Black, fissile shale, the Athens also includes layers of impure, dark-gray to black, argillaceous, micritic limestone, the proportion of which increases to the north (Thomas and Drahovzal, 1973). The Athens is generally less than 295 ft (90 m) thick (Thomas and Osborne, 1995). The Athens Shale is mapped with the Lenoir and Little Oak limestones as cropping out in the Helena thrust sheet of the BTZ (Figure 5.7).

**Ordovician Chickamauga Limestone**

The Chickamauga Limestone is composed of medium-light gray, fenestral micrite and light-gray, crystalline limestone overlain by medium-dark gray, micritic, medium- to thick-bedded, pure to argillaceous limestones (Osborne, 1992; 1996). The Attalla Chert Conglomerate Member is located at the base of the Chickamauga Group and contains subangular to rounded pebbles, cobbles, and boulders of light- to medium-gray chert in a chert matrix (Osborne, 1992, 1996). In the middle part of the Chickamauga Limestone, several thin bentonite beds have been mapped (Thomas and Drahovzal, 1973).

The Chickamauga Limestone is varies from 820 ft (250 m) to 655 ft (200 m) thick in the BTZ and crops out in the Blue Creek and Jones Valley thrust sheets (Thomas, 1982; Bayona, 2003). The limestone has been mapped in the Concord and McCalla 7.5’ quadrangles (Figure 5.8).

**Silurian Red Mountain Formation**

The Red Mountain Formation contains sandstone, siltstone, shale, and hematite with thin interbeds of bioclastic limestone (Thomas and Drahovzal, 1973). Local facies variations in the Red Mountain Formation have been attributed to syn-depositional deformation along the Birmingham anticlinorium (Bearce, 1973; Wu, 1989). The Red Mountain Formation reaches a maximum thickness of 500 ft (152 m) in the BTZ. The Red Mountain Formation crops out in the Blue Creek and Jones Valley thrust sheets and has been mapped in the Concord and McCalla 7.5’ quadrangles (Figure 5.9).

**Devonian Frog Mountain Sandstone**

The Frog Mountain Sandstone is a thin, but complex unit that is unconformity-bounded and bears several intraformational unconformities (Ferrill, 1984).
formation is a medium- to very coarse-grained sandstone that consists of well-rounded quartz and scattered feldspar grains (Thomas and Drahovzal, 1973). Thickness and lithology vary locally. The upper part of the formation is typically a coarse-grained sandstone; whereas, the lower part of the formation contains fine-grained sandstones, siltstones, shales, and chert beds (Thomas and Drahovzal, 1973). Finer grained parts of the sandstone and siltstone lithologies are commonly interbedded with clay shale. The lower part of the unit includes thin beds of chert, which are interlayered with the clay shale. In some locations, the lower part of the formation also contains interbeds of limestone (Thomas and Drahovzal, 1973). The sandstones in the Frog Mountain are compositionally similar to arkosic sandstone and granite-clast-bearing diamicites in the Talladega slate belt (Ferrill and Thomas, 1988). A fossiliferous, shallow-marine chert in the Talladega slate belt (Jemison Chert, part of the Talladega Group) is biostratigraphically equivalent to the Frog Mountain (Thomas and Osborne, 1995).

The Frog Mountain Formation is generally less than 65 ft (20 m) thick (Thomas and Osborne, 1995). The Frog Mountain Formation crops out in the Blue Creek, Jones Valley, and Yellowleaf thrust sheets (Figure 5.10).

**Devonian Chattanooga Shale**

The Chattanooga Shale is a brown-black to gray-black, silty, organic shale that contains lesser amounts of light- to dark-gray, fine-grained pyritic and phosphatic sandstone (Raymond et al., 1988).

The Chattanooga Shale crops out in the Jones Valley thrust sheet.

**Mississippian Fort Payne Chert/Tuscumbia Limestone**

The Fort Payne Chert is a thin- to medium-bedded, medium- to dark-gray-orange-white chert with undulatory, thin- to medium-bedding and layers containing abundant invertebrate fossils (Osborne, 1992, 1995, 1996; Osborne et al., 1998). A carbonate facies is also present within the unit as a medium-gray, nodular-bedded, micritic limestone and light-medium-gray, irregularly bedded, fine-crystalline, gray chert-bearing dolomite (Osborne, 1992, 1995, 1996; Osborne et al., 1998). The Tuscumbia Limestone overlies the Fort Payne Chert in northwestern Alabama.
The units range from 100 to 250 ft (30 to 76 m) in the Concord and McCalla 7.5’ quadrangles to less than 3 ft (1 m) thick near Kelley Mountain in the Yellowleaf thrust sheet. The Fort Payne-Tusculumbia formations crop out in the Blue Creek, Jones Valley, Helena, Yellowleaf, and Dry Creek thrust sheets (Figure 5.11).

**Mississippian Pride Mountain Formation**

The Pride Mountain Formation is a medium- to dark-gray, fissile, siderite-nodule-bearing, clay shale (Thomas, 1972). Interbedded with the clay shale are very rare dark-red and green mudstones, calcareous clay shales, shaly argillaceous limestones, and packages containing variable combinations of sandstone and limestones (Thomas, 1972). The Pride Mountain Formation is distinguishable in outcrop only where the Mississippian Hartselle quartz sandstones overlie the unit. Where the Hartselle Formation is absent, the Pride Mountain Formation is indistinguishable from the Mississippian Floyd Shale; and as such, the entire shale succession is assigned to the Floyd Shale.

The Pride Mountain Formation is approximately 120 ft (36 m) thick in the BTZ. The Pride Mountain Formation crops out in the Blue Creek and Jones Valley thrust sheets and has been mapped in the Concord and McCalla 7.5’ quadrangles (Figure 5.12).

**Mississippian Hartselle Sandstone**

This unit is light gray to tan, fine- to medium-grained, well-sorted, thick- to massive-bedded quartz sandstone. The unit is partly calcareous and contains interbeds of clay shale (Raymond et al., 1988).

The Hartselle Formation ranges from a feather edge to 160 ft (49 m) thick in the BTZ. The unit pinches out to the southwest along strike in the Blue Creek thrust sheet in the Concord and McCalla 7.5’ quadrangles (Plate 13). The Hartselle Sandstone crops out in the Blue Creek and Jones Valley thrust sheets in the BTZ (Figure 5.13).

**Mississippian Floyd Shale**

The Floyd Shale is a dark-gray to black, fissile, siderite-nodule and siderite-claystone-nodule-bearing shale. By definition, the Floyd is devoid of sandstone, because the presence of the lowest sandstone unit makes the base of the overlying
Parkwood Formation; however, a few thin beds of sandstone are present near the base of the shale, below the thicker sandstone units that define the Floyd-Parkwood contact (Thomas, 1972).

The Floyd Shale ranges from 87 to 400 ft (26 to 124 m) thick in the BTZ and crops out on all thrust sheets of the BTZ.

**Mississippian Bangor Limestone**

The Bangor Limestone is a medium- to medium-light-gray, medium-bedded, bioclastic, oolitic limestone that is interbedded with micrite, shaly argillaceous limestone, calcareous shale, and dolomite (Thomas, 1972). Dark-red and olive-green mudstones are present in the upper parts of the formation (Thomas, 1972). The Bangor Limestone thins and grades southwestward into the Floyd Shale.

The Bangor Limestone is mapped in conjunction with the Floyd Shale in the Concord and McCalla 7.5’ quadrangles and the Floyd Shale thicknesses listed above include the Bangor interval. The Bangor crops out in the Blue Creek and Jones Valley thrust sheets in the BTZ.

**Mississippian-Pennsylvanian Parkwood Formation**

The Parkwood Formation is primarily medium- to dark-gray shale and mudstone containing interbedded units of light- to medium-gray sandstone (Thomas, 1972; Osborne, 1996). The sandstones are very fine to fine grained and thin to locally thick bedded. Coals and carbonaceous shales are present throughout the unit, but are more prevalent in the upper levels of the Parkwood (Osborne, 1996).

The Parkwood Formation ranges from 400 to 820 ft (121 to 250 m) thick in the BTZ and crops out in the Opossum Valley, Blue Creek, Jones Valley, Helena, and Yellowleaf thrust sheets of the BTZ (Figure 5.14).

**Pennsylvanian Pottsville Formation**

The Pottsville Formation is divided into two parts. The lower unit contains quartz-pebble, conglomerate-bearing, quartzose sandstones separated by thick shale sequences (Osborne, 1996, 1998). The upper part of the Pottsville Formation contains dark-gray, silty shale with interbedded, laterally discontinuous, light- to medium-gray lithic sandstones; and, in the Cahaba synclinorium, polymictic conglomerates are
present (Osborne, 1996, 1998). The Pottsville is coal bearing and contains coal underclays, as well as some marine shales. The lower Pottsville is divided into three members, the Shades, Pine, and Chestnut sandstone members (Osborne, 1996, 1998). The upper Pottsville includes the Wolf Ridge and Straight Ridge Sandstone Members (Osborne, 1996, 1998). The remainder of the upper Pottsville is undifferentiated.

The Shades Sandstone Member is a very light- to light-gray, fine-grained, quartz-pebble-bearing, quartzose sandstone (Osborne, 1996, 1998).

The Pine Sandstone Member is very light-gray, fine- to coarse-grained, quartzose sandstone containing common to abundant quartz pebbles (Osborne, 1996, 1998). Medium- to coarse-grained sandstones are the predominant lithology.

Quartzose sandstone comprises the Chestnut Sandstone Member of the Pottsville Formation. The unit varies in thickness along the strike of the Cahaba synclinorium, ranging from 100 ft (30.5 m) in the northeast to 200 ft (61 m) in the southwest (Raymond et al., 1988).

Very light-gray, fine-grained, quartzose sandstone comprises the Wolf Ridge Sandstone Member (Osborne, 1996, 1998).

Fine- to medium-grained, lithic sandstone comprises the Straight Ridge Sandstone Member.

The Pottsville Formation ranges in thickness from 900 to approximately 8,000 ft (275 to 2,438 m) in the BTZ and crops out in the Blue Creek, Jones Valley, Helena and Yellowleaf thrust sheets (Figure 5.15).

Lithologies of the Piedmont Physiographic Province

Introduction

The Piedmont Physiographic Province in the BTZ is underlain by Neoproterozoic to Lower Devonian, unmetamorphosed to lower greenschist rocks emplaced along the Talladega thrust fault. The section of the Piedmont province located in the BTZ is known regionally as the Talladega slate belt and is located in the Talladega thrust sheet. The stratigraphy of the Talladega slate belt is divided into four parts: the lower elastic sequence of the Kahatchee Mountain Group, conformably overlain by the Sylacauga Marble Group, unconformably overlain by the elastic
Talladega Group, which in turn is conformably overlain by a volcanic sequence, the Hillabee Greenstone (Bearce, 1973; Carrington, 1973; Guthrie, 1985; Tull, 1979, 1982, 1985; Tull et al., 1988). With the exception of the Hillabee Greenstone, all of the Talladega slate belt rocks are interpreted as being partly equivalent to stratigraphic units in the adjacent thrust belt, on the basis of lithostratigraphic and biostratigraphic evidence (Tull and Guthrie, 1983, 1985; Harris et al., 1984; Tull et al., 1988; Guthrie, 1989). “Differences in stratigraphic nomenclature that still exist between lithologic units in the Piedmont and the thrust belt are due to metamorphic variability, subtle sedimentological facies variations, the occurrence of several unique stratigraphic units in the Talladega belt, and the paucity of fossils in Piedmont lithologies” (Guthrie, 1994, p.27).

**Neoproterozoic-Cambrian? Kahatchee Mountain Group**

The Kahatchee Mountain Group is heterogeneous assemblage of fine-grained metaclastic rocks containing minor amounts of marble (Tull, 1982, Tull et al., 1988). Divided into four formation subdivisions, the Kahatchee Mountain Group contains the Waxahatchee Slate, Brewer Phyllite, Stumps Creek Formation, and Wash Creek Slate (Butts, 1926, 1940; Warren, 1969; Carrington, 1973; Guthrie, 1985). The Waxahatchee Slate has been lithostratigraphically correlated with the upper part of the syn-Iapetan rift Ocoee Supergroup in the Great Smoky Mountains, Tennessee (Guthrie, 1983, 1985; Tull and Guthrie, 1985). The Brewer, Stumps Creek, and Wash Creek Formations are correlated with the Chilhowee Group, which overlies the Ocoee Supergroup in the southern Appalachians (Butts, 1926, 1940; Guthrie, 1985, 1994A, B, C, D; Prouty, 1922, Rodgers and Shaw, 1962; Shaw, 1970; Tull, 1982; Tull and Guthrie, 1985).

**Neoproterozoic-Cambrian? Waxahatchee Slate**

Geologic mapping by Guthrie (1985) in the Ozan and Shelby 7.5’ quadrangles has delimited two member subdivisions of the Waxahatchee Slate: the Buxahatchee Creek Member and the Long Branch Sandstone Member. The Buxahatchee Creek Member is 4,242 ft (1,293 m) thick and composed of black to dark-gray, green, and red, interlayered, arenaceous and sericitic slates (Guthrie, 1994A, B, C, D). The upper part of the Buxahatchee Creek contains dark-gray, very fine-grained, thin-bedded limestone
beds containing claystone laminae (Guthrie, 1994A, B, C, D). The Long Branch Sandstone Member is 2,494 ft (760 m) thick and contains dark-gray to green, very fine-grained, micaceous, feldspathic, parallel-bedded sandstone intercalated with siltstone. Calcareous sandstone is present in the upper parts of the unit (Guthrie, 1994A, B, C, D). The Waxahatchee Slate crops out in the Talladega thrust sheet (Figure 5.16).

*Neoproterozoic-Cambrian? Brewer Phyllite*

A very heterogeneous mix of metasedimentary rocks, the Brewer Phyllite contains varying proportions of dark-red and green phyllites; micaceous, calcareous and arkosic sandstones and siltstones; felspathic, hematitic and conglomeratic wackestones; micaceous, feldspathic, and arenaceous siltstones; dolomitic marbles and conglomeratic sandstones (Guthrie, 1994A, B, C, D). Thickness of the Brewer Phyllite varies from 3,051 ft (930 m) in the Columbiana syncline and thins to 1,880 ft (575 m) to the southeast and southwest (Guthrie, 1994 A, B, C, D).

The unit has been divided into two members, the Sawyer Limestone and the conglomeratic sandstone member.

The Sawyer Limestone is interlayered, thin-bedded, dolomitic marble and slate. Originally described by Butts (1926, 1940) as limestone bearing, the Sawyer has been mapped as marble, not limestone, in Guthrie’s (1994) investigation. The marbles in the lower parts of the unit are pink to light gray and fine grained; bedding varies from 6 to 12 in (15 to 30 cm) thick (Guthrie, 1994A, B, C, D). Marbles in the upper part are gray to light brown, medium to coarsely crystalline, and in beds as much as 2 ft (0.6 m) thick (Guthrie, 1994A, B, C, D).

The conglomeratic sandstone member is light-gray, poorly sorted, orthoconglomerate/conglomeratic sandstone. Clasts in the member are subangular blocks of sandstone and laminated siltstone. An intraformational disconformity is interpreted from the presence of an irregular basal contact and siltstone inclusions near the base of the unit (Guthrie, 1994A, B, C, D). The upper part of the conglomeratic sandstone member is white, poorly sorted, conglomeratic, feldspathic sandstone. Bedding is graded and 4 to 24 in (10 to 61 cm) thick. The member is 56 ft (17 m) thick.
east of Ozan; however, it is thin to absent in the Montevallo and Shelby 7.5’ quadrangles (Guthrie, 1994A, B, C, D).

The Brewer Phyllite crops out in the Talladega thrust sheet (Figure 5.17).

*Neoproterozoic-Cambrian? Stumps Creek Formation*

The Stumps Creek Formation is characterized by olive-gray to gray-olive-green shale; micaceous, arenaceous siltstone, and fine-grained sandstone. Bedding ranges from thin to massive; fine-grained, pelitic units contain millimeter-scale laminations (Guthrie, 1994A, B, C, D). Thickness of the Stumps Creek Formation varies from approximately 2000 ft (610 m) to approximately 2,700 ft (825 m) in the Talladega thrust sheet (Guthrie, 1994A, B, C, D). A quartzite unit, however, is a distinctive mid-section marker horizon and is named the Watson Creek Sandstone Member (Guthrie, 1994A, B, C, D). Dark-green, fine- to medium-grained, thin- to massive-bedded, pyritic, feldspathic sandstone is the dominant lithology within the Watson Creek Sandstone Member. Two sandstone units are separated in the Watson Creek by interlayered shale and siltstone units typical of the remainder of the Stumps Creek Formation (Guthrie, 1994A, B, C, D). A thickness of 778 ft (237 m) has been measured for the Watson Creek Member in the southernmost mapped outcrop areas in the Lay Dam 7.5’ quadrangle, (Guthrie, 1994A, B, C, D). The Stumps Creek crops out in the Talladega thrust sheet.

*Neoproterozoic-Cambrian? Wash Creek Slate*

Earlier investigations (Butts, 1926, 1940; Osborne et al., 1988, 1998) mapped the Wash Creek as equivalent to the Weisner or Weisner-Wilson Ridge Formation, a thrust belt unit that is part of the Chilhowee Group (Guthrie, 1994A, B, C, D). The Wash Creek Slate is subdivided into four members; the ferruginous sandstone member, the Hillsdale Sandstone Member, the Kalona Quartzite Member, and the Mount Zion Church Member (Guthrie 1994A, B, C, D). Where the upper and lower contacts are preserved (in the Jemison, Ozan, Lay Dam, Shelby, and Talladega Springs 7.5’ quadrangles), the unit is approximately 5,988 ft (1,825 m) thick.

The ferruginous sandstone member is a dark-red, coarse-grained, calcareous, feldspar-chlorite-hematite-quartz wackestone that is approximately 70 to 100 ft (21 to
30 m) thick (Guthrie, 1994A, B, C, D). Bedding is generally massive; horizontal-laminations, graded-bedding, and cross bedding are present locally. Very dark-red, horizontally laminated siltstones, micaceous-hematitic siltstones, and fine-grained, gray-green, calcareous sandstones are interlayered with the wackestone (Guthrie, 1994A, B, C, D).

The Hillsdale Sandstone Member is dominated by black, horizontally laminated, clay-slate or shale. Interspersed in the lower part of the unit is a thin-bedded, medium-gray, laminated siltstone and fine-grained sandstone. Dark-gray, laminated, micaceous siltstone and medium- to dark-gray, thin-bedded, pyritic, feldspathic sandstone are present in the upper part of the member (Guthrie, 1994A, B, C, D). In the sandstone and siltstone units, parallel, lenticular and flaser beds; oscillation and cross-laminated current ripples; scour-and-fill channels; and liquefaction features are common (Guthrie, 1994A, B, C, D).

Forming a discontinuous belt across northern Chilton County, the Kalona Quartzite underlies the highest ridges of Columbiana Mountain (Guthrie, 1994A, B, C, D). The section is 1,099 ft (334 m) thick in the Columbiana area, where it is best preserved, containing white- to light-gray, medium- to coarse-grained, sandstone (Guthrie, 1994A, B, C, D). Guthrie (1994A, B, C, D) mapped four medium-grained to conglomeratic, feldspathic, cross-bedded, sandstone units. Each sandstone unit is underlain by black shale and siltstone and overlain by thin- to medium-bedded, fine- to medium-grained, quartz arenite. Bedding varies from medium- to thick-bedded, cross beds and channel structures are primary features (Guthrie, 1994A, B, C, D).

The Mount Zion Church Member is a black, carbonaceous, graphitic, laminated to massive, dolomitic shale/slate that is locally stratified with thin-bedded, dark-gray, micaceous siltstone (Guthrie, 1994A, B, C, D). The unit is exposed on the slopes of Columbiana Mountain and is approximately 226 ft (68 m) thick (Guthrie, 1994A, B, C, D).

The Wash Creek Slate crops out in the Talladega thrust sheet (Figure 5.18).
Cambrian Shady Dolomite

Mapping relations of the unit mapped on Columbiana Mountain (Figure 5.19) are the sole source of information on the lithology of the Shady, which is a light-gray to gray-orange, thin- to medium-bedded, micritic to medium-grained dolomite (Guthrie, 1994A, B, C, D). Massive, limonitic chert characteristic of the unit is not present in the BTZ (Guthrie, 1994A, B, C, D). Thickness of the unit in the BTZ is estimated from 600 to 750 ft (182 to 228 m) (Guthrie, 1989).

Cambrian-Ordovician Sylacauga Marble Group

The Sylacauga Marble is a carbonate succession composed of interlayered calcite and dolomite marble, metachert, and metapelitic rocks (Tull, 1982, 1985; Raymond et al., 1988). The unit has been divided into five parts: the Jumbo Dolomite, Fayetteville Phyllite, Shelvin Rock Church Formation, Gooch Branch Chert, and Gantts Quarry Formation (Tull, 1982; Raymond et al., 1988). Only the Jumbo Dolomite crops out in the BTZ and will be described in this section. A regional unconformity (pre-Lay Dam unconformity) truncates the Sylacauga Marble Group, which is approximately 11,500 ft (3,505 m) to the northeast in Georgia and thins to a “feather edge”, (Tull et al., 1988, p; 1293) to the southwest in Alabama (Tull et al., 1988). Northwest of the BTZ, the “feather edge” of the Sylacauga Marble is represented by the Jumbo Dolomite in the Talladega thrust sheet southeast of the Kelley Mountain anticline (Figure 5.20). Southwest of the BTZ, the Sylacauga Marble Group is unconformably absent in the Columbiana syncline (Figure 5.20).

Order of stratigraphic succession, similarity of rock type and biostratigraphic data (Early Cambrian archaeocyathids in the Jumbo Dolomite, Early Ordovician conodonts in the Gantts Quarry Formation) are evidence for correlation of the Sylacauga Marble Group to Cambrian and Ordovician carbonate platform rocks in the northwestern Alleghanian thrust belt (McCalley, 1897; Prouty, 1916; Shaw, 1970; Gilbert, 1973; Tull, 1982; Bocz, 1985; Tull et al., 1988)

Lower Cambrian Jumbo Dolomite

The Jumbo Dolomite is a medium- to light-gray, fine- to coarse-crystalline, silty, sandy, intraclastic, laminated to massive-bedded dolomite (Tull, 1982; Raymond et al.,
The lower part of the Jumbo is a thin-bedded ribbon dolomite that grades upsection into massive, thick-bedded dolomites (Tull et al., 1988). Metachert is present mid-unit (Tull et al., 1988). Biostratigraphic (archaeocyaths {Class Irregulares, Order Archaeocyathida and Superfamily Tumulocyathacea, Class Regulares, Order Ajaicicyathida}, echinoderm plates, possible trilobite fragments) and lithostratigraphic evidence have been used to correlate the Jumbo Dolomite with the Lower Cambrian Shady Dolomite that is present in the thrust belt in Alabama, Georgia, Tennessee and Virginia (Hull, 1920; Resser, 1938; Butts and Gildersleeve, 1948; Kesler, 1950; Balsam, 1974; Bearce and McKinney, 1977). The Jumbo Dolomite crops out in the Talladega thrust sheet (Figure 5.20).

**Silurian-Devonian Talladega Group**

The Talladega Group is described by Tull (1982) as a predominantly clastic sequence beneath the Hillabee metavolcanic sequence and above the pre-Lay Dam unconformity. The magnitude of the pre-Lay Dam unconformity increases to the southwest. In the BTZ, the Talladega Group unconformably overlies the upper Kahatchie Mountain Group, where the Sylacauga Group is absent in the Columbiana syncline (Figure 5.21) (Shaw, 1970).

The clastic sequence is divided into upper and lower units. The lower unit contains calcareous slate and chlorite-phylite, calcareous arkose and quartzite, and thin-bedded limestones (Raymond et al., 1988). Graphitic slates and phyllites, coarse-grained arkoses, and conglomeratic quartzites comprise the upper unit of the Talladega Group (Raymond et al., 1988). The group is formally subdivided into five formation subdivisions; the Lay Dam Formation, the Cheaha Quartzite, the Butting Ram Sandstone, the Jemison Chert, and the Chulafinne Schist. The Cheaha Quartzite and Chulafinne Schist do not crop out in the BTZ and will not be discussed in this section.

**Silurian-Devonian Lay Dam Formation**

Rhythmically layered and laminated phyllite, metasandstone, and olistostromal facies of unsorted, unbedded, polymictic, boulder- and pebble-metamudstones, approximately 8,200 ft (2,500 m) thick, comprise the Lay Dam Formation (Telle et al., 1979; Telle, 1983; Tull and Telle, 1988; Tull et al., 1988). At the base of the formation,
a significant regional angular unconformity (pre-Lay Dam unconformity) is present. Post-Ordovician conodont molds were located in the upper part of the Lay Dam (Sutley, 1977; Harris et al., 1984; Tull et al., 1988). The conodont molds are reported as preserving elements of a post-Ordovician morphotype (Tull et al., 1988). “The Pb element is characteristic of Silurian through Mississippian conodont apparatuses” (Tull et al., 1988, p. 1298). The presence of fossiliferous Lower Devonian chert stratigraphically above the Lay Dam Formation, and the presence of the post-Ordovician conodont molds, is used as evidence for a Silurian-Early Devonian age for the Lay Dam (Tull et al., 1988). The Lay Dam Formation crops out in the Talladega thrust sheet (Figure 5.21).

**Devonian Butting Ram Quartzite**

Quartzitic sandstone that is white to light-blue-gray, medium- to coarse-grained, locally conglomeratic and thick-bedded (Butts, 1926; Carrington, 1964; Tull, 1982; Raymond et al., 1988) comprises the Butting Ram Quartzite. The lower contact of the unit is gradational with the Lay Dam Formation. Tull (1982) interprets the Butting Ram as representing the final phase of coarse-grained, clastic deposition related to the Lay Dam Formation. The upper contact of the Butting Ram Sandstone is also gradational with the Jemison Chert. The thickness of this unit is highly variable, ranging from 2,788 ft (850 m) near the Coastal Plain overlap to a pinchout located to the east of Coosa County (Figure 5.22) (Tull, 1982).

**Devonian Jemison Chert**

The Jemison Chert is a gray-white to yellow-orange, fine-grained, locally argillaceous, thick- to massive-bedded chert that contains marine invertebrate fossils (brachiopods \{*Acrospirifer Murchisoni*, *Deltthyris* sp., *Leptaena rhomboidalis* Wilckens, *Meristella* sp., *Stropheodonta* sp., chonetids and spiriferids\}, tentaculitids \{*Tentaculites* cf.\,*T. elongates*\}, bryozoans \{*Cystodictya* sp.\}, corals \{*Favosites* sp.\}, trilobites, and sponge spicules of Early to Middle Devonian age (Butts, 1926; Carrington, 1973; Sutley, 1977; Tull, 1979, 1982; Raymond et al., 1988). Where the Jemison outcrop belt trends eastward, the macroscopic appearance of the chert changes along strike to a gray-black, argillaceous, highly foliated, mica- and ribbon quartz-bearing mosaic of
polygonal quartz grains. This macroscopic change is caused by increasing metamorphic grades toward the orogenic hinterland (Tull, 1982). The Jemison Chert is between 655 and 985 ft (between 200 and 300 m) thick (Carrington, 1973; Sutley, 1977; Tull, 1979, 1982). The macroinvertebrate fossils present in the Jemison chert are evidence for correlation with the Oriskany Group in the Appalachian foreland (Tull et al., 1988).

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Figure 5.1: Schematic map of Alleghanian thrust belt in Alabama and Georgia, showing the locations of four transverse zones (modified from Thomas, 1990). The Bessemer transverse zone is shaded in the blue-purple domain gradient.
Figure 5.2: Late Ordovician paleocontinental reconstruction (modified from Stanley, 1986) illustrating the distribution of the Taconic Mountains and Queenston delta. The distal equivalents of the Queenston delta are the Sequatchie and Red Mountain formations of Alabama (Blount clastic wedge).
Figure 5.3: Outcrop distribution of the Cambrian Rome Formation in the Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.4: Outcrop distribution of the Cambrian Ketona Dolomite, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.5: Outcrop distribution of the Cambrian Conasauga Formation, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.6: Outcrop distribution of the Cambrian-Ordovician Knox Group, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.7: Outcrop distribution of the Ordovician Lenoir/Little Oak and Athens formations, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.8: Outcrop distribution of the Ordovician Chickamauga Limestone, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.9: Outcrop distribution of the Silurian Red Mountain Formation, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.10: Outcrop distribution of the Devonian-Mississippian? Frog Mountain Sandstone, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.11: Outcrop distribution of the Mississippian Fort Payne Chert/Tuscumbia Limestone, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.12: Outcrop distribution of the Mississippian Pride Mountain Formation, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.13: Outcrop distribution of the Mississippian Hartselle Sandstone, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.14: Outcrop distribution of the Mississippian-Pennsylvanian Parkwood Formation, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.15: Outcrop distribution of the Pennsylvanian Pottsville Formation, Bessmer transverse zone (modified from Szabo et al., 1988).
Figure 5.16: Outcrop distribution of the Neoproterozoic-Cambrian Waxahatchee Slate, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.17: Outcrop distribution of the Neoproterozoic-Cambrian? Brewer Phyllite, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.18: Outcrop distribution of the Neoproterozoic?-Cambrian Wash Creek Slate, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.19: Outcrop distribution of the Cambrian Shady Dolomite, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.20: Outcrop distribution of the Cambrian-Ordovician? Jumbo Dolomite, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.21: Outcrop distribution of the Silurian-Devonian? Lay Dam Formation, Bessemer transverse zone (modified from Szabo et al., 1988).
Figure 5.22: Outcrop distribution of the Devonian Butting Ram Sandstone, Bessemer transverse zone (modified from Szabo et al., 1988).
Chapter 6: Regional Outcrop Expression of the Bessemer Transverse Zone

Introduction

Large-scale structures in the BTZ are northeast-striking thrust faults (Blue Creek, Opossum Valley, Jones Valley, Helena, Yellowleaf, Dry Creek, and Talladega faults) and northeast- and southwest-plunging folds (Coalburg, Blue Creek, Cahaba, Coosa, and Columbiana synclines; Sequatchie, Blue Creek, Birmingham, and Kelley Mountain anticlines) (Figure 6.1, Plate 1) (Osborne et al., 1988; Szabo et al., 1988). These structures are divided areally into four mappable domains; the northwestern, central, southeastern, and Piedmont metamorphic domains. The northwestern domain contains all geologic entities located to the northwest of the map traces of the Opossum Valley and Jones Valley thrust faults (Figure 6.1). Rocks and structural features between the Opossum Valley-Jones Valley and Helena thrust faults belong to the central domain (Figure 6.1). The southeastern domain encompasses the geology between the Helena and Talladega thrust faults (Figure 6.1). Metamorphic rocks of the Piedmont metamorphic domain are mapped to the southeast of the Talladega fault (Figure 6.1).

For this discussion of along-strike changes in the map expression of fault traces and fold geometries in the BTZ, a classification terminology is used here to explain the map representation of thrust sheet anatomy in the BTZ. Thrust sheets are bounded on all sides by thrust faults. The forelandmost edge of a thrust sheet, bounded by the fault that gives the thrust sheet its name, is called the leading edge of the thrust sheet. The hinterlandmost edge of the thrust sheet is the trailing edge. The sides of a thrust sheet are the lateral (if the side edge is parallel to the translation direction of the allochthon) or oblique (if the side edge is at an angle to the translation direction of the allochthons) edges. The leading, trailing, and lateral/oblique map representations of thrust sheet edges are ramps (frontal, trailing, lateral/oblique ramps, respectively), where the fault trace bounding the respective thrust sheet edge cuts across the stratigraphy mapped in the fault hanging wall. Alternatively, where the leading, trailing, and lateral/oblique map representations of thrust sheets contain faults that do not cut across the stratigraphy mapped in the hanging wall, i.e. a detachment is maintained within one unit and does not cut across the stratigraphy of the unit, the respective edges are termed flats (frontal,
trailing and lateral/oblique flats, respectively). These terms refer solely to the map representation of thrust sheet anatomy in the BTZ.

**Northwestern Domain**

**Leading Edge of the Appalachian Alleghanian Thrust Belt**

Northwest of the BTZ, the northwesternmost expression of the Alleghanian allochthon is the northwest-verging, asymmetric Sequatchie anticline, which is interpreted as being the surficial expression of the blind, northward-terminating, flat-lying beds across the BTZ (Thomas and Neathery, 1980; Thomas and Osborne, 1995). Southwest of the southwest termination of the Sequatchie anticline, the Blue Creek anticline is the leading structure of the Alleghanian thrust belt. The Blue Creek anticline dips into the broad, flat-bottomed Blue Creek syncline.

**Blue Creek Thrust Sheet**

In the BTZ, the Blue Creek fault branches from the northeast-striking map trace of the Opossum Valley fault, where the Opossum Valley frontal ramp curves into a north-south oriented oblique ramp in the Conasauga Formation (Figure 6.2 [Bessemer 7.5’ Quadrangle]) (Plate 2 [Location 1]). The Blue Creek fault maintains a northeast-strike orientation across the BTZ and culminates southwestward in the low-amplitude Blue Creek anticline as a blind thrust in Mississippian-Pennsylvanian rocks (Figure 6.2 [Concord and McCalla 7.5’ quadrangles]) (Plate 2 [Location 2]) (Thomas, 1994).

A frontal ramp in the Blue Creek thrust sheet truncates the axial plane and leading limb of an unnamed, southwest-plunging anticline (Figure 6.2 [Bessemer 7.5’ Quadrangle]) (Plate 2 [Location 1]), southwest of the Opossum Valley-Blue Creek branch point. The frontal ramp cuts up section, across a shared leading anticlinal-trailing synclinal limb (Figure 6.2 [Concord 7.5’ Quadrangle]) (Plate 2 [Location 3]). The trailing synclinal limb is part of the up-plunge termination of the Blue Creek
syncline. Southwestward along strike, the Blue Creek frontal ramp truncates the trailing synclinal limb and cuts up section from the Mississippian Hartselle Sandstone, across the Blue Creek synclinal axis, to the Pennsylvanian Pottsville Formation in the frontal synclinal limb (Figure 6.2 [Concord 7.5’ Quadrangle]) (Plate 2 [Location 4]). A transverse fault is truncated by the Blue Creek frontal ramp in the Blue Creek syncline (Plate 2 [Location 4]). Southwestward along strike from the transverse fault, the frontal ramp changes to a frontal fault-strike parallel (FSP) ramp in the Pennsylvanian Parkwood Formation (Figure 6.2 [Concord 7.5’ Quadrangle]) (Plate 2 [Location 5]). Another transverse fault is truncated by the Blue Creek fault (Plate 2 [Location 5]).

Southwestward along strike, the Blue Creek fault maintains a frontal FSP ramp in the Pottsville Formation (Plate 2 [Location 6]). The Blue Creek fault becomes blind in the core of the Blue Creek anticline, southwest along strike, in the BTZ (Figure 6.2 [Concord and McCalla 7.5’ quadrangles]) (Plate 2 [Location 2]).

The two transverse faults described above are part of several cross-strike links in the Blue Creek thrust sheet (Bessemer, Concord and McCalla 7.5’ quadrangles). The cross-strike links are herein grouped into the Concord cross-strike link zone (Concord CSL zone). Spanning the Blue Creek thrust sheet, the Concord CSL zone transfers displacement across strike between the Blue Creek and Opossum Valley faults.

Southeastward across allochthon strike, in the Blue Creek thrust sheet, strata are folded into the broad, flat-bottomed, northwest-verging Blue Creek syncline (Plates 1 and 4) (Szabo et al., 1988). The Blue Creek thrust sheet maintains two differing trailing ramps in the BTZ. The northeastern part of the Blue Creek trailing ramp is truncated by the Opossum Valley thrust fault (Plate 2 [Location 7]). The southwestern part of the Blue Creek trailing ramp is truncated by the Jones Valley thrust fault (Plate 2 [Location 8]).

The origin of the Blue Creek trailing ramp with the Opossum Valley fault is at the shared branch point of these two faults (Plate 2 [Location 1]). The Blue Creek trailing ramp cuts up section from the Knox Group to the Mississippian Tuscumbia-Fort Payne formations along the trailing limb of the unnamed, southwest-plunging anticline in the Blue Creek thrust sheet (Figure 6.2 [Concord and Bessemer 7.5’ quadrangles]) (Plate 1). The trailing ramp cuts across the Silurian Red Mountain-cored, northeast-
plunging, syncline that is paired with the unnamed anticline (Figure 6.2 [Concord and Bessemer 7.5’ quadrangles]) (Plate 2 [Location 9]). A small thrust fault in the Concord CSL zone is truncated by the Opossum Valley fault near the origin of a trailing FSP ramp in the Mississippian Hartselle Sandstone (Figure 6.2 [Concord 7.5’ Quadrangle]) (Plate 2 [west of Location 9]). A transverse fault in the Concord CSL zone is truncated by the Opossum Valley fault near another trailing ramp in the Blue Creek thrust sheet that cuts up section from the Red Mountain Formation to the Hartselle Sandstone. The Red Mountain-Hartselle trailing ramp is informally referred to as “the Knot”, a fault-bounded segment of the Blue Creek thrust sheet that is of a smaller-scale than the larger transverse-fault-bounded segments comprising the Concord CSL zone. Because of the small-scale of “the Knot”, this area is introduced in this chapter, but will be discussed in greater detail in Chapter 8. The Opossum Valley fault truncates the southwest-bounding fault of “the Knot” and transects a trailing FSP ramp that persists in the Ordovician Chickamauga Limestone of the Blue Creek thrust sheet. The Chickamauga trailing FSP ramp is terminated at the corner of the Blue Creek thrust sheet that is near the Opossum Valley, northwest-striking, lateral ramp (Figure 6.2 [McCalla 7.5’ Quadrangle]) (Plate 2 [Location 10]).

Another CSL zone in the Blue Creek thrust sheet is herein identified as the McAshan Mountain CSL zone (McCalla 7.5’ Quadrangle). The small scale of the McAshan Mountain CSL zone restricts discussion of the structure to an introduction in this chapter. The McAshan Mountain CSL zone will be discussed in detail in Chapter 8. The McAshan Mountain CSL zone is bounded on the northwest by a back-thrust splay of the Blue Creek thrust sheet, on the northeast by the northwest-striking lateral ramp of the Opossum Valley thrust fault, on the southwest by an unnamed transverse fault that crops out southwest of the BTZ, and on the southeast by the Jones Valley fault. The trailing edge of the Blue Creek thrust sheet, southwest of the Opossum Valley lateral ramp, is the McAshan Mountain CSL zone (Figure 6.2 [McCalla 7.5’ Quadrangle]) (Plate 2 [area near Locations 8 and 10]). The McAshan Mountain trailing edge of the Blue Creek thrust sheet persists as a trailing FSP ramp in the Knox Group to the southwest of the BTZ (Figure 6.2 [McCalla 7.5’ Quadrangle]) (Plate 2 [area near Locations 8 and 10]).
Central Domain

**Opossum Valley Thrust Sheet**

The northwesternmost expression of the central domain of the Alleghanian thrust belt is the Opossum Valley thrust fault (Figure 6.1) ([Plate 1](#)). Northeast of the BTZ, the Opossum Valley thrust fault is located along the southeast limb of the Coalburg syncline (Concord and Bessemer 7.5’ quadrangles) (Figure 6.1) ([Plate 1](#)) (Szabo et al., 1988). The Opossum Valley fault has three abrupt sinistral curves in strike across the BTZ; strike curves at two places from northeast to north-northeast in both the Bessemer and in the Concord 7.5’ quadrangles ([Plate 2](#) [Locations 1 and 9], and curves from northeast to northwest in the McCalla 7.5’ Quadrangle, where it is truncated by the Jones Valley thrust fault ([Plate 2](#) [Location 10]).

The Opossum Valley fault is the leading of two frontal ramps (the trailing frontal ramp is the Jones Valley thrust fault) comprising the Birmingham anticlinorium. The Birmingham anticlinorium contains two anticlines separated by a shallow, medial syncline (Thomas and Neathery, 1980; Osborne et al., 1988; Szabo et al., 1988). The frontal Birmingham anticline is a frontal ramp-anticline in the Opossum Valley thrust sheet, the trailing Birmingham anticline is a frontal ramp-anticline in the Jones Valley thrust sheet ([Plate 1](#)). The medial syncline is the trailing limb of the Opossum Valley ramp anticline and the footwall of the Jones Valley fault.

Northeast of the BTZ, the Opossum Valley thrust sheet maintains a frontal flat in theCambrian Conasauga Formation. Near the BTZ, a frontal ramp (Figure 6.2 [Bessemer 7.5’ Quadrangle]) cuts up section into the Cambrian Ketona Dolomite ([Plate 2](#) [Location 11]) (Szabo et al, 1988). Farther southwest along strike, the frontal ramp cuts down section into the Conasauga Formation within the BTZ (Figure 6.2 [Bessemer 7.5’ Quadrangle]) ([Plate 2](#) [hanging wall of Opossum Valley fault near Location 1]).

Southwest along strike, in the BTZ, the Opossum Valley frontal ramp changes into an oblique ramp ([Plate 2](#) [Location 1]) and cuts up section southwestward through the Ketona Dolomite and the Cambrian-Ordovician Knox Group (Copper Ridge Dolomite) (Figure 6.2 [Bessemer, Concord and McCalla 7.5’ quadrangles]) ([Plate 2](#) [near Location 9]) (Szabo et al., 1988). The Opossum Valley fault truncates the medial
syncline of the Birmingham anticlinorium along its northwest-striking lateral ramp section (Figure 6.2 [McCalla 7.5’ Quadrangle]) (Plate 2 [Location 10]) (Szabo et al, 1988). The trailing Birmingham anticline in the Jones Valley thrust sheet continues southwestward through the transverse zone, exhibiting a northeast to north, back to northeast, strike variation across the BTZ (Plate 2 [Location 12]).

At trailing ramps in the Opossum Valley thrust sheet, the Jones Valley fault truncates the medial syncline of the Birmingham anticlinorium along strike in the BTZ. Northeast of the BTZ, an Opossum Valley trailing ramp cuts down stratigraphic section southwestward from the Copper Ridge Dolomite to the Ketona and Conasauga formations (Figure 6.2 [Bessemer 7.5’ Quadrangle]) (Plate 2 [Location 13]). The Opossum Valley thrust sheet maintains a trailing ramp in the Conasauga Formation, where the Conasauga is exposed as a culmination in the Birmingham anticlinorium (Concord, Bessemer, McCalla and Greenwood 7.5’ quadrangles) (Figure 6.2) (Plate 1). Southwest of the Conasauga culmination, the Opossum Valley trailing ramp cuts southwestward up stratigraphic section, from the Ketona to the Knox carbonates (Figure 6.2 [Bessemer and Greenwood 7.5’ quadrangles]) (Plate 2 [Location 14]). Another trailing ramp is maintained in the Opossum Valley thrust sheet beneath the Knox in a depression of the Birmingham anticlinorium (Figure 6.2 [Bessemer and Greenwood 7.5’ quadrangles]) (Plate 2 [Location 15]). Southwestward of the Knox depression, another Opossum Valley trailing ramp cuts down section from the Copper Ridge to the Conasauga. This trailing ramp is terminated by the intersection of the Jones Valley fault with the northwest-striking Opossum Valley lateral ramp (Figure 6.2 [McCalla 7.5’ Quadrangle]) (Plate 2 [Location 10]).

**Jones Valley Thrust Sheet**

The northeast-striking Jones Valley fault in the BTZ crops out from the Bessemer to the Greenwood and McCalla 7.5’ quadrangles (Figure 6.2) (Plate 1). One sinistral curve in the strike of the thrust fault is in the Conasauga culmination of the Birmingham anticlinorium (Figure 6.2 [junction of Concord, Bessemer, McCalla and Greenwood 7.5’ quadrangles]) (Plate 2 [Location 12]). Northeast of the BTZ, the Jones Valley fault is a forelimb thrust on the northwest limb of the trailing anticline of the Birmingham anticlinorium. The Jones Valley fault continues along strike through the
transverse zone in this structural position (Szabo et al., 1988). The fault also maintains a frontal flat in the Cambrian Conasauga Formation and does not have exposed frontal, trailing, or lateral/oblique ramps across the BTZ.

The Cahaba synclinorium comprises the trailing part of the Jones Valley thrust sheet (Figure 6.2. [Bessemer, McCalla, Greenwood, Helena and Pea Ridge 7.5’ quadrangles]) (Plate 1) (Osborne et al., 1988; Szabo et al., 1988). The synclinorium is wider and deeper southwest of the transverse zone than it is to the northeast (Plate 1) (Thomas, 1994; Thomas and Osborne, 1995). Enclosed within the larger scale synclinorium are a number of small-scale anticlines in the northeastern part of the BTZ (Figure 6.2 [Bessemer and Greenwood 7.5’ quadrangles]) (Plate 2 [Location 16]) (Thomas, 1994). This system of anticlines is part of a large sinistral curve in the synclinorium where the structure crosses the BTZ. The anticlines plunge to the west-southwest and end within the BTZ.

The Jones Valley thrust sheet maintains a trailing ramp in the Pennsylvanian Pottsville Formation across the map expression of the BTZ (Plate 1).

Southeastern Domain

Helena Thrust Sheet

The boundary between the central and southeastern domains is the Helena thrust fault. The Helena fault in the BTZ bounds the southeastern, trailing edge of the Cahaba synclinorium, from the Helena to the Alabaster and Pea Ridge 7.5’ quadrangles (Figure 6.2) (Plate 1) (Osborne et al., 1988; Szabo et al., 1988). The Helena fault exhibits a sinistral curve in strike of more than 5.5 mi (8.8 km) southeastward across the transverse zone (Figure 6.2 [Helena and Alabaster 7.5’ quadrangles]) (Plate 2 [Location 17]) (Thomas, 1994), but curves to a more southwesterly strike southwesterly of the transverse zone (Figure 6.2 [Pea Ridge 7.5’ quadrangle]) (Plate 1) (Szabo et al., 1988). The Helena thrust detachment ramps along strike from the Cambrian Ketona down section northeastward into the Rome Formation northeast of the BTZ (Plate 2 [Location 18]). A frontal FSP ramp in the Rome is maintained along strike of the Helena thrust sheet to the curve in strike (Figure 6.2 [Alabaster 7.5’ quadrangle]) where an oblique ramp cuts up section southwestward into the Cambrian Ketona-Brierfield dolomites
An oblique-hanging-wall ramp in the Pea Ridge 7.5’ Quadrangle cuts down section southwestward into the Rome Formation in the core of an accommodation fold at the up-plunge end of the Coosa synclinorium (Plate 2 [Location 20]) (Szabo et al., 1988). The Helena fault changes from a moderately dipping fault northeast of and within the BTZ to a shallow, low-angle fault southwest of the BTZ (Plate 1) (Thomas and Osborne, 1995).

Across allochthon strike, to the southeast of the Helena fault, the second-order Elliotsville thrust fault is an out of the syncline thrust at the up-plunge end of the Coosa synclinorium (Figure 6.2 [Alabaster 7.5’ quadrangle]), and terminates southwest of the BTZ in the core of a second-order anticline (Figure 6.2 [Alabaster 7.5’ quadrangle]) (Plate 2 [Location 21]) (Osborne et al., 1988; 1998). The Elliotsville fault has an oblique ramp (Plate 2 [Location 22]) that continues southwest along strike as a frontal ramp in the Alabaster 7.5’ quadrangle (Figure 6.2) (Plate 1). The Elliotsville oblique ramp cuts down section southwestward from the Cambrian-Ordovician Knox Group into the Cambrian Bibb Dolomite (Plate 1). The frontal ramp cuts down section southwestward along strike from the Bibb to the Conasauga formations. The Elliotsville frontal ramp displaces the second-order anticline and terminates near the anticlinal axis (Plate 2 [Location 21]).

The Helena thrust sheet in the BTZ contains the northeast-plunging, southwestern segment of the doubly plunging Coosa synclinorium (Plate 1) (Szabo et al., 1988). The synclinorium is relatively steep and narrow, in contrast to the Cahaba synclinorium in the Jones Valley thrust sheet (Thomas and Osborne, 1995). Two northeast-trending synclines (Plate 2 [Locations 23 and 24]) separated by a medial anticline (Plate 2 [Location 25]) comprise the Coosa synclinorium fold train. Oblique ramps in the Helena and Elliotsville faults are geometrically related to the up-plunge termination of the Coosa synclinorium structures and the accommodation anticlines at the Coosa termination (Figure 6.2 [Helena, Alabaster and Bounds Lake 7.5’ quadrangles]) (Plate 1) (Szabo et al., 1988).

The trailing edge of the Helena thrust sheet maintains trailing ramps with the Yellowleaf fault to the northeast of the BTZ and the Dry Creek fault to the southwest of the BTZ (Plate 1). The trailing ramp with the overlying Yellowleaf fault cuts down
section from the upper Pennsylvanian Pottsville Formation to the Mississippian Floyd Shale southwestward along strike, into the BTZ. The trailing edge of the Helena thrust sheet with the overlying Dry Creek thrust fault cuts down section along strike southwestward from the Mississippian Parkwood-Floyd formations to the Ordovician Newala Limestone (Plate 1).

Yellowleaf Thrust Sheet

The Yellowleaf thrust fault in the BTZ is exposed in the Bounds Lake 7.5’ quadrangle (Figure 6.2) (Plate 1). The Yellowleaf fault, bounding the southeastern limb of the Coosa synclinorium, changes southwestward along strike to a blind thrust in the BTZ (Figure 6.2 [Bounds Lake 7.5’ quadrangle]) (Plate 2 [Location 26]). A sinistral curve in the northeast-strike of the Yellowleaf fault is in the BTZ near the blind termination (Plate 2 [Location 27]).

It is not clear from the map expression of the Yellowleaf fault whether the leading edge is a frontal flat or frontal ramp. The Yellowleaf detachment is maintained in the Mississippian-Pennsylvanian Parkwood-Floyd formations along the outcrop; however, the sinistral curve in fault strike may represent cutting of the fault across Parkwood-Floyd strata, suggesting a frontal ramp.

The trailing edge of the Yellowleaf thrust sheet is folded into the Fourmile Creek anticline (FMCA), structurally below the Columbiana syncline (which is part of the higher thrust sheet, bounded by the Talladega fault (TF)), and the Kelley Mountain anticline (KMA) (which is exposed through a breached window in the Talladega thrust sheet). The anticlines are doubly plunging and bring the Cambrian-Ordovician Knox Group to the surface (Plate 1). The trailing ramp of the Yellowleaf thrust sheet with the overlying Talladega fault transects the limbs and cores of the Kelley Mountain and Fourmile Creek anticlines. From the southeastern side of the Kelly Mountain window, northwestward toward the frontal part of the Yellowleaf thrust sheet, the trailing ramp cuts down section southwestward in the southeastern limb of the Kelley Mountain anticline from the Mississippian Parkwood-Floyd formations to the Ordovician Newala Limestone (Plate 2 [Location 28]. Crossing the axis of the Kelley Mountain anticline, the trailing ramp cuts back upsection from the Newala Limestone to the Mississippian-Pennsylvanian Parkwood-Floyd formations (Plate 2 [Location 29]). On the
northwestern limb of the Kelley Mountain anticline, the Yellowleaf trailing ramp cuts down stratigraphic section northward from the Mississippian-Pennsylvanian rocks, across the map trace of the Shelby Valley fault (SVF), to the Cambrian-Ordovician Knox Group and cuts upsection to the Newala Limestone exposed on the northwestern limb of the Fourmile Creek anticline, in the Shelby Valley fault block ([Plate 2](#)[Location 30]). The trailing ramp persists in the Newala Limestone to the core of the Fourmile Creek anticline, where the trailing ramp cuts down section into the Knox Group ([Plate 2](#)[Location 31]). On the northwestern limb of the Fourmile Creek anticline, the trailing ramp cuts up section into the Pennsylvanian Floyd-Parkwood rocks ([Plate 2](#)[Location 32]). It is not clear from the map expression of the trailing Yellowleaf thrust sheet whether the Pottsville edge is a trailing flat or a trailing ramp. The trailing Yellowleaf thrust sheet is truncated by a trailing imbricate of the Dry Creek thrust sheet bearing the Newala Limestone ([Plate 2](#)[Location 33]).

**Dry Creek Thrust Sheet**

The Dry Creek fault is exposed in the Montevallo 7.5’ Quadrangle and changes along strike to a blind thrust northeastward into the BTZ (Figure 6.2) ([Plate 2](#)[Location 34]). The Dry Creek thrust sheet southwest of the BTZ exhibits a frontal ramp that cuts down section along strike from the Mississippian Parkwood-Floyd formations to the Cambrian-Ordovician Knox Group ([Plate 2](#)[Location 35]) (Szabo et al., 1988).

The map expression of the trailing Dry Creek thrust sheet does not elucidate whether the trailing thrust sheet is a trailing flat or a trailing ramp. The trailing Dry Creek thrust sheet edge is maintained as a trailing imbricate exposing the Ordovician Newala Limestone on the surface in the BTZ (Figure 6.2 [Montevallo 7.5’ Quadrangle]) ([Plate 2](#)[Location 36]).

**Piedmont Metamorphic Domain**

**Talladega Thrust Sheet**

The Talladega thrust sheet marks the boundary between the southeastern domain and the Piedmont metamorphic domain (Figure 6.1). The Talladega thrust sheet is folded and shallowly dipping in the BTZ (Figure 6.2 [Columbiana, Bounds Lake, Shelby, Ozan and Montevallo 7.5’ quadrangles]) ([Plate 1](#)); dips increase to the
southwest across the transverse zone (Plate 1). The Talladega thrust sheet is folded into the doubly plunging Columbiana syncline. Northeast of the BTZ, the Columbiana syncline plunges to the northeast, an unnamed culmination is present in the BTZ (Bounds Lake and Columbiana 7.5’ quadrangles), and the syncline plunges to the southwest (Ozan 7.5’ Quadrangle), southwest of the transverse zone (Figure 6.2) (Plate 1).

The Talladega fault exhibits a large, folded, frontal ramp northeast of the BTZ (Plate 2 [Location 37]) and a frontal flat to the southwest of the BTZ (Plate 2 [Location 38]). From the southeastern part of the Kelley Mountain window (Plate 1) and northwestward toward the foreland, the frontal ramp cuts down section from the Neoproterozoic-Cambrian Wash Creek Slate through the Neoproterozoic-Cambrian Waxahatchee Slate across the axis of the Kelley Mountain anticline (Plate 2 [Location 39]). Northwestward from the hinge of the Kelley Mountain anticline, the folded frontal ramp cuts up across the stratigraphic section into the Cambrian Shady Dolomite through the Cambrian Conasauga Formation in the hinge of the northeast-plunging part of the Columbiana syncline (Plate 2 [Location 37]). Across the Columbiana synclinal axis the frontal ramp cuts down section from the Conasauga Formation to the Waxahatchee Slate (Plate 2 [Location 40]). A detachment horizon is maintained in the Waxahatchee Slate along the frontal flat section of the Talladega fault southwestward across the BTZ (Plate 1).

**Discussion**

The map expression of the BTZ is delineated by changes in the structural expression of each thrust fault, and thrust-related structure, that crosses the transverse zone. Except for the Blue Creek and Dry Creek faults, each thrust fault exhibits a sinistral change in strike orientation where it crosses the BTZ. Four of the seven thrust faults terminate in the BTZ and transfer displacement to en-echelon faults across strike. All of the thrust-related folds have plunge terminations in the BTZ; location of fold terminations corresponds geometrically to terminations, or lateral changes, in the host thrust sheet crossing the BTZ.

The Blue Creek and Opossum Valley faults change orientation, and the thrust sheets terminate along strike in opposite directions in the BTZ. The Blue Creek fault
maintains a consistent northeast-strike orientation in the BTZ and increases stratigraphic separation to the northeast along strike, where it branches with the Opossum Valley fault in the BTZ. In the Blue Creek hanging wall, the Blue Creek syncline ends up plunge to the northeast. The Opossum Valley fault exhibits numerous, sinistral, strike changes and decreases stratigraphic separation to the southwest along strike in the BTZ. The Opossum Valley lateral ramp marks the lateral termination of the thrust sheet in the BTZ and truncates the leading Birmingham anticline along strike to the southwest. The Concord CSL zone accommodates displacement transfer between the Blue Creek and Opossum Valley thrust faults via a number of transverse faults serving as cross-strike links.

The Blue Creek fault is unique in the BTZ; it is a doubly terminating thrust fault, also terminating along strike to the southwest as a blind termination in the Blue Creek anticline. The blind termination of the Blue Creek fault is in cross-strike alignment with the Jones Valley thrust fault. The McAshan Mountain CSL zone contains a lateral ramp and several transverse faults transferring displacement between the Blue Creek and Jones Valley thrust faults.

The Jones Valley thrust fault is devoid of exposed frontal, and/or lateral/oblique ramps, displacement-transfer zones and cross-strike links in the BTZ. The Jones Valley fault does exhibit, however, a sinistral curve in strike in the BTZ. The Cahaba synclinorium has small back-limb folds that terminate across the transverse zone. Geometrically, the plunge of the back-limb folds is in cross-strike alignment with the sinistral curve in Jones Valley strike.

The Helena fault also exhibits a sinistral curve in strike in the BTZ. Like the internal structures of the Birmingham anticlinorium, the frontal and trailing synclines, and medial anticline of the Coosa synclinorium, have plunge terminations in the BTZ. The plunge terminations of the Coosa second-order folds are in cross-strike alignment with the sinistral curve of the Helena fault.

The Yellowleaf and Dry Creek faults change orientation and/or displacement in the BTZ. The Yellowleaf fault exhibits a sinistral strike change and decrease in displacement to the southwest along strike in the BTZ, blindly terminating in the Parkwood-Floyd formations. Plunging folds are not mapped in the hanging wall of the
Yellowleaf thrust fault. The Dry Creek fault maintains a consistent northeast-strike orientation in the BTZ; however it decreases displacement to the northeast along strike, also blindly terminating in the Parkwood-Floyd formations. An unnamed anticline in the Dry Creek hanging wall has a down-plunge termination in the BTZ. Unlike the Blue Creek-Opossum Valley system, cross-strike links associated with the Yellowleaf-Dry Creek system are not exposed on the surface in the BTZ. The map geometry of the Yellowleaf-Dry Creek system is that of a lap-joint displacement-transfer zone (Dahlstrom, 1970).

The Piedmont metamorphic domain rests on the Talladega thrust fault that is shallowly dipping and folded in the BTZ. Individual cross-strike links are not exposed in this domain.

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Figure 6.1: Schematic map of the Alleghanian thrust belt in Alabama and Georgia, showing the locations of four transverse zones (modified from Thomas, 1990). The Bessemer transverse zone is shaded in the blue-purple domain gradient.
Figure 6.2: Geologic map of the Bessemer transverse zone (modified from Szabo et al., 1988), showing the extent of the Bessemer transverse zone (cross sections A and B).
Figure 6.2A: Explanation for Figure 6.2 geologic map.
Chapter 7: Large-Scale Subsurface Structural Expression of the Bessemer Transverse Zone

Introduction

The subsurface structural expression of the BTZ, as discussed in this chapter, is interpreted from two strike-perpendicular cross sections: A-A’ (northeast of BTZ) and B-B’ (southwest of BTZ) and five strike-parallel cross sections (C-C’ through G-G’) constructed from the 1:250,000-scale map of the BTZ (Plates 3, 4, 5, 6, 7, 8, and 9). The strike-perpendicular cross sections were bed-length and/or area balanced and restored using the techniques of Dahlstrom (1969) and Marshak and Woodward (1988) (Plates 3A and 4A). The five strike-parallel cross sections cannot, in theory, be balanced or restored (Dahlstrom, 1969; Marshak and Woodward, 1988).

Discussion of transverse-zone structures at depth utilizes the domain concept outlined in Chapter 6 by projecting the outcrop location of domainal boundaries down to Proterozoic basement rocks beneath the Alleghanian basal decollement. Geologic formations and structures located at depth between these projected boundaries are grouped into the respective domain subdivisions.

The Paleozoic stratigraphy of the thrust belt is divided into four rheologic units, on the basis of relative ductility or brittleness of packaged stratigraphic units. Mechanical unit 1 contains the Cambrian Rome and Conasauga Formations, including the Conasauga facies equivalents (Brierfield, Ketona and Bibb dolomites). The Cambrian-Ordovician Knox Group comprises unit 2. The overlying Ordovician carbonate to Mississippian Tuscumbia-Fort Payne rocks are identified as unit 3. All Paleozoic rocks above the Tuscumbia-Fort Payne interval, up to and including the Pennsylvanian Pottsville Formation, form unit 4. The cross sections used to interpret the subsurface geometry of the BTZ utilize the mechanical stratigraphy (Plates 3, 3A, 4, 4A, 5, 6, 7, 8, and 9).

The thrust-sheet classification discussed in Chapter 6 is also applicable to the cross-sectional representation of thrust sheets. The forelandmost exposed edge of a thrust sheet, bounded by the fault that gives the thrust sheet its name, is called the leading edge of the thrust sheet, although erosion may have removed some of the original leading part. The hinterlandmost margin of the thrust sheet in the subsurface is
the trailing edge. The sides of a thrust sheet are the lateral (where the side edge is parallel to the translation direction of the allochthon) or oblique (where the side edge is at an angle to the translation direction of the allochthon) edges. The leading, trailing, and lateral/oblique edges of thrust-sheet edges are ramps where the respective thrust-sheet margin cuts across stratigraphy in the cross-sectional representation of the fault hanging wall. Alternatively, where the leading, trailing, and lateral/oblique cross-sectional representations of thrust sheets remain parallel to the stratigraphy of the hanging wall, i.e. the detachment is maintained within one unit, the respective edges are termed flats.

**Basement Depth**

**Introduction**

Depth of the Proterozoic basement underlying the Alleghanian allochthon varies because of the Birmingham basement fault system, an Ouachita rift structure interpreted from industry seismic lines and deep wells (Thomas, 1991). Proterozoic basement underlying the BTZ has been modeled using two seismic reflection profiles. Seismic reflectors representing top of basement were identified by correlation with deep, basement-penetrating wells located near the seismic profiles. Top of basement configuration was interpreted by tracing basement reflectors on the seismic profiles and interpreting breaks in the reflectors as probable locations of basement faults. The difference in the depth of basement reflectors on either side of a reflector break is interpreted as vertical separation on the inferred basement faults. Transfer of basement depth information from seismic profiles to the 1:250,000-scale map representation of the BTZ was accomplished by projecting point locations on the seismic reflectors up to ground surface and correlating location of the seismic profile to the BTZ map. Tracing of the basement fault locations across the BTZ was conducted by utilizing sense of separation, basement fault-scarp facing direction, and position within the regional Birmingham basement fault system. The 1:250,000-scale map locations of basement faults were utilized to constrain the basement configuration in the strike-perpendicular and strike-parallel cross sections traversing the BTZ.
General Basement Structure

The Birmingham basement fault system underlying the BTZ contains two, northeast-striking grabens separated by one northeast-striking basement horst block (Plates 3 and 4). The northwesternmost graben (graben 1) is bounded by a down-to-southeast normal fault (basement fault 1) on the northwest and a down-to-northwest normal fault (basement fault 2) on the southwest. The southwesternmost graben (graben 2) is also bounded by a down-to-southeast normal fault (basement fault 3) on the northwest. No southeastern boundary fault of graben 2 is imaged on the industry seismic profiles near the BTZ. Therefore, the southeast boundary of graben 2 is inferred to be southeast of the southeastern ends of the seismic profiles and of cross sections A and B.

Basement Relationship to Alleghanian Allochthon

The surficial traces of the Blue Creek and Opossum Valley thrust faults (northwestern and central domains, respectively) overlie shallow basement northwest of the Birmingham graben (Plates 3 and 4). The surficial trace of the Jones Valley fault (central domain) changes along strike with respect to the Birmingham basement fault system. Northeast of the BTZ, the Jones Valley fault overlies the shallow basement northwest of the Birmingham basement fault system. Southwestward along strike, the map trace of the Jones Valley fault overlies basement fault 1. The Cahaba synclinorium, in the trailing Jones Valley thrust sheet, is situated over graben 1. The position of the map trace of the Helena thrust fault (southeastern domain), with respect to the basement fault system, persists along the strike of the allochthon, across the BTZ, over graben 1. The Yellowleaf and Dry Creek (southeastern domain) faults both terminate along strike in the BTZ. The Yellowleaf fault terminates to the southwest in the BTZ and the Dry Creek fault terminates to the northeast in the BTZ. The map trace of the Yellowleaf fault directly overlies graben 1. The Dry Creek fault, however, overlies the uplifted basement block that separates grabens 1 and 2. The surficial trace of the Talladega fault persists with respect to the underlying basement fault system, and overlaps the basement block separating grabens 1 and 2.
Northwestern Domain

Depth of Proterozoic basement in the northwestern domain ranges from approximately –11,000 ft (-3,352 m) (Plate 3) to -12,000 ft (-3,657 m) (Plate 4) below average mean sea level. On a regional scale the basement has a very low, southwest dip, as evidenced by several seismic profiles flanking the BTZ (Thomas, 1988; Thomas and Bayona, in press).

Seismic profiles southwest of the BTZ images an offset in the basement reflectors of approximately 7,000 ft (2,136 m). The basement reflector separation is evidence for inferring an approximate 7,000 ft (2,133 m) displacement on basement fault 1. The floor of graben 1 has an elevation that ranges from approximately -19,000 ft to –20,000 ft (-5,791 m to –6,096 m) (Plates 3 and 4).

Central Domain

Basement fault 1 crosses beneath the northwestern-central domain boundary where it crosses the BTZ in a northeasterly direction (Plates 3 and 4). The 7,000 ft (2,133 m) fault separation is generally consistent along the northeasterly fault strike.

Southeastern Domain

The elevation of the floor of graben 1 shallows southeastward across the strike of the Alleghanian thrust belt, toward basement fault 2 (Plates 3 and 4). Basement elevations northeast of the BTZ range from approximately -19,000 ft (-5,790 m) near basement fault 1 to -17,000 ft (-5,181 m) near basement 2 (Plate 3). The corresponding elevations southwest of the BTZ range from –19,500 ft (-5,943 m) to –19,000 ft (-5,791 m) (Plate 4).

Seismic reflector and well data used for the cross sections have been used to interpret a 4,000 ft (1,219 m) separation on basement fault 2 northeast of the BTZ (Plate 3) and a 2,500 ft (760 m) separation southwest of the BTZ (Plate 4). The difference in relative amount of fault separation is interpreted as a northeastward increase in displacement of basement fault 2 parallel to allochthon strike. The elevation of the upthrown basement block separating grabens 1 and 2 correspondingly changes across the BTZ. Northeast of the BTZ, the basement block is –13,000 ft.
Southwest of the BTZ, the basement block is approximately 16,500 ft (-5,030 m) (Plate 4). Additionally, the width of graben 1 underlying the northwestern, central, and southeastern domains varies across the BTZ. Northeast of the transverse zone, the graben has a width of 117,245 ft (35,736 m) (Plate 3). Southeastward across the BTZ, the graben narrows in width to approximately 107,985 ft (32,913 m) (Plate 4).

**Piedmont Metamorphic Domain**

Elevation of the upthrown basement block separating grabens 1 and 2 remains consistent across the strike of the allochthon. Basement fault 3, which forms the northwest border of graben 2 underlies the Piedmont metamorphic domain. Seismic reflection data for graben 2 reveal that the elevation of the basement northeast of the BTZ deepens to -17,500 ft (-5,334 m), which is interpreted as a 3,500 ft (1,066 m) separation on basement fault 3. Southwest of the transverse zone, graben 2 basement elevation deepens to approximately -19,000 ft (-5,790 m); a separation of 2,000 ft (610 m) on basement fault 3.

**Depth to Decollement**

**Introduction**

The depth of the basal decollement in the Alleghanian allochthon is interpreted from the two industry seismic profiles traversing the Alabama Alleghanian thrust belt near the BTZ (Figure 7.1). Seismic reflectors were interpreted as representing the basal decollement because of lateral continuity of deeper reflectors beneath dipping reflectors interpreted to be within the allochthon. The ramping of all major thrust sheets interpreted on the seismic profiles from the common basal reflector horizon is the primary evidence supporting the location of the basal decollement.

The basal decollement in the BTZ persists in the same stratigraphic mechanical unit, the Cambrian Rome and Conasauga Formations (unit 1). Elevation of the decollement changes, however, where ramps connect lower and higher decollement flats. Changes in decollement-flat elevation are interpreted as a response to changes in the elevation of the sub-allochthon Proterozoic basement. The presence of basement faults may be responsible for instability in the stress field during emplacement of the
allochthon (Wiltschko and Eastman, 1983). This instability may be represented by the refraction of the basal decollement up stratigraphic section proximal to basement faults (Plates 3 and 4). The decollement ramps into structurally higher and thinner sections of unit 1 on the horst blocks of the Birmingham basement fault system.

**Northwestern Domain**

The basal decollement is shallowest in the northwestern domain where it underlies the surficial trace of the Opossum Valley-Blue Creek faults. Northeast of the transverse zone, the decollement is approximately −10,000 ft (-3,048 m) (Plate 3), but deepens along strike southwestward to approximately −11,000 ft (-3,350 m) (Plate 4).

A southeast-dipping ramp (ramp 1) in the decollement is present in the northwestern domain to the southwest of the BTZ. Ramp 1 directly overlies basement fault 1 (Plates 3 and 4). Ramp 1 connects the decollement flat underneath the Opossum Valley and Blue Creek faults with a deeper decollement flat in graben 1. Elevation of the decollement in the graben ranges from −18,000 ft (-5,638 m) northeast of the BTZ (Plate 3) to −16,500 ft (5,029 m) southwest of the BTZ (Plate 4).

**Central Domain**

Decollement ramp 1 in the northwestern domain southwest of the BTZ crosses into the central domain northeast of the BTZ (Plates 3 and 4). Ramp 1 maintains a structural position over basement fault 1 along the strike of the allochthon.

**Southeastern Domain**

A northwest-dipping decollement ramp (ramp 2) is present in the southeastern domain of the BTZ. Ramp 2 overlies basement fault 2, the northwest-facing boundary fault for graben 1, and dips in the direction of allochthon displacement (Plates 3 and 4). The position of ramp 2 over basement fault 2 does not change across the strike of the BTZ (Plates 3 and 4). Ramp 2 connects the deeper decollement flat in graben 1 to the shallower decollement flat above the basement block separating grabens 1 and 2. An along-strike change in the elevation of the basement block decollement flat is evidenced in cross sections A and B (Plates 3 and 4). The decollement flat northeast of the BTZ is at an elevation of −12,500 ft (-3,810 m) and dips along strike to the southwest to an elevation of −15,000 ft (-4,570 m) southwest of the BTZ.
**Piedmont Metamorphic Domain**

The decollement flat above the basement block separating grabens 1 and 2 extends beneath the Piedmont metamorphic domain. The basement block decollement flat northeast of the transverse zone is at –12,500 ft (-3,810 m) elevation and dips southwestward along strike to an elevation of –16,000 ft (-4,876 m). A southeast-dipping decollement ramp (ramp 3) connects the basement block decollement flat to a decollement flat in graben 2 (Plates 3 and 4). The graben 2 flat also decreases in elevation along the strike of the allochthon, from –16,000 ft (-4,876 m) in the northeast to approximately –18,000 ft (-5,485 m) in the southwest.

**Subsurface Structural Expression in the Bessemer Transverse Zone**

**Northwestern-Central Domain**

**Opossum Valley-Blue Creek Footwall**

*Introduction*

The stratigraphic succession in the Blue Creek-Opossum Valley footwall is floored by the Cambrian Rome and Conasauga formations (unit 1) and capped by the Pennsylvanian Pottsville Formation (unit 4) (Plates 3 and 4). The strike-parallel cross sections C through G do not model the Blue Creek-Opossum Valley footwall of the BTZ. The along-strike cross sections were placed along thrust belt structures that exhibit along-strike changes crossing the BTZ. The geologic map of the Blue Creek-Opossum Valley footwall shows that such structures are not present in this section of the BTZ (Plate 1); therefore, along-strike cross sections were not placed at this location.

*Strike-Perpendicular Cross Section A-A’*

The frontal Alleghanian structure shown in cross section A is the Sequatchie anticline, a northwest-verging detachment anticline accommodating displacement at the leading termination of the underlying basal decollement (Plate 3). The Sequatchie anticline affects the entire Paleozoic succession, which is flat lying and undeformed farther northwest. The trailing limb of the Sequatchie anticline is shared with the flat-lying forelimb of the Coalburg syncline. The trailing limb of the Coalburg syncline (including the basal decollement) is deformed into an overturned, northwest verging, syncline (Coalburg)-anticline (northwestern Birmingham anticline) pair. The Coalburg-
Birmingham fold pair is detached in their shared limb by the Opossum Valley thrust fault. The Coalburg syncline is a footwall-trailing ramp underlying the Opossum Valley fault.

The Bessemer mushwad is imaged on seismic reflection profiles adjacent to the BTZ as a wide expanse of tectonically thickened rock bounded by roof and floor thrusts. The rock incorporated into the Bessemer mushwad is interpreted from the seismic profiles as unit 1. Unit 1 rocks in the Bessemer mushwad are not exposed in the BTZ; however, outcrop exposures of unit 1 rocks in the Gadsden mushwad (Alabama Anniston transverse zone northeast of the BTZ) (Figure 7.2) can be used as a model for strain in the Bessemer mushwad. “The mechanism of accretion of a mushwad is not well constrained by presently available data; however, bulk ductile flow can be inferred at the scale of the entire mushwad. Observations of deformed rocks of the Conasauga Formation …(unit 1)… suggest disharmonic folding and faulting of limestone beds and ductile flow of shale beds at outcrop scale. Discontinuous and anastomosing shear surfaces may bound internally deformed structural lithons at several scales.” (Thomas, 2001, p. 1867). Ductile strain observed in the rocks of the Gadsden mushwad permits inference of ductile strain in the Bessemer mushwad; “disharmonic small-scale folds, discontinuous faults, and possibly thrust faults” (Thomas, 2001, p. 1860) partition the Bessemer mushwad into internally deformed horses. Tectonic thickening of the Bessemer mushwad is interpreted as elevating and deforming the overlying stiff layer. “Elevation of the roof over a mushwad is geometrically and kinematically similar to the doming of thrust sheets over brittle duplexes (e.g., Hatcher, 1991)” (Thomas, 2001, p.1860).

The leading cut-off of the Bessemer mushwad in cross section A is a tectonic wedge underneath the overturned limb of the Coalburg syncline. Propagation of the mushwad proceeded forelandward of graben 1 and a wedge was created between the upthrown, forelandward horst of graben 1 and the overlying Paleozoic stratigraphy (Plate 3). The trailing cut-off of the mushwad in cross section A is the branch point where the Opossum Valley and Jones Valley faults ramp from the basal decollement (Plate 3). The mechanical stratigraphic unit comprising the Bessemer mushwad is interpreted to be unit 1 (Plate 3). The mushwad forming the footwall for the Opossum
Valley and Jones Valley faults has a measured cross-sectional area of approximately 556,200,000 ft² (1.70 x 10⁸ m²) and extends across approximately one-half of the width of graben 1 in cross section A (Plate 3). The emplacement of the Bessemer mushwad in unit 1 provides a kinematic mechanism to elevate and deform the overlying stiff layer (unit 2), creating the Birmingham anticlinorium and initiating the propagation of the Opossum Valley and Jones Valley faults (Thomas, 2001).

**Strike-Perpendicular Cross Section B-B’**

The leading structure of the BTZ in cross section B is the plunging termination of the Sequatchie anticline, the northwest-verging detachment fold accommodating displacement for the basal decollement (Plate 4). The trailing limb of the Sequatchie anticline and the Coalburg syncline extend into the relatively undeformed footwall of the Blue Creek fault. The entire Paleozoic section in the Sequatchie trailing limb is flat lying above the basal decollement (Plate 4). The trailing Sequatchie antclinal limb and Coalburg synclinal flat extend to a trailing ramp underlying the Blue Creek fault; in the footwall ramp the Blue Creek fault cuts up through stratigraphic mechanical units 1 to 4 in cross section B (Plate 4). The expression of the Coalburg-Birmingham fold pair does not extend along strike to the Blue Creek footwall, but is in the hanging wall of the Blue Creek fault (as the Blue Creek-Birmingham fold pair) southwest of the transverse zone (Plate 4).

The trailing footwall of the Blue Creek thrust sheet is the Bessemer mushwad. The mushwad supports the overlying thrust sheet, transporting the thrust sheet and its related structures to a higher structural position (Plate 4). Southwest of the BTZ, the Bessemer mushwad has a cross-sectional area of approximately 360,000,000 ft² (1.09 x 10⁸ m²). The mushwad extends across approximately one-quarter of graben 1 in cross section B (Plate 4).

**Along-Strike Variation of the Blue Creek-Opossum Valley Footwall in the BTZ**

The Opossum Valley footwall northeast of the BTZ is the upturned, trailing, vertical limb of the Coalburg syncline (Plate 3). Along strike, to the southwest of the BTZ, the Blue Creek footwall is undeformed (Plate 3) and the structural equivalent of
the vertical limb of the Opossum Valley footwall is in the Blue Creek hanging wall (Plate 4). The dip of the trailing limb of the Coalburg/Blue Creek syncline changes along strike from an overturned 70° SE (northeast of the BTZ) to approximately 50° NW (southwest of the BTZ) (Plates 3 and 4).

The Bessemer mushwad varies in geometry along strike. The cross-sectional area ranges from approximately 556,200,000 ft² (1.70 x 10⁸ m²) northeast of the BTZ to approximately 360,000,000 ft² (1.09 x 10⁸ m²) southwest of the BTZ. A tectonic wedge of the mushwad is thrust over the horst block of basement fault 1 and interjected between the Proterozoic basement and the overlying Paleozoic stratigraphy to the northeast of the BTZ (Plate 3). Southwestward along strike the tectonic wedge is not present and the mushwad is constrained within the hanging wall of a decollement ramp that branches up section with the Blue Creek thrust fault (Plate 4). The magnitude of tectonic accretion of the mushwad increases northeastward along strike. The mushwad occupies the foreland half of graben 1 northeast of the BTZ; to the southwest, the mushwad occupies the forelandward quarter of graben 1. The amplitude of the mushwad is higher southwest of the BTZ because of the increased magnitude of tectonic thickening southwest of the BTZ.

**Blue Creek Thrust Sheet**

*Introduction*

The Blue Creek thrust sheet contains rocks from unit 1 through unit 4. The branch point of the Opossum Valley and Blue Creek faults is located to the southwest of cross section A, and the Blue Creek fault is modeled only on cross section B.

Strike-parallel cross section C transects the Blue Creek thrust sheet parallel to the Blue Creek synclinal hinge and curves near the Blue Creek-Opossum Valley branch point to transect the Opossum Valley thrust sheet.

Strike-parallel cross section D transects the Blue Creek thrust sheet to the southwest of the Opossum Valley boundary of the McAscan Mountain CSL zone. The cross-section line is placed in the hanging wall of the McAscan Mountain back thrust.
The Blue Creek thrust sheet contains leading and trailing ramps to the southwest of the BTZ (Plate 4). Folded over the Bessemer mushwad (the Blue Creek fault is the roof thrust of the Bessemer mushwad in cross section B), the Blue Creek fault is emplaced over basement fault 1 and propagates upward through all four stratigraphic units. The Blue Creek fault is a blind upper-level detachment in unit 4 and displacement is absorbed in the Blue Creek anticline (Plate 4).

The Blue Creek syncline-Birmingham anticlinorium fold pair is present in the Blue Creek hanging wall (Plate 4). The Jones Valley fault truncates the trailing edge of the Blue Creek thrust sheet and offsets the Blue Creek syncline-Birmingham anticlinorium shared limb; the Blue Creek syncline remains in the Blue Creek hanging wall (Plate 4). A northwest-dipping back thrust, the McAshan Mountain back thrust, break the Blue Creek thrust sheet in cross section B. The McAshan Mountain back thrust shortens the steep trailing limb of the Blue Creek syncline in the Blue Creek hanging wall (Plate 4). The back thrust has a leading ramp that displaces units 1 though 3. The trailing edge of the back thrust is a flat in unit 1.

Along -Strike Variations of the Blue Creek Thrust Sheet in the BTZ

Strike-Parallel Cross Section C-C’

The Blue Creek fault is at an elevation of approximately –3,000 ft (-915 m) at the intersections of cross sections B and C. The fault rises to higher elevations along strike to the northeast, where it is truncated in the subsurface by the Opossum Valley fault near cross section A (Plate 5).

A hanging-wall lateral flat in unit 3 is modeled in the Blue Creek thrust sheet in cross section C, from the C’ point on the cross section northeastward to the intersection with cross section 3. The lateral flat changes to a hanging-wall lateral ramp between the intersections with cross section 3 and 1. The hanging-wall lateral ramp cuts up section along strike from unit 3 to unit 4. A footwall lateral flat in unit 4 is present underneath the Blue Creek fault in cross section C (Plate 5).

Seven transverse faults are present in the Blue Creek thrust sheet and are part of the Concord CSL zone (Concord and McCalla 7.5’ quadrangles) (Figure 7.1) (Plate 5).
All of the transverse faults shorten the Blue Creek syncline along the axial trace. The rocks in the Blue Creek thrust sheet are interpreted as the strike-parallel expression of the trailing limb of the Blue Creek syncline. Because the cross section transects the Blue Creek trailing limb parallel to the axial plane of the fold, the rocks appear relatively undeformed in this section, with the exception of the up-plunge termination between cross sections 3 and 1 (Plate 5).

*Strike-Parallel Cross Section D-D’*

The Blue Creek fault splaying from the basal decollement at an elevation of approximately -9,000 ft (-2,740 m) between cross sections B and 5 (Plate 6). The Blue Creek fault is shallower to the northeast along strike and is nearly emergent between cross sections 3 and 1; at this location, the Blue Creek fault branches with the Opossum Valley fault (Plate 6).

The leading edge of the Bessemer mushwad underlies the Blue Creek thrust sheet in cross section D (note the feather edge thickness of mushwad across strike in cross section C, where C intersects cross sections 3 and 5; cross section C is northwest of most of the leading edge of the mushwad). The mushwad thins to the southwest along cross section D because of the oblique trace of the cross section with respect to the leading edge of the mushwad. Thickness of the mushwad is approximately 8,500 ft (2,590 m) at the A-D intersection (Plate 6). The roof detachment for the mushwad, the Blue Creek fault, is folded because of along-strike thickness variations of the Bessemer mushwad (Plate 6).

The back thrust that forms the northwestern boundary fault of the McAsham Mountain CSL zone appears in cross section D. The back thrust has an elevation of -7,500 ft (-2,290 m) at cross section B and shallows along strike to the northeast (Plate 6). The back thrust is truncated in the subsurface by the Opossum Valley fault along strike to the northeast (between cross section B and 5) (Plate 6).
Central Domain

Opossum Valley Thrust Sheet

Introduction

The stratigraphic successions preserved in the Opossum Valley thrust sheet are units 1 and 2. Along-strike cross section C transects part of the Opossum Valley thrust sheet, near the curve into the Conasauga oblique ramp at the BTZ (Bessemer 7.5’ Quadrangle) (Figure 7.1, Plate 1). Cross section C intersects strike-perpendicular cross section A in the Opossum Valley thrust sheet. Cross section D transects the Opossum Valley thrust sheet along the hinge line of the northwestern anticline of the Birmingham anticlinorium and extends to the northwest-striking segment of the Opossum Valley fault, where the fault is the northeast-bounding transverse fault of the McAshan Mountain CSL zone (Plate 1). Farther southwest from this location, cross section D transects the Blue Creek thrust sheet.

Strike-Perpendicular Cross Section A-A’

In cross section A, the Opossum Valley fault ramps from the basal decollement and overlies the Bessemer mushwad (the Opossum Valley fault is the roof thrust of the Bessemer mushwad in cross section A). The Opossum Valley thrust sheet has frontal and trailing ramps that cut through stratigraphic units 1 and 2. The Opossum Valley frontal ramp displaces the forelimb of the northwestern anticline of the Birmingham anticlinorium, separating the Coalburg syncline-Birmingham anticlinorium fold pair (Plate 3). The Opossum Valley trailing ramp contains the medial syncline of the Birmingham anticlinorium.

Strike-Perpendicular Cross Section B-B’

The Opossum Valley thrust fault does not extend along strike to cross section B. The fault curves in strike orientation to the northeast of cross section B and strikes northwest as the northeast-bounding transverse fault of the McAshan Mountain CSL zone (Plate 1).
Along-Strike Variations of the Opossum Valley Thrust Sheet in the BTZ
Along-Strike Cross Section C-C’

Cross section C exhibits the Opossum Valley fault in a very shallow structural position at cross section A (approximately 500 ft (150 m) above mean sea level) (Plate 5). The Opossum Valley thrust sheet contains units 1 and 2 as rocks comprising the forelimb of the Birmingham anticlinorium in cross section C. Units 1 and 2 are part of a lateral hanging-wall ramp in the Opossum Valley thrust sheet. The Opossum Valley fault terminates along strike between cross sections A and B (Plate 5). At the termination, the fault changes strike from northeast to northwest where it cuts across the allochthon as a northwest-striking lateral ramp. A footwall lateral ramp underlies the Opossum Valley fault in cross section C; the Opossum Valley fault cuts across units 2 through 4 in the footwall lateral ramp.

Strike-Parallel Cross Section D-D’

The Opossum Valley fault is relatively shallow in the along-strike cross section D. At the intersection with cross section A, the fault has an elevation of –2,000 ft (-610 m) (Plate 6). The elevation of the thrust fault is interpreted as varying sinusoidally southwestward through the transverse zone, and it ramps up along strike to the erosional surface, northeast of the intersection with cross section B (Plate 6). The sinusoidal variation in elevation is interpreted as folding of the thrust sheet by the underlying Bessemer mushwad (Plate 6). As shown on cross section D, a lateral hanging-wall flat in unit 1 of the Opossum Valley thrust sheet extends from cross section A southwestward to the intersection with cross section 5 (Plate 6).

Jones Valley Thrust Sheet

Introduction

The stratigraphy in the Jones Valley thrust sheet is floored by unit 1 and extends to unit 4. The Jones Valley fault has one sinistral curve in strike and persists in stratigraphic level of detachment across the BTZ. Because of the lack of along strike structural changes in the Jones Valley thrust sheet (Plate 1), strike parallel cross sections have not been constructed in the Jones Valley hanging wall.
Strike-Perpendicular Cross Section A-A’

The Jones Valley thrust sheet in cross section A forms the roof of the Bessemer mushwad and ramps to the present-day erosional surface (Plate 3). The Bessemer mushwad comprises the footwall for both the Opossum Valley and Jones Valley faults (Plate 3). The geometric shape of the Jones Valley trailing flat is controlled by the geometry of the Bessemer mushwad in the footwall. The frontal ramp of the Jones Valley thrust sheet displaces the forelimb of the trailing anticline of the Birmingham anticlinorium (Plate 3).

The Cahaba synclinorium is the trailing structure of the Jones Valley thrust sheet. A ramp is formed at the trailing edge of the Cahaba synclinorium, where the overlying Helena fault cuts through all four mechanical units. The deepest part of the Cahaba synclinorium corresponds to the location where the Jones Valley thrust sheet is a trailing flat on the basal decollement southeast of the trailing edge of the Bessemer mushwad, and the Jones Valley thrust sheet is not structurally elevated by the Bessemer mushwad (Plate 3). The elevation of the Jones Valley fault over the Bessemer mushwad constrains the structural width of the Cahaba synclinorium (Plate 3).

Strike-Perpendicular Cross Section B-B’

The preserved part of the Jones Valley thrust fault in cross section B is a trailing flat in unit 1. The Jones Valley frontal ramp is interpreted as being in the eroded part of the thrust sheet. The trailing flat of the Jones Valley fault is emplaced along the top of the underlying Bessemer mushwad. The trailing Jones Valley thrust sheet contains the Cahaba synclinorium. The synclinorium is structurally deep in cross section B; the base of the synclinorium rests on the basal decollement. The trailing edge of the Jones Valley thrust sheet is truncated by the overlying Helena fault in a trailing ramp that cuts through units 1 to 4.

Along-Strike Variations of the Jones Valley Fault in the BTZ

Although the Jones Valley thrust sheet persists as a ramp from the basal decollement southwestward across the BTZ, the thrust sheet extends farther across the width of graben 1 southwest of the transverse zone. The greater forelandward
translation of the Bessemer mushwad along strike in graben 1 permits the draping of the brittle roof (Jones Valley thrust sheet) onto the basal decollement in a more forelandward structural position to the southwest along strike. This change in structural position of the Bessemer mushwad permits an increase in the outcrop width of the Jones Valley thrust sheet along strike. Additionally, a southwestward along-strike change in the Jones Valley trailing edge, from a trailing ramp northeast of the BTZ to an oblique ramp at the BTZ, increases the width of the Jones Valley thrust sheet to the southwest.

In the northeastern part of the BTZ, the thrust sheet is approximately 90,000 ft (27,430 m) wide from the erosional tip line on the present ground surface to the trailing cut-off with the Helena thrust fault (Plate 3). Cross section B displays a width of the Jones Valley thrust sheet of approximately 117,000 ft (35,660 m) from the same structural positions as described for cross section A (Plate 4).

Southeastern Domain

Helena Thrust Sheet

Introduction

The Helena thrust sheet preserves stratigraphy from unit 1 to unit 4 (Plates 3 and 4). Cross section E-E’ models along-strike changes in the Helena thrust sheet at the BTZ. The E cross section extends from cross section A, through to cross section B and beyond to the map trace of the Helena fault southwest of the BTZ (Plate 1). Cross section E is placed close to the hinge line of the southeastern syncline in the Coosa synclinorium, and through the accommodation folds in the oblique ramp sections of the Elliotsville and Helena faults. The cross section extends through the entire Paleozoic succession.

Strike-Perpendicular Cross Section A-A’

The trailing edge of the Helena thrust sheet is in graben 2. The Helena fault ramps from the basal decollement in graben 2 to a decollement flat over the width of the basement horst separating grabens 1 and 2. At the northwest edge of the basement horst, the Helena fault ramps downward into graben 1 (Plate 3). The deepening of the Helena thrust sheet in graben 1 forms the Coosa synclinorium in the trailing part of the Helena thrust sheet (Plate 3). As measured from the outcrop traces of the Helena and
Yellowleaf faults, the Coosa synclinorium has a width of approximately 45,000 ft (13,700 m) in cross section A. The Helena leading edge is a frontal flat near the midsection of graben 1, bringing unit 1 rocks to the erosional surface. The frontal ramp of the Helena thrust sheet is interpreted as being eroded. A duplex in the Helena thrust sheet in the Coosa synclinorium involves strata from the basal decollement into an upper-level roof detachment at the unit 2-unit 3 contact. The upper-level, unit 2-unit 3 detachment horizon supports two fault splays that duplicate unit 3 and expose the unit on the surface in the BTZ.

The trailing edge of the Helena thrust sheet in graben 2 of the Birmingham basement fault system is a trailing ramp. The overlying Yellowleaf fault cuts through the upper part of unit 1 and through units 2 and 3 to an upper-level flat at the unit 3-unit 4 contact (Plate 3). The Helena thrust sheet in cross section A is approximately 189,000 ft (57,600 m) wide, as measured from the erosional tip line on the ground surface to the trailing cutoff at the basal decollement (Plate 3).

**Strike-Perpendicular Cross Section B-B’**

The Helena fault in cross section B ramps from the basal decollement, above the horst block separating grabens 1 and 2, to the present erosional surface. The frontal Helena ramp is interpreted as eroded from the leading edge of the Helena thrust sheet. An imbricate fan system in the leading edge of the Helena thrust sheet includes six splays that branch from the frontal flat, displacing unit 1 and folding the overlying stratigraphy.

The Coosa synclinorium in cross section B is located over the basement block separating grabens 1 and 2 (Plate 4). The Coosa synclinorium is approximately 38,000 ft (11,580 m) wide in cross section B (as measured between the outcrop traces of the Helena and Dry Creek thrust faults).

**Along-Strike Variations of the Helena Thrust Sheet in the BTZ**

**Strike-Parallel Cross Section E-E’**

The Helena fault has an elevation of approximately -15,000 ft (-4,570 m) at the intersection of cross sections A and E (Plate 7). The lateral edge of the Helena fault is a hanging-wall lateral flat in unit 1 that rises to the southwest over a footwall lateral ramp
in the underlying Jones Valley thrust sheet. The footwall detachment beneath the Helena hanging-wall lateral flat ramps along strike to an upper-level detachment near sea level in unit 4 (Plate 7). In the hanging wall of the Helena thrust sheet one duplex duplicates units 1 and 2. The floor detachment of the duplex is at an elevation of approximately -13,000 ft (-3,960 m). The roof thrust in unit 2 is at an elevation of approximately -7,800 ft (-2,380 m). The roof thrust of the duplex is interpreted as a lateral flat at the unit 2-unit 3 boundary. The lateral ramp section of the duplex roof thrust is interpreted as being part of the eroded section of the Helena fault (Plate 7).

The up-plunge termination of the Coosa synclinorium in the Helena thrust sheet is interpreted as overlying the Jones Valley footwall lateral ramp (Plate 6).

The Elliotsville fault is a splay off the Helena fault at an elevation of approximately -6,500 ft (-1,980 m). The Elliotsville fault repeats unit 1 and tightens the Coosa synclinorium along strike (Plate 7).

**Along-Strike Changes in the Helena Thrust Sheet Not Represented in Cross Section E.**

The position of the Coosa synclinorium changes along strike from cross section A to cross section B. To the northeast of the BTZ, the Coosa synclinorium is within graben 1. Along strike to the southwest, the Coosa synclinorium overlies the basement block separating grabens 1 and 2 (Plates 3 and 4). Therefore, the Coosa synclinorium is shallower and narrower to the southwest across the BTZ; approximately 45,000 ft (13,700 m) wide northeast of the BTZ to approximately 38,000 ft (11,580 m) wide southwest of the BTZ (as measured between the outcrop traces of the Helena and Yellowleaf faults in cross section A and between the outcrop traces the Helena and Dry Creek faults in cross section B). Narrowing of the Coosa synclinorium corresponds to a narrowing of the width of the Helena thrust sheet to the southwest of the BTZ. The Helena thrust sheet northeast of the BTZ is approximately 174,000 ft (53,000 m) wide. Southwest of the BTZ, the Helena thrust sheet is approximately 127,000 ft (38,700 m), as measured using the palinspastically restored, base of Knox, line-length dimensions for the Helena thrust sheet, measured from the leading to the trailing, base of Knox, cut-off points (Plates 3A and 4A).
Yellowleaf Thrust Sheet

Introduction

A complete succession of Paleozoic rocks is represented in the Yellowleaf thrust sheet, with the exception of the Pennsylvanian Pottsville Formation. The Yellowleaf thrust sheet terminates to the southwest along strike in the BTZ, and is represented only in cross section A. Along-strike cross sections F and G are placed along the trailing margin of the Yellowleaf thrust sheet, on the Kelley Mountain anticline. However, because these cross sections primarily transect the Talladega thrust sheet, the cross sections will be discussed in the chapter section titled, “Talladega Thrust Sheet”.

Strike-Perpendicular Cross Section A-A’

The trailing edge of the Yellowleaf thrust sheet is in graben 2; the fault splays from a lower-level detachment in unit 1 (not the basal decollement) to an upper-level detachment at the upper contact of unit 3. The upper-level flat in unit 3 extends for approximately 72,000 ft (21,950 m) to the northwest. The frontal ramp in the Yellowleaf fault is complex because of the presence of the upper-level flat in unit 3. The frontal ramp cuts up stratigraphic section through units 1, 2, and 3; however, the corresponding frontal flat in unit 4 extends to the erosional surface. The frontal ramp that contains unit 4 is interpreted as being in the eroded section of the Yellowleaf fault (Plate 3).

Four synthetic splays (two blind, two breaching the erosional surface) propagate from the upper-level detachment and fold the Mississippian stratigraphy in the Yellowleaf hanging wall. The frontal synthetic splay deforms the Yellowleaf hanging wall into the Kelley Mountain anticline (Plate 3). One back thrust, the Shelby Springs fault, splays off the upper-level detachment of the Yellowleaf thrust sheet and deforms units 1 through 4 into the Fourmile Creek anticline.

A trailing ramp terminates the Yellowleaf thrust sheet. The overlying Talladega fault splays from the basal decollement through units 1 and 2 to an upper-level detachment at the contact between units 2 and 3 (Plate 3). A eroded trailing flat in the Yellowleaf thrust sheet along the upper-level detachment at the base of unit 3 is the glide horizon for the overlying Talladega thrust fault.
Dry Creek Thrust Sheet

Introduction

The complete Paleozoic succession is represented in the Dry Creek thrust sheet. The Dry Creek thrust sheet terminates along strike to the northeast in the BTZ and as such is represented only in cross section B. Along strike sections F and G model the subcrop expression of the Dry Creek thrust sheet; however, the cross section will be described in the chapter section titled, “Talladega Thrust Sheet”, because the trace of the cross section transects the outcrop traces of the thrust sheet.

Strike-Perpendicular Cross Section B-B’

The frontal ramp of the Dry Creek fault that corresponds to the underlying trailing ramp in the Helena thrust sheet is partly eroded. Units 1 to 3 are present, but unit 4 is eroded from the ramp (Plate 4). A trailing flat in unit 1 comprises the remainder of the Dry Creek hanging wall to the trailing ramp, which cuts up section from unit 1 to unit 2. The top of unit 2 is an upper-level detachment for the overlying Talladega thrust sheet, and as such units 3 and 4 have been mechanically stripped from the Dry Creek thrust sheet (Plate 4). Two duplex horses shorten the Dry Creek thrust sheet along the trailing edge; only one of the duplexes crops out on the erosional surface (the foreland most and structurally highest duplex) (Plate 4). The trailing blind duplex is interpreted as existing in the subsurface in order to accommodate the space beneath the overlying, shallow-dipping, Talladega thrust sheet that is currently at the erosional surface (Plate 4). The trailing blind duplex duplicates units 1 and 2 and has a roof thrust in a unit 2 detachment.

Piedmont Metamorphic Domain

Talladega Thrust Sheet

Introduction

The Talladega thrust sheet contains rocks of the Piedmont physiographic province: the Neoproterozoic-Cambrian? Waxahatchee Slate, Brewer Phyllite, Stumps Creek Formation, and Wash Creek Slate of the Kahatchee Mountain Group; the Cambrian-Ordovician Jumbo Dolomite of the Sylacauga Marble Group; the Silurian-Devonian Lay Dam and Butting Ram formations of the Talladega Group; and Devonian
Jemison Chert. The map trace of the Talladega fault is sinuous in the BTZ, because of the shallow dip of the Talladega trust fault (Plate 1). Additionally, the Talladega thrust sheet is underlain by a folded footwall (the Yellowleaf and Dry Creek thrust sheets) and both footwall and hanging wall were folded after emplacement (Plates 1, 3, and 4).

Two along-strike cross sections, F and G, are placed along the Yellowleaf, Dry Creek, and Talladega thrust sheets. Cross section F intersects both cross sections A and B; however, section F extends to the northeast to depict the Columbiana syncline and the Fourmile Creek anticline. Cross section G also intersects both cross sections A and B, and is extended to the southwest beyond the transverse zone to the edge of coastal plain strata of the Gulf Coastal Plain. Section G is placed to transect the Kelley Mountain anticline and breached window in the Talladega thrust sheet. Both cross sections transect Piedmont metasedimentary rocks, from the Waxahatchee Slate to the Lay Dam Formation. The Ordovician Newala Limestone (unit 3) is exposed where cross section F transects the Fourmile Creek anticline. Cross section G transects outcrops of unit 2 through unit 4 in the Kelley Mountain anticline.

*Strike-Perpendicular Cross Section A-A’*

The Talladega fault in cross section A splays off the basal decollement in graben 2 and cuts up section through unit 1 and unit 2 in a footwall ramp at the trailing cutoff of the underlying Yellowleaf thrust sheet. The trailing cutoff of the Yellowleaf thrust sheet contains units 1 and 2 of the Valley and Ridge stratigraphy; however, the preserved remnants of the Talladega thrust sheet contain a metamorphosed Piedmont stratigraphy. As described in Chapter 5, some of the metamorphosed rocks in the Piedmont have been correlated with the unmetamorphosed rocks in the frontal structures of the Alleghanian thrust belt (Tull, 1979, 1982, 1985; Tull and Guthrie, 1983, 1985; Tull and Stow, 1980A, 1980B; Tull and Telle, 1988; Tull et al., 1998). Because the stratigraphy in the frontal Talladega ramp does not correspond to the stratigraphy in the trailing ramp in the underlying Yellowleaf thrust sheet; the nature of the frontal cutoff of the Talladega fault is uncertain.

The trailing Talladega thrust sheet in cross section A (Plate 3) shows an upper level, trailing flat along the contact of units 2 and 3 of the Yellowleaf thrust sheet for
approximately 33,000 ft (10,060 m). The rocks of the Waxahatchee Slate are the detachment for the Talladega trailing flat.

*Strike-Perpendicular Cross Section B-B’*

The Talladega fault in cross section B splays off the basal decollement in graben 2 and cuts up section through unit 1 and unit 2 in a footwall ramp at the trailing cutoff of the underlying Dry Creek thrust sheet. The Talladega fault propagates along an upper level footwall detachment at the top of unit 2 (approximately 37,500 ft/11,450 m) to the erosional surface. The Talladega frontal ramp is eroded and not preserved at the present erosional surface.

*Along-Strike Variations of the Talladega Thrust Sheet in the BTZ*

*Strike-Parallel Cross Section F-F’*

The Yellowleaf fault is relatively shallow northeast of the BTZ (−1,500 ft /−455 m) at cross section A (Plate 8). To the southwest along strike, the Yellowleaf fault deepens to approximately −10,000 ft (−3,050 m) in the transverse zone between cross sections A and B (Plate 8).

A hanging-wall lateral flat in the Yellowleaf thrust sheet is maintained in unit 2, with respect to the underlying Helena fault, across the BTZ (Plate 8). A Talladega footwall lateral flat in unit 3 of the Yellowleaf thrust sheet is maintained with respect to the overlying Talladega fault to the northeast of the BTZ (Plate 8). At the BTZ, the footwall lateral flat changes to a footwall lateral ramp between cross sections A and B, where the overlying Talladega thrust fault cuts down stratigraphic section from unit 3 to unit 2 (Plate 8). The underlying Helena thrust sheet maintains a footwall lateral flat in unit 3, with respect to the overlying Yellowleaf thrust fault. The Helena lateral flat changes along strike to a lateral ramp; the overlying Yellowleaf fault cuts down section from unit 3 to unit 2 (near cross section A) (Plate 8). The Yellowleaf fault terminates to the southwest along strike in unit 2.

The Dry Creek fault splays off the basal decollement at cross section B and ramps along strike to the northeast from unit 1 to unit 2 (Plate 8). The Dry Creek fault terminates to the northeast along strike in unit 2. A footwall lateral flat in unit 2 of the Dry Creek thrust sheet is maintained with respect to the overlying Talladega thrust fault.
A hanging-wall lateral ramp is present in the Dry Creek thrust sheet with respect to the underlying Helena thrust sheet. The hanging-wall lateral ramp cuts up section along strike from unit 1 to unit 2. The underlying Helena thrust sheet maintains a footwall lateral ramp, where the overlying Dry Creek fault cuts down section through unit 2 to unit 1, southwestward along strike.

The en-echelon terminations of the Yellowleaf and Dry Creek faults in unit 2 are interpreted as a lap-joint displacement transfer zone (Dahlstrom, 1970), overlying the lateral ramp in the underlying Helena thrust sheet (Plate 8).

The Talladega fault crops out near the Fourmile Creek anticline to the northeast of the BTZ and descends along strike to approximately −7,000 ft (−2,130 m) at the intersection of cross sections B and F (Plate 8). A hanging-wall lateral ramp in the Talladega thrust sheet near the Fourmile Creek anticline extends from unit 1 into the Shady Dolomite of the Piedmont metamorphic domain. A hanging-wall lateral flat is maintained in the Talladega thrust sheet in the Waxahatchee Slate to the southwest along strike (Plate 8). The fault surface is folded, however, by the along-strike elevation changes and folds of the underlying Yellowleaf and Dry Creek thrust sheets. The folding in the Yellowleaf and Dry Creek thrust sheets is the result of the lateral ramp in the underlying Helena thrust sheet.

*Strike-Parallel Cross Section G-G’*

The Yellowleaf fault in cross section G maintains a hanging-wall lateral flat, with respect to the underlying Helena fault, in unit 1 across the BTZ. The underlying Helena thrust sheet has a footwall lateral ramp where the Yellowleaf fault cuts down section across the BTZ from unit 3 to unit 1. A duplex in the Yellowleaf thrust sheet duplicates units 1 and 2 (Plate 9). The roof thrust of the duplex is a footwall lateral ramp, cutting through units 1 and 2. The floor thrust of the duplex is interpreted as the Yellowleaf fault. Southwestward along strike, an emergent splay from the Yellowleaf fault displaces the Paleozoic succession and exposes the Cambrian-Ordovician Knox Group on the erosional surface in the Fourmile Creek anticline (Plate 9). The splay is the along-strike expression of the Shelby Valley back thrust. The Kelley Mountain anticline is interpreted as part of the duplex of the Yellowleaf thrust sheet. The
Yellowleaf fault terminates to the southwest along strike in the BTZ. The tip point of the fault is located in unit 1.

The Talladega fault exhibits abrupt elevation changes in cross section G, extending from the erosional surface at the BTZ between cross sections A and B to approximately –14,000 ft (–4,270 m) southwest of the location of cross section B (Plate 9). The Talladega fault is a hanging-wall lateral flat in the Waxahatchee Slate, with respect to the Dry Creek footwall. The underlying Dry Creek thrust sheet is a footwall lateral ramp with the overlying Talladega fault. The Talladega fault cuts through folds in units 4 to 2 in the footwall lateral ramp southwest along strike in the BTZ. Southwest of the BTZ, the footwall lateral ramp connects to a footwall lateral flat in unit 1 in the Dry Creek thrust sheet. The Dry Creek fault splays from the basal decollement and terminates to the northeast in the BTZ in unit 1. The en-echelon terminations of the Yellowleaf and Dry Creek faults create a lap joint displacement transfer zone in unit 1 (Dahlstrom, 1970). The displacement transfer zone overlies the lateral ramp in the Helena thrust sheet beneath both the Yellowleaf and Dry Creek faults (Plate 9).

Discussion

Ideally, transverse zones extend across the entire allochthon and each strike-parallel structure exhibits some along-strike change at a transverse zone (Thomas, 1994). This observation is relevant in the surficial expression of the transverse zone, as well as the subsurface expression of the transverse zone (Chapter 6 and Chapter 7). Along-strike changes of subsurface structures in a transverse zone include:

1). terminations of thrust faults
2). changes in dip of fold hinges
3). changes in stratigraphic level of detachment
4). changes in structural style.

Two possible exceptions are thrust faults that cross the transverse zone and exhibit no change in strike and cross-strike links attaching two en echelon frontal ramps that are not aligned with a transverse zone.

Terminations of thrust faults in the subsurface are aligned along strike in the BTZ. The terminations of the Blue Creek, Opossum Valley, Dry Creek, and Yellowleaf
thrust faults, where they transect the transverse zone, are modeled in both strike-perpendicular cross sections and strike-parallel sections C, D, F, and G.

The Blue Creek and Opossum Valley thrust sheets end in opposite directions along strike in the subsurface transverse zone. The Blue Creek fault terminates to the northeast along strike, whereas the Opossum Valley fault ends to the southwest along strike (Plates 5 and 6). The faults have en-echelon overlaps and branch in the subsurface.

The Dry Creek fault decreases displacement to the northeast along strike, blindly terminating in unit 1 in cross section G and unit 2 in cross section F (Plates 8 and 9). The Yellowleaf fault decreases in displacement to the southwest along strike in the BTZ, blindly terminating in unit 1 in cross section G and unit 2 in cross section F (Plates 8 and 9). Similar to the Blue Creek and Opossum Valley faults, the Dry Creek and Yellowleaf faults have en-echelon overlaps in the subsurface; however, they do not branch together.

A change in the dip of the Coalburg-Blue Creek syncline is evident along the strike of the transverse zone. The dip of the Coalburg synclinal hinge and trailing limb is steeper in the strike-perpendicular section A (overturned to vertical) than the dips of the Blue Creek hinge and trailing limb in the strike-perpendicular section B (approximately 50° NW).

Changes in the stratigraphic level of detachment are evident in the BTZ. The basal decollement persists in the Cambrian Rome and Conasauga Formations, but ramps to higher stratigraphic levels within unit 1 across the thrust belt. These changes are evident in strike-perpendicular sections A and B, where decollement ramps are localized over basement faults 1, 2, and 3 of the Birmingham basement fault system.

Finally, changes in structural style across the transverse zone are evident in the Helena and Yellowleaf-Dry Creek thrust sheets. A large lateral-ramp offset in the trace of the Helena fault coincides with an along-strike change in cross-sectional structural position, as is shown from strike-perpendicular section A to strike-perpendicular section B. Duplexes in the Helena thrust sheet northeast of the BTZ may be absent along strike to the southwest. An imbricate fan system is preserved southwest of the BTZ. If the
imbricate fan system was a duplex, the roof thrust has been eroded, leaving the lower parts of the duplex at the present erosional surface. In the Yellowleaf-Dry Creek thrust sheets, the number of upper-level detachments decreases along strike to the southwest.

One exception regarding along-strike changes in thrust belt structures across transverse zones is applicable to the BTZ. Not all of cross-strike links in the thrust belt are aligned with the trend of the transverse zone. Further examination of the non-alignment of cross-strike links indicates that this anomaly may be scale-dependent in nature. Groupings of cross-strike links, such as the Concord and McCalla CSL zones, are aligned with the northwest-southeast trend of the transverse zone. However, individual cross-strike links are not necessarily aligned with the trend of the BTZ, but form at angles of 45° to 55° to the northwest-southeast transverse zone axis. Individual cross-strike links are perpendicular to local strike (i.e., the strike of the limbs of second-order folds within thrust sheets); however, they are not parallel to transverse zone trend. This is evident in the map view of the transverse faults in the Concord CSL zone and the alignment of the oblique ramps in the Helena and Elliotsville faults (Plate 1).
Figure 7.1: Geologic map of the Bessemer transverse zone (modified from Szabo et al., 1988), showing the extent of the Bessemer transverse zone (between cross sections A and B).
Figure 7.1A: Explanation for Figure 7.1 geologic map.
Figure 7.2: Schematic map of the Alleghanian thrust belt in Alabama and Georgia, showing the locations of four transverse zones (modified from Thomas, 1990). The Bessemer transverse zone is shaded in the blue-purple domain gradient.
Chapter 8: Outcrop Geology of the Concord-McCalla 7.5’ Quadrangles, Northwestern Bessemer Transverse Zone

Introduction

Cross-strike links connecting the Blue Creek, Opossum Valley, and Jones Valley thrust faults are exposed in the northwestern part of the BTZ in the Concord and McCalla 7.5’ quadrangles (Figure 8.1, Plate 13). Cross-strike links mapped in these quadrangles are fundamental components of the BTZ. Exposure of the cross-strike links at the erosional surface allowed mapping (1:24,000 scale) of the geometric relationships between the cross-strike links and the thrust faults that they connect.

The thrust belt terminology developed in Chapter 6 is utilized in this chapter. Mapped thrust sheets have leading, trailing, and lateral/oblique flats and ramps. The geometry of the map traces of these flats and ramps is the focus of this chapter.

Description of Analytical Techniques

Geological mapping (1:24,000 scale) of the cross-strike links; the Blue Creek, Opossum Valley, and Jones Valley thrust faults; and the McAshan Mountain back thrust was conducted in the Concord and McCalla 7.5-minute quadrangles during the winter and spring field seasons of 1999 and 2000. Geologic mapping of stratigraphic contacts, with bedding attitude measurements, was conducted by traversing perpendicular to regional strike to determine the nature of the contacts between stratigraphic units, then tracing the contacts along strike to map the aerial distribution. Variances in strike and dip measurements, omission and/or repetition of stratigraphic units, and bedding-cleavage relationships were used to locate fold limbs, hinges, and fault surfaces and to determine overturning of strata. Fold hinges are not preserved in outcrop and were derived from stereographic projections of fold limb measurements and interpolated onto the geologic map. Fault surfaces are also not preserved in outcrop and were interpolated onto the geologic map where stratigraphic repetition or omission observations are available. Fault kinematic interpretations are based on amount of separation of stratigraphic contacts.

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Surficial Geology of the Concord and McCalla 7.5’ Quadrangles

Stratigraphic Framework

The Paleozoic succession, from the Cambrian Conasauga to the Pennsylvanian Pottsville formations, is present in the Concord and McCalla, 7.5’ quadrangles (Plate 13). Stratigraphic units young towards the western boundaries of the quadrangles. Weak units within the succession are the basal decollement-bearing horizon (the Cambrian Conasauga Formation) and a number of stratigraphic units higher in the Paleozoic succession (the Silurian Red Mountain Formation, the Mississippian Pride Mountain Formation and Floyd Shale, the Mississippian-Pennsylvanian Parkwood Formation and the upper levels of the Pennsylvanian Pottsville Formation). Competent units are the Cambrian Ketona Dolomite, the Cambrian-Ordovician Knox Group (Copper Ridge Dolomite), the Ordovician Chickamauga Limestone, the Mississippian Tuscumbia Limestone, the Fort Payne Chert, the Hartselle Sandstone, and the Bangor Limestone.

Structural Framework

Introduction

The structures of the Concord and McCalla 7.5’ quadrangles are within the northwestern and central structural domains of the thrust belt, as outlined in Chapter 6. Three thrust faults have been mapped in the quadrangle; the Opossum Valley, the Blue Creek, and the Jones Valley (Plate 13). One antithetic back thrust in the Blue Creek thrust sheet is identified as the McAshan Mountain back thrust (Plate 13).

Three fault-related folds are present within the quadrangles; the Blue Creek syncline, the Blue Creek anticline, and the Birmingham anticlinorium (Plate 13). The Blue Creek syncline is located in the Blue Creek thrust sheet. The up-plunge termination of the Blue Creek syncline in the Concord and McCalla 7.5’ quadrangles is transected by three northwest-striking transverse faults. These transverse faults are the cross-strike links between the Blue Creek fault and the McAshan Mountain back thrust (cross-strike links 1 and 3) and between the Blue Creek and Opossum Valley faults (cross-strike link 2), (Plate 13). The Blue Creek anticline is in the Blue Creek thrust sheet in the Concord and McCalla 7.5’ quadrangles. The Birmingham anticlinorium is
divided into the Opossum Valley (Bessemer 7.5’ Quadrangle) and Jones Valley (McCalla 7.5’ Quadrangle) ramp anticlines, which are separated by the unnamed medial syncline in the trailing part of the Opossum Valley thrust sheet within the anticlinorium (Plate 13). Four small-scale folds are present in the Blue Creek-trailing limb in the Concord 7.5’ Quadrangle. Three of the folds are unnamed; one fold has been named the West End anticline (Plate 13).

**Opossum Valley Thrust Sheet**

The Cambrian Conasauga to Copper Ridge dolomites are preserved in the Opossum Valley thrust sheet in the Concord and McCalla 7.5’ quadrangles (Plate 13). The Opossum Valley thrust fault has several strike-orientation changes in the BTZ, only one of which is in the Concord and McCalla 7.5’ quadrangles (Plate 13). The regional northeast-southwest strike of the fault, as shown in the Concord and McCalla 7.5’ quadrangles curves to northwest-southeast in the McCalla 7.5’ Quadrangle at cross-strike link 4 (Plate 13). The northwest-striking part of the Opossum Valley fault is truncated by the northeast-striking Jones Valley thrust fault (Plate 13).

A rejoining splay from the Opossum Valley fault in the Concord 7.5’ Quadrangle contains Copper Ridge Dolomite at the present erosional surface (Plate 13). The Opossum Valley fault proper is a frontal ramp cutting up section from the Conasauga through Ketona and Copper Ridge dolomites (Plate 14 [Location 1]). The Opossum Valley frontal ramp curves into a lateral ramp in the McCalla 7.5’ Quadrangle where the fault changes strike to northwest; along the northwest-trending lateral ramp the fault cuts up section from the Conasauga Formation to the Knox Group (Plate 14 [Location 2]).

The trailing edge of the Opossum Valley thrust sheet in the McCalla 7.5’ Quadrangle is a trailing ramp with the overlying Jones Valley fault (Plate 13). The ramp cuts down section from the Copper Ridge Dolomite to the Conasauga Formation, southwestward along strike in the BTZ (Plate 14 [Location 3]). The trailing edge of the Opossum Valley thrust sheet extends northeastward from the McCalla 7.5’ Quadrangle into the Greenwood 7.5’ Quadrangle to the east (Plate 13). Two unnamed, small-scale, folds are mapped at the Opossum Valley lateral ramp, a leading syncline and a trailing
anticline. These structures will be discussed under the heading “Cross-Strike Links and Related Structures”.

**Blue Creek Thrust Sheet**

The branch point between the Opossum Valley and Blue Creek thrust faults is in the Bessemer 7.5’ Quadrangle, east of the Concord 7.5’ Quadrangle (Figure 8.1). The Blue Creek fault continues along the regional northeast strike of the Opossum Valley fault and terminates southwestward in the BTZ as a blind thrust in the low-amplitude Blue Creek anticline (McCalla 7.5’ Quadrangle) ([Plate 14](#)[Location 4]). Originally, the Blue Creek fault was mapped as the Opossum Valley thrust fault (Kidd and Shannon, 1970), but was remapped during this investigation as an independent thrust fault, on the basis of consistency of stratigraphic displacement. The remapped Blue Creek fault cuts across the entire Paleozoic succession (Figure 8.1), whereas the remapped Opossum Valley fault maintains a detachment in the Conasauga-lower Knox succession ([Plate 13](#)).

The Blue Creek thrust sheet in the Concord 7.5’ Quadrangle is divided into three sections by northwest-striking transverse faults. Section 1 is the northeasternmost section near the eastern boundary of the Concord 7.5’ Quadrangle ([Plate 14](#)). Section 2 is the medial section between sections 1 and 3. Section 3 is the southwesternmost section transecting the Concord-McCalla quadrangle boundary ([Plate 14](#)).

The dip of the trailing limb of the Blue Creek syncline varies in each section of the Blue Creek thrust sheet. Near the branch point of the Opossum Valley and Blue Creek faults (section 1), the dip of the Blue Creek trailing limb is overturned an average of 40° to the southeast. Southwest along strike, the Blue Creek trailing limb steepens to vertical (section 2) ([Plate 13](#)). Vertical dips change farther along strike to northwest dips of an average 50° (section 3) ([Plate 13](#)).

The leading and trailing edges of the Blue Creek thrust sheet also differ from section to section. The leading edge of section 1 is an oblique ramp in the Floyd Shale that cuts up section into the Parkwood Formation ([Plate 14](#)[Blue Creek hanging wall across from Location 5]). The oblique ramp continues into a frontal ramp in the upsection transition from the Parkwood Formation into the Pottsville Formation ([Plate 14](#)).
McAskan fault near the Hartselle Sandstone ([Blue Creek hanging wall across from Location 6]). The frontal ramp in section 1 continues into a frontal FSP ramp in section 2. The detachment horizon in the section 2 frontal FSP ramp is the Parkwood Formation ([Plate 14] [Blue Creek hanging wall across from Location 7]). The Blue Creek frontal FSP ramp continues across a transverse fault into section 3, but the detachment horizon in section 3 is in the Pottsville Formation ([Plate 14] [Location 8]).

The trailing edge of the Blue Creek thrust sheet is complicated by small-scale folds ([Plate 13]). Part of the Blue Creek trailing edge in section 1 is mapped in the adjacent Bessemer 7.5' Quadrangle to the east of the Concord 7.5' Quadrangle (Figure 8.1). The Bessemer part of the Blue Creek trailing edge is discussed in Chapter 6; the Concord part of the Blue Creek trailing edge is discussed in this chapter. The Blue Creek trailing edge in section 2 is present in the Concord and McCalla 7.5' quadrangles along the Opossum Valley fault. The Blue Creek trailing edge in section 3 is along the Opossum Valley fault in the Concord and McCalla 7.5' quadrangles and changes along strike, across the northwest-striking Opossum Valley fault (cross-strike link 4), to intersect the Jones Valley fault in the McCalla 7.5' Quadrangle ([Plate 13]).

The section 2 part of the Blue Creek trailing edge, and part of the section 3 trailing edge, are along the rejoining splay of the Opossum Valley fault ([Plate 13]). The trailing edge of section 2 is an oblique ramp that changes along strike to a footwall FSP ramp ([Plate 14] [Location 9]). The oblique ramp truncates the trailing limb of the West End anticline, and cuts up section from the Fort Payne Chert through the Pride Mountain Formation into the Hartselle Sandstone. The oblique ramp extends into a trailing FSP ramp to the southwest along strike. The trailing FSP ramp is maintained in the Hartselle Sandstone ([Plate 13]).

The trailing edge of the Blue Creek thrust sheet in section 3 is an oblique ramp near the branch point of the Opossum Valley rejoining splay and the Opossum Valley fault proper ([Plate 14] [Location 10]), the area known informally as “the Knot” by field geologists working in the area. The oblique ramp (eastern boundary of “the Knot”) cuts up section from the Red Mountain Formation to the Hartselle Sandstone. A transverse fault bounding “the Knot” to the west-southwest (the northeastern extension of the McAskan Mountain back thrust, as discussed below) is truncated by the Opossum
Valley fault ([Plate 14] [Location 11]). Southwest of the back-thrust fault, the trailing edge of the Blue Creek thrust sheet is a trailing FSP ramp in the Chickamauga Limestone. The trailing Chickamauga ramp continues along strike to the southwest where it is interrupted by the northwest-striking lateral ramp termination of the Opossum Valley thrust sheet (cross-strike link 4) ([Plate 14] [Location 12]). Southwest of this juncture, the Blue Creek trailing edge is overlain by the Jones Valley fault ([Plate 13]).

The trailing edge of the Blue Creek thrust sheet in the Jones Valley footwall is a trailing FSP ramp in the Copper Ridge Dolomite to the northeast of cross-strike link 5 ([Plate 13]). Southwest of cross-strike link 5, a footwall splay of the Jones Valley fault truncates the Blue Creek footwall maintaining a trailing FSP ramp in the underlying Red Mountain Formation ([Plate 13]). The Blue Creek trailing edge persists in this structural position along strike southwest of the BTZ.

**McAshan Mountain Back Thrust**

The trailing part of the Blue Creek thrust sheet is shortened by the northwest-dipping, McAshan Mountain back thrust. The northeast-striking back thrust is truncated by cross-strike links 1, 2, 4, 5, and 6 to the southwest along strike. The McAshan Mountain back thrust was initially mapped in the McAshan Mountain CSL zone. Correlation of the McAshan Mountain back thrust with back thrusts in sections 3 and 2 is based on kinematic modeling and the consideration of hanging-wall stratigraphic relationships in the section 3 and section 2 back thrusts along strike. Discussion of the McAshan Mountain back thrust in this chapter will describe the McAshan Mountain CSL area first, then extend northeast along strike into sections 3, and 2 of the Blue Creek thrust sheet. Finally, back-thrust discussion will focus on the back-thrust structure to the southwest of the McAshan Mountain CSL zone where the McAshan Mountain back thrust terminates southwestward along strike.

A back thrust mapped on McAshan Mountain, McCalla 7.5’ Quadrangle, shortens the trailing limb of the Blue Creek syncline. The McAshan Mountain back thrust juxtaposes Copper Ridge Dolomite in the hanging wall, next to Fort Payne Chert in the footwall ([Plate 13]). Northeast of the McAshan Mountain CSL zone, a northwest-striking back thrust forms the west-southwestern border of “the Knot” in section 3.
The back thrust in “the Knot” maintains a detachment in the Chickamauga Limestone, the stratigraphic unit overlying the Copper Ridge Dolomite. The McAshan Mountain back thrust is interpreted as plunging to the northeast underneath cross-strike link 4 and the Opossum Valley thrust sheet (Plate 14 [Location 13]), and emerging along strike in section 3 as the back thrust in “the Knot” (Plate 14 [Location 11]). A Copper Ridge hanging-wall detachment in the McAshan back thrust southwest of cross-strike link 4 and a Chickamauga hanging-wall detachment in the back thrust in “the Knot” is interpreted as a hanging-wall ramp in the McAshan Mountain back thrust that is covered by the Opossum Valley thrust sheet (Plate 13).

North along strike, three back thrusts are mapped in section 2. The easternmost back thrust has a hanging-wall detachment in the Red Mountain Formation. The medial and western back thrusts in section 2 have hanging-wall detachments in the Floyd and Parkwood formations, respectively. The Red Mountain Formation is the stratigraphic unit overlying the Chickamauga Limestone in the Concord and McCalla 7.5’ quadrangles. The back thrust with a detachment in the Red Mountain Formation is interpreted as the section 2 continuation of the McAshan Mountain back thrust; the along-strike continuation of a frontal ramp extending from the Copper Ridge Dolomite southwest of cross-strike link 4, to the Chickamauga Limestone in section 3, to the Red Mountain Formation in section 2 (Plate 14 [fault labeled MBT]). The McAshan Mountain back thrust in “the Knot” is inferred to be plunging to the north along strike, under cross-strike link 2 and emerging in section 2 as the back thrust with a hanging-wall detachment in the Red Mountain Formation. The McAshan Mountain back thrust in section 2 continues to the northeast along strike as a hanging-wall ramp, cutting up section from the Red Mountain Formation to the Fort Payne and Pride Mountain rocks and branching with cross-strike link 1 (Plate 13). The medial and western back thrusts are interpreted as splays off of the McAshan back thrust because of the detachments they maintain in the middle-upper Paleozoic stratigraphy, the Floyd through Parkwood formations, respectively (Plate 14 [faults labeled Splay 1 and Splay 2]).

Southwest of cross-strike link 4, the back thrust maintains a frontal FSP ramp in the Copper Ridge Dolomite. Cross-strike link 5 splay with the McAshan Mountain back thrust, but does not truncate the structure. The back thrust is terminated to the
southwest along strike by a curve in the strike of the Jones Valley fault (cross-strike link 6) (Plate 13). The southwestern lateral edge of the McAshan back thrust is a lateral ramp in the Copper Ridge Dolomite near cross-strike link 6 (Plate 13).

The leading edge of the back thrust footwall varies along strike in the BTZ. The northeastern frontal edge, near cross-strike link 1, is an oblique ramp beneath the back thrust in the Pottsville Formation that cuts down section into the Parkwood and Floyd formations (Plate 14 [Location 14]). Farther southeast, the oblique ramp cuts across the structures of the unnamed, Pride-Mountain-cored anticline, plunging to the northeast away from cross-strike link 1 (Plate 14 [Location 15]). The oblique footwall ramp of the McAshan Mountain back thrust cuts across the leading Hartselle limb, the Pride Mountain hinge, and the trailing Hartselle limb to the south-southwest along strike. The oblique footwall ramp extends into a leading FSP footwall ramp in the Hartselle Sandstone (Plate 14 [Location 16]) that extends to “the Knot” and plunges underneath the Opossum Valley thrust sheet (Plate 14 [footwall across from Location 11]). Underneath the Opossum Valley thrust sheet, the Hartselle footwall ramp extends southwestward down section into the Fort Payne Chert. A FSP footwall ramp in the Fort Payne Chert is maintained to the southwest along strike. Near cross-strike link 5, the FSP footwall ramp cuts down section from the Fort Payne to the Red Mountain Formation (Plate 14 [Location 17]). A southwest-dipping thrust fault (cross-strike link 5) truncates the back-thrust footwall, juxtaposing the Copper Ridge Dolomite against a lateral ramp in the Red Mountain, Chickamauga, and Copper Ridge formations (Plate 14 [footwall across from Location 18]). The leading edge of the back-thrust footwall southwest of cross-strike link 5 is a frontal ramp refracting up and down stratigraphic section from the Red Mountain Formation, to the Fort Payne Chert, to the Red Mountain Formation (Plate 14 [Locations 19 and 20]). The back-thrust sheet is terminated to the southwest by a small along-strike curve in the Jones Valley fault (cross-strike link 6) (Plate 14 [Location 20]).

**Jones Valley Thrust Sheet**

The Jones Valley fault truncates two unnamed transverse faults (cross-strike links 5 and 6) in the Copper Ridge Dolomite in the trailing FSP ramp of the Jones
Valley footwall splay (Plate 13). These transverse faults are discussed in the Cross-Strike Links section.

Cross-Strike Links and Related Structures

Introduction

Cross-strike links in the Concord and McCalla 7.5’ quadrangles connect the Blue Creek, McAshan Mountain back thrust, Opossum Valley, and Jones Valley thrust faults. The cross-strike links are grouped by location and by similarity in structural style. Three northwest-trending transverse faults (cross-strike links 1, 2, and 3) connecting the Blue Creek with the Opossum Valley, McAshan Mountain, and Jones Valley faults are grouped into the Concord CSL zone, as defined in Chapter 6. The McAshan Mountain area is a northeast-trending group of structures composed of two northeast-striking thrust faults (the McAshan Mountain back thrust and the Jones Valley fault) and three northwest-striking faults, the Opossum Valley lateral ramp (cross-strike link 4) and two unnamed transverse faults (cross-strike links 5 and 6). The two transverse faults connect the McAshan Mountain back thrust with the Jones Valley fault across strike. The Opossum Valley lateral ramp (cross-strike link 4) connects the Opossum Valley fault with the McAshan Mountain back thrust and the Jones Valley fault across strike. These three northwest-striking faults are grouped into the McAshan Mountain CSL zone, as defined in Chapter 6. Because the areal distribution of the Opossum Valley fault, the McAshan Mountain back thrust, and the Jones Valley fault have been previously described in this chapter, only the northwest-striking structures will be discussed in this section.

Concord CSL Zone

Cross-Strike Link 1

Cross-strike link 1 is the northeastern transverse fault in the Concord 7.5’ Quadrangle and is the southwest boundary of section 1 of the Blue Creek thrust sheet (Plate 14). Cross-strike link 1 connects the Blue Creek fault and the McAshan Mountain back thrust across strike. The transverse fault strikes northwest across the axial plane of the Blue Creek syncline, and curves to a north-northwest strike in the trailing limb of the Blue Creek syncline to branch with the McAshan Mountain back
thrust ([Plate 14][back-thrust hanging wall across from Location 14]). The outcrop trace of the transverse fault across the landscape implies that the fault is steeply dipping. Section 1 is inferred to be the downthrown block with respect to cross-strike link 1, on the basis of the juxtaposition of older (section 2) over younger (section 1) stratigraphy along the fault outcrop trace ([Plate 13]). Two splays branch from the transverse fault into the upthrown block where the fault curves from northwest to northeast strike ([Plate 13]).

In the downthrown block of cross-strike link 1, the fault cuts across section in the Pottsville Formation in the core of the Blue Creek syncline. The cross-strike link branches with the McAshan Mountain back thrust in the Pottsville Formation.

In the upthrown block of cross-strike link 1, cross-strike link 1 ramps up section from the Floyd Shale to the Parkwood Formation (in the direction of thrust transport), where it branches with the McAshan Mountain back thrust.

Two north-northeast-striking splays are associated with cross-strike link 1. Both splays are back thrusts that crop out in the upthrown block of the cross-strike link and shorten the up-plunge termination of the Blue Creek syncline in section 2 ([Plate 13]). Splay 1 crops out at the lower contact of the Floyd Shale ([Plate 14]). The footwall of splay 1 is a ramp from the Pride Mountain Formation to the Hartselle Sandstone; the boundary between the Pride Mountain and Hartselle formations is a small, unnamed transverse fault truncated by splay 1 ([Plate 14][footwall across from Location 21]). The second splay of cross-strike link 1 crops out along the shared contact of the Floyd-Parkwood formations and is parallel with bedding strike on both sides of the fault plane ([Plate 13]).

A small-scale, northwest-verging, northeast-plunging anticline-syncline pair is present in the downthrown block of the cross-strike link 1, proximal to where cross-strike link 1 branches with the McAshan Mountain back thrust ([Plate 14][Location 15]). The frontal limb of the anticline is overturned to an average 35° SE dip. The trailing limb dips at an average 40° SE ([Plate 13]). The leading limb of the trailing syncline shares the 40° SE-dipping limb with the leading anticline. The trailing limb of the trailing syncline is shared with the leading limb of the West End anticline ([Plate 13]).
The trailing synclinal limb/frontal West End anticline limb is overturned to an average 40° SE (Plate 13).

**Cross-Strike Link 2**

The medial, north-northwest-striking, steeply dipping, transverse fault that is the boundary for section 2 of the Blue Creek thrust sheet is cross-strike link 2. On the basis of apparent stratigraphic contact migration in the direction of dip with respect to the fault surface, the upthrown block for cross-strike link 2 is section 2 and the downthrown block is section 3 (Plate 13). The fault cuts across the entire Blue Creek syncline to a branch point with the rejoining splay of the Opossum Valley fault (Plate 13).

Cross-strike link 2 ramps up section from the Red Mountain Formation to the Parkwood Formation, truncates the McAshan Mountain back thrust and branches with both splays of the back thrust in section 2. Cross-strike link 2 curves in strike from northwest to east-west at the truncation of the McAshan Mountain back thrust (Plate 13). An unnamed, northeast-plunging, Pride Mountain-cored anticline is also truncated by the east-west-striking cross-strike link 2, in the upthrown block (Plate 13). The small-scale, Pride Mountain-cored anticline plunges to the northeast, away from the map trace of cross-strike link 2. The frontal limb of the anticline dips at approximately 45° NW and the trailing limb of the anticline dips at an average 37° SE (Plate 13). The anticline is the southwestern extension of the anticline-syncline fold pair near cross-strike link 1 (Plate 13). A branch between cross-strike link 2 and the Opossum Valley rejoining splay is mapped east of the truncation of the Pride Mountain-cored anticline (Plate 14 [Location 22]).

In the downthrown block of cross-strike link 2, the transverse fault ramps up section from the Floyd Shale in the trailing Blue Creek synclinal limb to the Pottsville Formation in the hinge zone of the Blue Creek syncline (Plate 13).

Cross-strike link 2 branches with the Blue Creek fault to the northwest and with the Opossum Valley rejoining splay to the southeast (Plate 13). This cross-strike link is inferred as transferring displacement between the Blue Creek fault and the Opossum Valley fault. The cross-strike link truncates the western boundary fault of “the Knot”, which in turn truncates the McAshan Mountain back thrust southwest along strike.
Displacement transfer may also occur between the Blue Creek fault and the McAsahan Mountain back thrust along cross-strike link 2 (Plate 13).

**Cross-Strike Link 3**

Cross-strike link 3 is the southwesternmost transverse fault of the Concord CSL zone and is the southwest boundary fault for section 3 of the Blue Creek thrust sheet. The northwest-striking linear fault trace implies that the fault is steeply dipping (Plate 13). The eroded Pottsville-Parkwood contact in section 3 has migrated along dip direction with respect to the cross-strike link, implying that section 3 is the upthrown block and the part of the Blue Creek syncline southwest of cross-strike link 3 is the downthrown block (Plate 13).

The transverse fault displaces the stratigraphic succession from Pottsville Formation to the Floyd Shale in both the upthrown and downthrown blocks. The displacement of the cross-strike link is transferred across strike into a detachment fold in the northwest-dipping hanging wall of the McAsahan Mountain back thrust (Plate 14 [Location 23]). The weak Floyd Shale has a thicker outcrop width in the upthrown block of cross-strike link 3. Dip angles in the upthrown and downthrown blocks of cross-strike link 3 range from 40° to 60° on both sides of the fault trace, implying that variance in dip angle is not the cause of thickening of the Floyd outcrop width (Plate 13). Weak Floyd shales have flowed into the hinge zone of the fold, accommodating space generated at the cross-strike link 3 tip point. The detachment fold strains the McAsahan Mountain back thrust and the trailing edge of the Blue Creek thrust sheet (footwall of the McAsahan Mountain back thrust) (Plate 13).

Cross-stripe link 3 splays from the Blue Creek fault on the northwest and terminates in the unnamed detachment fold to the southeast (Plate 13). A branch point between cross-strike link 3 and the Opossum Valley fault, McAsahan Mountain back thrust, or Jones Valley fault is not preserved at the present erosional surface. The detachment fold is truncated by cross-stripe link 4 of the Opossum Valley thrust sheet (Plate 14 [Locations 12 and 13]) and by the leading edge of the Jones Valley thrust sheet (Plate 13). Displacement transfer along cross-strike link 3 from the Blue Creek fault to the Opossum Valley, McAsahan Mountain back thrust, and Jones Valley faults is
inferred to have occurred via the detachment fold that is truncated by these structures (Opossum Valley and Jones Valley faults) and/or deforms them (McAsahan Mountain back thrust).

**McAsahan CSL Zone**

**Cross-Strike Link 4**

The northeasternmost structure of the McAsahan Mountain CSL zone is the Opossum Valley lateral ramp (cross-strike link 4). The northwest-striking segment of the Opossum Valley fault is the northeast boundary fault of the McAsahan Mountain CSL zone. As described in previous sections of this chapter, the lateral ramp is a footwall and hanging-wall ramp truncated by the Jones Valley fault.

Two small-scale folds are mapped at the Opossum Valley lateral ramp, a leading syncline and a trailing anticline that are part of the medial syncline of the Birmingham anticlinorium (Plate 13). Both structures plunge to the northeast away from the map trace of the lateral ramp (Plate 13). The frontal syncline has a steep leading limb that dips on average 80° SE. The trailing limb dips on average 40° NW. The trailing anticline shares the 40°-dipping limb of the leading syncline. The trailing antclinal limb has an average dip of 25° SE (Plate 13).

The Opossum Valley lateral ramp branches with the Opossum Valley fault on the northwest and with the Jones Valley thrust fault across strike on the southeast. The Opossum Valley lateral ramp is inferred to be a cross-strike link that directly connects two major thrust faults across strike (Plate 13).

**Cross-Strike Link 5**

A northwest-striking transverse fault located in the middle of the McAsahan Mountain CSL is cross-strike link 5 (Plate 13). The transverse fault dips to the southwest and is a footwall lateral ramp, as discussed in previous sections of this chapter. The transverse fault is a thrust fault that juxtaposes a Copper Ridge-bearing, footwall splay of the Jones Valley fault against the Blue Creek footwall lateral ramp of truncated Copper Ridge, Chickamauga, and Red Mountain formations (Plate 13). The strata in the Blue Creek footwall lateral ramp dip an average of 45° NW. One vertical
bedding attitude measurement is measured in the hanging wall of the Jones Valley splay (Plate 13).

Cross-strike link 5 branches with the McAshan Mountain back thrust to the northwest and with the Jones Valley fault across strike to the southeast (Plate 13).

**Cross-Strike Line 6**

Cross-strike link 6 is the southwestern termination of the McAshan Mountain CSL zone (Plate 13). Along-strike changes in the strike of the Jones Valley fault, from northeast to northwest and back to northeast, are abrupt; and the northwest-striking segment can be classified as a small lateral ramp. The displacement on the Jones Valley lateral ramp is too small to be mappable at the scale of the 1:250,000 BTZ map (Plate 1). Therefore, the Jones Valley lateral ramp has not been discussed in Chapters 6 and 7. A footwall lateral ramp is present at the McAshan Mountain CSL zone termination, as discussed previously in this chapter.

A footwall splay from the Jones Valley fault at cross-strike link 6 shortens the Copper Ridge outcrop expression in this area. The splay also shortens the trailing limb of the Blue Creek syncline and forms a frontal ramp with the underlying Blue Creek thrust sheet that cuts up section from the Copper Ridge Dolomite to the Red Mountain Formation (Plate 14 [Location 24]).

The McAshan Mountain back thrust is truncated along strike by cross-strike link 6.

**Additional Cross-Strike Links**

One cross-strike link in the Concord 7.5’ Quadrangle is not classified with either the Concord or McAshan Mountain CSL zones. Cross-strike link 7 is a lateral ramp at the trailing edge of the Blue Creek thrust sheet and a hanging-wall lateral ramp that cuts across the Copper Ridge stratigraphy in the overlying rejoining splay of the Opossum Valley thrust sheet (Plate 13).

The footwall lateral ramp has previously been described in this chapter. A small-scale fold in the Blue Creek syncline, the West End anticline, plunges toward the lateral ramp (Plate 13). The fold is distinct from other cross-strike link folds because it
plunges towards the CSL map trace, rather than away from it as in the other cross-strike links (Plate 13).

**Jones Valley Thrust Sheet**

In the Concord and McCalla 7.5’ quadrangles, only the Conasauga Formation has been mapped at the current erosional level of the Jones Valley thrust sheet (Plate 13). The Jones Valley thrust fault extends from north of the BTZ as a forelimb thrust of the southwestern anticline in the Birmingham anticlinorum and continues along strike through the transverse zone in this structural position (Szabo et al., 1988).

The leading edge of the Jones Valley thrust fault is a frontal flat in the Conasauga Formation (Plate 13). The trailing edge of the Jones Valley thrust sheet crops out southeast of the Concord and McCalla 7.5’ Quadrangles.

**Conclusion**

The Concord and McCalla 7.5’ quadrangles include two domains of cross-strike links, the Concord CSL zone and the McAshan Mountain CSL zone. The cross-strike links in the Concord CSL zone are all in the Blue Creek thrust sheet, the McAshan Mountain back thrust part of the Blue Creek thrust sheet, in particular. The cross-strike links in the McAshan Mountain CSL zone are in the Opossum Valley (cross-strike link 4) and Blue Creek (cross-strike links 5 and 6) thrust sheets.

The cross-strike links of the Concord CSL zone are all steeply dipping transverse faults connecting differing thrust faults across strike. The cross-strike links of the McAshan Mountain CSL zone are all transverse faults that are the lateral terminations of a thrust sheet. The McAshan Mountain cross-strike links do not branch with the trailing Jones Valley fault, but at the present erosional surface are truncated by the northeast-striking fault.

The Concord cross-strike links are in mechanical units 3 and 4 (as defined in Chapter 6), in the Red Mountain to Pottsville formations. The units comprise the layered, upper weak units of the Appalachian stratigraphic framework. The McAshan Mountain cross-strike links are in unit 2 (as defined in Chapter 6), the Copper Ridge Dolomite. Although the cross-strike links may truncate unit 3 in the footwall blocks,
the cross-strike links maintain hanging-wall detachments in the Appalachian competent unit (as defined in Chapter 4).

The Concord cross-strike links are associated with folds that plunge away from the map traces of the transverse faults. The exception is cross-strike link 3, which forms a detachment fold in the Floyd Shale. The McAshan Mountain cross-strike links are not associated with folds. One apparent exception is cross-strike link 4, which has hanging-wall folds plunging away from the transverse fault map trace. It is not apparent if these hanging-wall folds are associated with the cross-strike link or if they are part of the Birmingham medial syncline (Plate 13).
Figure 8.1: Geologic map of the Bessemer transverse zone (modified from Szabo et al., 1988), showing the extent of the Bessemer transverse zone (between cross sections A and B).
Figure 8.1A: Explanation for Figure 8.1 geologic map.
Chapter 9: Small-Scale Subsurface Structural Expression of Northwestern Bessemer Transverse Zone, Concord and McCalla 7.5’ Quadrangles

Introduction

The subsurface structural expression of the BTZ in the Concord and McCalla 7.5’ quadrangles is determined from seven strike-perpendicular cross sections (1-1’ to 7-7’) (Plates 16, 17, 18, 19, 20, 21, and 22) and one strike-parallel cross section (8-8’) (Plate 23). The cross sections were constructed from the 1:24,000-scale geologic maps of the Concord, McCalla (Plate 13), and Bessemer 7.5’ quadrangles (Figure 9.1). Extension of the cross sections into the Bessemer 7.5’ Quadrangle was conducted to ensure all cross sections transected both the Opossum Valley and Jones Valley faults, which crop out only in parts of the Concord and McCalla 7.5’ quadrangles. The cross sections were balanced and restored. A palinspastic map of the thrust faults and cross-strike links in the Concord and McCalla 7.5’ quadrangles was developed, providing further control for the viability of the balanced and restored cross sections (Plate 26). The balanced and restored cross sections, and the palinspastic map, were used to develop a three-dimensional model of the cross-strike links in the Concord and McCalla 7.5’ quadrangles. Interpretation of the structural geometry and hypothesized pre-kinematic and/or syn-kinematic controls of the formation, location, and types of cross-strike links in this part of the BTZ was the result of the three-dimensional analysis.

Analytical Methodology

Eight geologic cross sections (seven strike-perpendicular, and one strike-parallel) were constructed from the geologic map data (Plates 16, 17, 18, 19, 20, 21, 22, and 23). The cross sections use mapped bedding attitudes and stratigraphic contacts, measured stratigraphic unit thickness, and available industry well and seismic reflection data. The Paleozoic stratigraphy is divided into formation subdivisions and is not grouped into the four mechanical units used in the large-scale, transverse-zone cross sections discussed in Chapter 7. The subsurface geometry of stratigraphic units and fault surfaces was interpreted from seismic reflection profiles constrained by map and well data. The cross sections were geometrically and kinematically balanced and palinspastically restored using bed-length and/or area restoration (Dahlstrom, 1969; Marshak and Woodward, 1988). Palinspastic maps of the lower and upper contacts of
the Cambrian Copper Ridge Dolomite and the upper contact of the Mississippian Fort Payne Chert (1:24,000 scale) were developed from the cross section interpretations. The palinspastic maps outline the pre-kinematic geometry of the cross-strike links and the connected thrust faults in this part of the BTZ. The thrust sheet classification used in Chapter 7 is used in this chapter. The leading, trailing, and lateral/oblique ramps and/or flats are described in terms of a hanging-wall and/or footwall relationships of each ramp and/or flat.

**Basement Configuration**

The elevation of Neoproterozoic basement forelandward of the northeast-striking Birmingham basement fault system is at approximately –12,000 ft (-3,660 m) (Plates 16, 17, 18, 19, 20, 21, and 22). Basement fault 1, as defined in Chapter 7, is shown in cross sections 4 to 7. The elevation of the floor of graben 1, as defined in Chapter 7, is approximately –19,500 ft (-5,943 m). Displacement on basement fault 1 is approximately 7,000 ft (2,133 m).

**Geometry of the Basal Decollement and the Bessemer Mushwad**

The basal decollement is hosted in the Cambrian Conasauga Formation in the Concord and McCalla 7.5’ quadrangles. Although maintaining constant stratigraphic level, the decollement ramps northwestward (ramp 1, as defined in Chapter 7) from –16,500 ft (-5,029 m) in graben 1 to approximately –11,000 ft (-3,050 m), above the basement horst northwest of the Birmingham basement fault system.

A ductile duplex, the Bessemer mushwad has been interpreted from seismic profiles in the subsurface of the McCalla and Concord 7.5’ quadrangles (Brewer and Thomas, 2000) (Plates 16, 17, 18, 19, 20, 21, and 22). The cross-sectional profile of the Bessemer mushwad is thickest where it overlies graben 1 and thins northwestward towards the foreland. Thickness of the foreland part of the Bessemer mushwad varies along strike. The part of the mushwad underlying the Concord and McCalla 7.5’ quadrangles in graben 1 ranges from 10,500 ft (3,200 m) thick northeast of the BTZ (cross section 1) to 15,500 ft (4,724 m) southwest along strike (cross section 7) (Plates 16, 17, 18, 19, 20, 21, and 22). In cross sections 6 and 7, the Bessemer mushwad does
not extend underneath the trailing limb of the Blue Creek syncline, but is limited to the hanging wall of the Blue Creek thrust sheet (Plates 21 and 22).

**Introduction: Subsurface Structural Expression in the Bessemer Transverse Zone, Concord and McCalla 7.5’ Quadrangles**

Strike-perpendicular cross sections 1 through 7 transect the trailing limb of the Blue Creek syncline, the Blue Creek and Opossum Valley thrust sheets, and the leading edge of the Jones Valley thrust sheet. The large-scale structural expressions of these thrust sheets are explained in Chapter 7. Only the main features of the trailing limb of the Blue Creek syncline and the Blue Creek, Opossum Valley and Jones Valley thrust sheets will be outlined in this introduction. The major differences between the strike-perpendicular cross sections are the structural expressions of the smaller-scale cross-strike links. Chapter 9 will focus on characteristics of the thrust sheets that are pertinent to the individual cross sections and the along-strike variations of the cross-strike links.

**Trailing Limb of the Blue Creek Syncline**

The trailing limb of the Blue Creek syncline is shortened by the Blue Creek thrust fault. The entire Paleozoic succession, including the upper detachment horizon of the Bessemer mushwad, is folded into the trailing limb of the Blue Creek syncline in cross sections 1, 2, 3, 4, and 5 (Plates 16, 17, 18, 19, and 20). Southwest along strike, as shown in cross section 6, the trailing Blue Creek limb is flat-lying under the Blue Creek thrust sheet (Plate 21). In strike-perpendicular cross sections 1 though 6, the trailing edge of the Blue Creek limb is a footwall ramp with the overlying Blue Creek fault. The ramp cuts up section from the Conasauga to the Pottsville formations.

**Blue Creek Thrust Sheet**

The Blue Creek thrust fault has two different geometric forms in the Concord and McCalla 7.5’ quadrangles. To the northeast, the fault is a splay from the folded upper detachment horizon of the Bessemer mushwad (Plates 16, 17, 18, 19, and 20), and southwestward along strike it is a splay from the basal decollement in graben 1 (Plates 21 and 22). Regardless of the geometry of the fault, the leading edge of the Blue Creek thrust sheet is a frontal ramp that cuts up section from the Conasauga Formation to the Pottsville Formation (Plates 16, 17, 18, 19, 20, and 21). The trailing edge of the Blue Creek thrust sheet underlies the Opossum Valley thrust sheet to the northeast.
(Plates 16, 17, 18, 19, and 20) and the Jones Valley thrust sheet to the southwest (Plates 21 and 22). The Blue Creek trailing edge is a trailing footwall ramp cutting from the Conasauga Formation to the Hartselle Sandstone, depending on the level of the present erosional surface.

**Opossum Valley Thrust Sheet**

The Opossum Valley thrust fault maintains a very shallow structural position to the northeast of the BTZ (Plates 16, 17, and 18), deepens to the southwest along strike into the BTZ (Plate 19) and terminates between cross sections 5 and 6 at a northwest-striking lateral ramp (Plates 20 and 21). The preserved leading edge of the Opossum Valley thrust sheet is a frontal ramp in the Conasauga and Copper Ridge formations. The preserved trailing edge of the Opossum Valley thrust sheet is a trailing footwall ramp in the Conasauga and Copper Ridge formations.

**Jones Valley Thrust Sheet**

The Jones Valley fault also maintains a very shallow structural position across the strike of the BTZ in the Concord and McCalla 7.5’ quadrangles (Plates 16, 17, 18, 19, 20, 21, and 22). The preserved leading edge of the Jones Valley thrust sheet is a frontal flat through the Conasauga Formation. The trailing edge of the Jones Valley thrust sheet is not shown in cross sections 1 to 7.

**Strike Perpendicular Cross Sections in the Concord, Bessemer and McCalla 7.5’ Quadrangles**

**Strike-Perpendicular Cross Section 1-1’**

Cross section 1 transects part of the Concord and Bessemer 7.5’ quadrangles. The Opossum Valley and Jones Valley thrust sheets do not crop out in the Concord 7.5’ Quadrangle along the line of cross section 1 (Plate 1). The cross section extends into the Bessemer 7.5’ Quadrangle to intersect the outcrop traces of the Opossum Valley and Jones Valley faults (Plate 1). The cross section trends northwest-southeast in the Concord 7.5’ Quadrangle, and changes trend to northeast-southwest in the Bessemer 7.5’ Quadrangle to be perpendicular to the strike of local structures. The boundary between the Concord and Bessemer 7.5’ quadrangles is marked on the geologic map and cross section as line 1A (Plates 13 and 16). The cross section intersects strike-parallel cross sections 8, C, D, and A along its trace.
Cross section 1 transects the upturned trailing limb of the Blue Creek syncline (Concord 7.5’ Quadrangle), and crosses the Blue Creek (Concord 7.5’ Quadrangle) and Opossum Valley (Bessemer 7.5’ Quadrangle) thrust sheets, and the leading edge of the Jones Valley thrust sheet (Bessemer 7.5’ Quadrangle).

The branch point of the Blue Creek fault and the folded upper detachment of the Bessemer mushwad is at approximately –3,500 ft (-1,065 m). The Opossum Valley and Jones Valley thrust sheets are in a shallow structural position above the Bessemer mushwad in cross section 1. The deepest elevation of the Opossum Valley fault in cross section 1 is approximately –250 ft (-75 m). The deepest elevation of the Jones Valley fault is approximately 200 ft (60 m) above sea level.

The trailing limb of the Blue Creek syncline, in the Blue Creek thrust sheet, is vertical. In the Blue Creek footwall, the dip of the synclinal trailing limb ranges from approximately 30° to 50° NW.

A small, southeast-dipping fault (Bessemer 7.5’ Quadrangle) splays from the Blue Creek fault in cross section 1. The unnamed, southeast-dipping fault has small displacement and terminates along strike in the Red Mountain Formation, between cross sections 1 and 2 (Plate 1). The fault does not connect major thrust structures and it does not transfer displacement between structures. It is not interpreted as a cross-strike link.

**Strike-Perpendicular Cross Section 2-2’**

Cross section 2 is located in the Concord and Bessemer 7.5’ quadrangles. Cross section 2 trends northwest-southeast along its entire extent and intersects cross sections 8, C, 3, and D. Line 2A is the boundary between the Concord and Bessemer quadrangles as located on cross section 2 (Plates 13 and 17). As in cross section 1, the Opossum Valley and Jones Valley faults do not crop out along the line of section 2 in the Concord 7.5’ Quadrangle. Cross section 2 extends into the Bessemer 7.5’ Quadrangle to intersect the outcrop traces of both the Opossum Valley and Jones Valley faults. The cross section extends from the Blue Creek syncline (Concord 7.5’ Quadrangle), across the Blue Creek (Concord 7.5’ Quadrangle) and Opossum Valley (Bessemer 7.5’ Quadrangle) thrust sheets to the leading edge of the Jones Valley (Bessemer 7.5’ Quadrangle) thrust sheet.
The trailing limb of the Blue Creek syncline, in the Blue Creek thrust sheet, is vertical. The vertical Blue Creek trailing limb is shared with the steep and overturned forelimb of the leading ramp anticline of the Birmingham anticlinorium (Plate 17). The trailing limb of the Birmingham ramp anticline is subhorizontal. The trailing synclinal limb in the Blue Creek footwall ranges in dip from approximately 20° NW to 60° NW.

The branch point of the Blue Creek thrust fault with the folded upper detachment of the Bessemer mushwad is located at an elevation of approximately –4,500 ft (-1,370 m) in cross section 2. The Opossum Valley and Jones Valley thrust faults maintain shallow elevations, approximately at -200 ft (-60 m) and at sea level, respectively.

Two antithetic, northwest-dipping, back thrusts (McAshan Mountain back thrust and splay 1) (Plate 17) are present in the Blue Creek thrust sheet. The faults are modeled in cross section 2 as out-of-syncline faults that splay from the Blue Creek fault at an elevation of approximately –200 ft (-60 m). The McAshan Mountain back thrust shortens the core of the Blue Creek syncline, duplicating the Floyd and Parkwood formations in the synclinal core. The hanging-wall detachment of the splays is in the Floyd Shale. The footwall detachment is in the Pottsville Formation.

**Strike-Perpendicular Cross Section 3-3’**

Cross section 3 also extends from the Blue Creek syncline and Blue Creek thrust sheet in the Concord 7.5’ Quadrangle into the Bessemer 7.5’ Quadrangle to intersect the outcrop trace of the Opossum Valley and Jones Valley faults. Line 3A denotes the boundary between the Concord and Bessemer 7.5’ quadrangles (Plates 13 and 18). The line of section in the Concord 7.5’ Quadrangle trends northwest-southeast in the Concord 7.5’ Quadrangle. A bend in the in the line of section to roughly east-west was made in the Bessemer 7.5’ Quadrangle to ensure that the section is perpendicular to the strike of local structures. Cross section 3 intersects cross sections 8, C, 2, and D.

The trailing limb of the Blue Creek syncline in the Blue Creek thrust sheet dips approximately 45°NW. The limb of the Blue Creek syncline in the footwall of the Blue Creek thrust sheet dips approximately 20°NW.
The elevation of the Blue Creek-upper mushwad detachment branch point is approximately −4,500 ft (-1,370 m) deep in cross section 3. The deepest point of the Opossum Valley fault is at approximately −250 ft (-75 m) cross section 3. The deepest part of the Jones Valley fault is at sea level.

Three antithetic back thrusts are present in the Blue Creek thrust sheet and comprise the McAshan Mountain back thrust and splays 1 and 2 in cross section 3. The hanging-wall and footwall detachments for the back thrusts are in the Floyd Shale. The elevation of the McAshan Mountain back thrust branch point with the Blue Creek fault is approximately −1,000 ft (-305 m).

**Strike-Perpendicular Cross Section 4-4’**

Cross section 4 also extends from the Blue Creek syncline and thrust sheet in the Concord 7.5 Quadrangle into the Bessemer 7.5’ Quadrangle to intersect the traces of the Opossum Valley and Jones Valley faults. Line 4A marks the boundary between the Concord and Bessemer 7.5’ quadrangles on the geologic map and cross section (Plates 13 and 19). Cross section 4 trends northwest-southeast and intersects cross sections 8, C, and D.

The trailing limb of the Blue Creek syncline in the Blue Creek thrust sheet has a very shallow (approximately 20° NW) dip in cross section 4. The expression of the Blue Creek trailing synclinal limb in the footwall of the Blue Creek thrust fault has dips ranging from 14° NW to 40° NW. The Blue Creek-upper mushwad detachment branch point has an elevation of approximately −7,500 ft (-2,286 m). The deepest points of the Opossum Valley and Jones Valley faults have elevations of approximately −2,200 ft (-670 m) and −500 ft (-150 m), respectively. An Opossum Valley rejoining splay is modeled in this cross section. The branch point of the rejoining splay is at an elevation of approximately −2,200 ft (-670 m), but the splay deepens across strike to nearly −3,000 ft (-915 m).

The McAshan Mountain back thrust branches from the Blue Creek thrust fault at approximately −2,500 ft (-762 m). Splays 1 and 2 branch from the McAshan Mountain back thrust, further shortening the displaced Blue Creek trailing limb. The McAshan Mountain footwall detachment extends from the Chickamauga Limestone to the Pride
Mountain Formation. The back thrust hanging-wall detachment extends from the Chickamauga Limestone to the Parkwood Formation.

**Strike-Perpendicular Cross Section 5-5’**

Cross section 5 spans the Concord and McCalla 7.5’ quadrangles. The cross section trends northwest-southeast and transects the Blue Creek syncline and Blue Creek, Opossum Valley, and Jones Valley thrust sheets. Cross sections 8, C, and D intersect cross section 5 (Plates 13 and 20).

The trailing limb of the Blue Creek syncline in the Blue Creek thrust sheet has a 35° NW dip in cross section 5. The dip of the synclinal limb in the Blue Creek footwall ranges from 10° NW to 20° NW.

The Blue Creek fault-upper mushwad detachment branch point is approximately –8,000 ft (-2,440 m) deep.

A northwest-dipping back thrust, the McAshan Mountain, splays from the Blue Creek thrust fault and is truncated by the Opossum Valley thrust fault at an elevation of approximately –500 ft (-152 m). The back thrust splays from the Conasauga Formation, forms a footwall ramp from the Conasauga to the Parkwood formations, and forms a hanging-wall ramp from the Conasauga to the Copper Ridge formations. The triangular-shaped horse of rock in the footwall of the back thrust is interpreted as the subsurface expression of the McAshan Mountain CSL zone. The deepest part of the Opossum Valley fault has a –1,000 ft (305 m) elevation in cross section 5.

Cross strike link 3 is modeled in cross section 5 as a southeast-dipping reverse fault that splays from the Blue Creek fault. The branch point is at an elevation of –4,500 ft (-1,372 m) deep. The splay forms footwall and hanging-wall ramps through the Copper Ridge to Pottsville formations.

**Strike-Perpendicular Cross Section 6-6’**

Cross section 6 is coincident with part of the 1:100,000-scale cross section B that extends across the Alabama thrust belt (Plates 22 and 22A). Cross section 6 extends from the southwest corner of the Concord 7.5’ Quadrangle into the McCalla 7.5’ Quadrangle. The cross section is placed southwest of the outcrop trace of the Blue Creek fault and transects two synthetic splays of the Blue Creek fault, the Blue Creek
anticline and syncline, the McAshan Mountain back thrust, and the Jones Valley thrust fault. Cross sections 8, C, and D intersect cross section 6 (Plates 13 and 21).

The Blue Creek thrust fault ramps from the basal decollement in graben 1, to from the upper mushwad detachment, as modeled in cross sections 1 to 5. The Blue Creek fault has a blind termination in the Blue Creek anticline. Two synthetic splays from the Blue Creek fault are present forelandward of the Blue Creek anticline.

The trailing limb of the Blue Creek syncline in the Blue Creek thrust sheet dips to the northwest at approximately 30°, where the Blue Creek syncline is horizontal in the Blue Creek footwall (Plate 21).

The McAshan Mountain back thrust splays from the Blue Creek thrust fault, displacing the Conasauga and Copper Ridge formations and tightening the Blue Creek trailing limb. The elevation of the back thrust-Blue Creek branch point is –8,000 ft (-2,440 m).

The McAshan Mountain CSL zone is emergent in cross section 6. The Copper Ridge to Fort Payne formations are exposed on the surface of the CSL zone. The leading edge of the McAshan Mountain CSL is a ramp from the Copper Ridge Dolomite to the Fort Payne Chert. The trailing edge of the CSL zone is preserved as a footwall ramp in the Conasauga Formation and is truncated by the Jones Valley fault.

**Strike-Perpendicular Cross Section 7-7’**

Cross section 7 extends across the southwestern part of the McCalla 7.5’ Quadrangle in a northwest-southeast trend. The line of section extends across the trailing limb of the Blue Creek syncline, and across the McAshan Mountain back thrust and CSL zone, into the Jones Valley thrust sheet, which includes a splay of the Jones Valley fault (Plates 13 and 22).

The Blue Creek fault splays from the basal decollement in graben 1. The trailing limb of the Blue Creek syncline is overturned in cross section 7, dipping to the southeast at approximately 45°. The McAshan Mountain back thrust splays from the Blue Creek thrust sheet (the branch point is off the line of section 7), displaces the Conasauga and Copper Ridge formations in the hanging wall, and ramps from the Conasauga through Fort Payne rocks in the footwall (the McAshan Mountain CSL
zone). The back thrust is overturned to the southeast by approximately 45°. The McAshan Mountain back thrust footwall dips steeply to the northwest by approximately 60°. A splay of the Jones Valley fault truncates the outcrop expression of the McAshan CSL zone in cross section 7. The Copper Ridge Dolomite is exposed at the surface in the Jones Valley splay. The Conasauga Formation is exposed at the surface in the Jones Valley thrust sheet proper.

**Along-Strike Variations of Concord and McCalla Cross-Strike Links**

**Strike-Parallel Cross Section 8-8’**

Cross section 8-8’ is a northeast-southwest trending line of section that is coincident with the Concord-McCalla segment of the 1:100,000-scale strike-parallel cross section C that extends across the BTZ. This strike-parallel cross section connects strike-perpendicular cross sections 1 to 6 (Plates 13 and 23).

In map view, cross section 8 trends parallel to the hinge line of the Blue Creek syncline. Point 8 is at the southwestern boundary of the McCalla 7.5’ Quadrangle. The cross section transects two unnamed transverse faults that shorten the hinge-zone of the Blue Creek syncline. Cross section 8 transects the McCalla-Concord border and intersects cross-strike links 3, 2, and 1, which also shorten the hinge-zone of the Blue Creek syncline. Near the northeastern border of the Concord 7.5’ Quadrangle, cross section 8 transects the up-plunge termination of the Blue Creek syncline. Cross section point 8’ is at the Concord-Bessemer 7.5’ quadrangle border.

Only the Blue Creek thrust sheet is modeled on the surface in cross section 8. The thrust sheet deepens southwestward along strike in the BTZ. Northeast of the BTZ, the Blue Creek thrust sheet is emergent near point 8’ and maintains a shallow elevation (sea level to 400 ft (120 m) above sea level) northeast of cross section 1. The fault deepens southwestward along strike to −2,500 ft (762 m) at point 8 on the cross section. The Blue Creek thrust sheet is a hanging-wall and footwall lateral ramp between point 8’ and cross section 5. A hanging-wall lateral flat in the Fort Payne Chert of the Blue Creek thrust is maintained southwest of cross section 5. Northeastward along strike, between cross sections 6 and 5, the Blue Creek fault in a footwall lateral ramp cuts up stratigraphic section from the Floyd Shale into the Pottsville Formation. Between cross
sections 5 and 4, the Fort Payne hanging-wall lateral flat changes to a lateral ramp where the Blue Creek fault cuts down section along strike from the Fort Payne into the Red Mountain Formation and the Chickamauga Limestone. The Pottsville footwall lateral ramp cuts down section into the Parkwood Formation between cross sections 5 and 4. Hanging-wall and footwall lateral ramp geometries are maintained between cross sections 4 and 1. The Blue Creek fault cuts up section in a hanging-wall lateral ramp from the Chickamauga Limestone to the Parkwood Formation between cross sections 4 and 1. The footwall of the Blue Creek fault is folded by the presence of the Bessemer mushwad, as modeled at the intersection of cross sections 8 and 3. The Blue Creek footwall detachment is maintained in the Parkwood Formation, but the fault cuts across a deformed footwall, thereby cutting up section across the fold structures as a lateral ramp. The Blue Creek footwall lateral ramp cuts up section from the Parkwood Formation to the Pottsville Formation between cross sections 2 and 1.

The plunge of the Blue Creek fault changes along strike in the BTZ. Very shallow apparent dips (horizontal to 7° SW) are prominent southwest of cross section 2. Between cross section 2 and 1, the apparent dip of the Blue Creek fault changes from approximately 7° SW to 40° SW. The fault plunge is horizontal northeast of cross section 1, and increases in apparent dip to approximately 7° near the fault outcrop.

The Bessemer mushwad is not continuously present along the line of cross section 8. Two thin lenses of the Bessemer mushwad are present at the intersection of cross sections 8 and 5 and the intersection of cross sections 8 and 3. The discontinuous presence of the Bessemer mushwad along cross section 8 is interpreted as evidence for a curvi-linear mushwad tip line where it propagated underneath the Blue Creek syncline, towards the foreland.

The strike-parallel geometry of cross-strike links 1, 2, and 3 is modeled in cross section 8. Cross-strike link 1 shows the most variability along strike; the apparent dip of the fault plane changes along strike from approximately 48° SW near the fault outcrop trace, to sub-horizontal/horizontal, to another dipping domain of approximately 45° SW. The branch point between cross-strike link 1 and the Blue Creek fault is near the intersection of cross section 8 with cross section 4. Cross-strike link 1 is a hanging
wall and footwall lateral ramp with Chickamauga to Parkwood rocks in the hanging wall and Chickamauga to Pottsville rocks in the footwall.

Using the fault-trace patterns described on the Concord-McCalla geologic map in Chapter 8, cross-strike link 2 is interpreted as a steep fault separating the upthrown section 2 block to the northeast from the downthrown section 3 block to the southwest. The cross-strike link cuts through the Chickamauga Limestone to the Pottsville Formation in both fault blocks and is, therefore, interpreted as a lateral ramp. The Chickamauga Formation serves as a detachment horizon where cross-strike link 2 branches with the Blue Creek fault.

Southwest along strike, cross-strike link 3 is also interpreted as a steeply dipping fault, using the fault-trace pattern on the Concord-McCalla geologic map (Plate 13). Cross-strike link 3 separates the upthrown section 3 block from the unnamed downthrown block southwest of the cross-strike link. Cutting through the Red Mountain to Pottsville formations in section 3, and the Fort Payne to Pottsville formations in the downthrown block to the southwest, the cross-strike link is interpreted as a lateral ramp. The cross-strike link branches with the Blue Creek fault in a Red Mountain-Fort Payne detachment zone. The utilization of the Red Mountain-Fort Payne formations as detachment horizons for cross-strike link 3 is controlled by the presence of the hanging-wall lateral ramp in the Blue Creek thrust sheet.

Discussion

Cross section 8 models the geometry of the Concord CSL zone along strike in the BTZ. All of the Concord cross-strike links are steeply dipping faults, truncating the Paleozoic succession from the Chickamauga Limestone and/or Red Mountain Formation to the Pottsville Formation. The cross-strike links all branch from the Blue Creek fault at depth, along the line of this section. Along-strike geometry of cross-strike link 1 is distinct from cross-strike links 2 and 3; the apparent dip of cross-strike link 1 varies along strike to the southwest. Cross-strike links 2 and 3 are not modeled as varying in along-strike geometry. The Blue Creek footwall is folded by the underlying Bessemer mushwad. Part of the folded footwall is incorporated into the Blue Creek hanging wall. Cross-strike link 1 shortens the folded Blue Creek hanging wall, maintaining a steep apparent dip where the link propagates along the southwestern
fold limb. Northeast along strike, in the hinge zone of the Blue Creek hanging-wall fold, cross-strike link 1 has a shallow apparent dip. The cross-strike link steepens northeast of the fold hinge where the fault emerges.

Southwest along strike, the structural style of the Blue Creek thrust sheet is relatively undeformed, shallowly dipping hanging-wall rocks plunge to the southwest along strike. The Pride Mountain and Hartselle formations pinch out stratigraphically between the intersection of cross section 8 with cross sections 5 and 6; however, along the line of cross section 8, the Pride Mountain-Hartselle pinch out does not have an apparent affect on the geometry of cross-strike links 2 and 3.

On the basis of these observations, variations in cross-strike link geometry in the Concord and McCalla 7.5’ quadrangles may be partially determined by the structural geometry of the hanging wall that the cross-strike links shorten.

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Figure 9.1: Geologic map of the Bessemer transverse zone (modified from Szabo et al., 1988), showing the extent of the Bessemer transverse zone (between cross sections A and B),
Figure 9.1A: Explanation for Figure 9.1 geologic map.
Chapter 10: Kinematic History and Genetic Controls of the Bessemer Transverse Zone, Alabama Alleghanian Allochthon

Introduction

The geometric modeling of the BTZ in chapters 6 through 9 was compiled for the purpose of understanding the kinematic evolution of the BTZ; i.e., the relative timing of emplacement of the seven thrust sheets comprising the BTZ, the kinematic relationship of the cross-strike links with the BTZ thrust sheets, and the causes for the kinematic setting of the BTZ. This chapter proposes a kinematic model for the formation of the BTZ, based on the geometric relationships compiled in Chapters 6 through 9. The kinematic evolution of the BTZ, and the evolution of the cross-strike links that comprise the transverse zone, elucidate the factors controlling the localization of the cross-strike links. The final section of this chapter summarizes the tectonic evolution of the Bessemer allochthon and addresses the mechanisms for allochthon emplacement.

Regional Kinematic History of the Bessemer Transverse Zone

Outcrop Indicators of the Kinematic History of the Bessemer Transverse Zone

The geometry of the geologic map traces of the seven thrust faults in the BTZ provide evidence for the relative timing of thrust sheet emplacement. Thrust sheet genesis is commonly theorized as following an in-sequence, or break-forward, deformation plan (Peach et al., 1907; Armstrong and Oriel, 1965; Bally et al., 1966; Boyer and Elliott, 1982) where deformation advances from the interior of an orogenic belt outward towards the foreland.

In a break-forward deformation plan, the Talladega thrust fault on the southeast of the BTZ (towards the Alleghanian hinterland) would have been the first structure formed in the BTZ, followed by the emplacement of the Yellowleaf and Dry Creek thrust faults comprising the footwall of the Talladega fault (Plate [1]). Progressive break-forward deformation would have resulted in the Helena thrust fault shortening the footwall of the Yellowleaf and Dry Creek faults, the Jones Valley fault deforming the footwall of the Helena fault, and the Opossum Valley and Blue Creek faults deforming the footwall of the Jones Valley fault (Plate [1]). The youngest thrust belt structure in the
BTZ would have deformed the footwall of the Opossum Valley fault, propagating to the Sequatchie anticline. This discussion starts with the structure that in a break-forward kinematic sequence should be the oldest thrust sheet in the BTZ, the Talladega fault. The map geometry of each thrust sheet forelandward of the Talladega fault is sequentially examined for geologic map evidence documenting the kinematic evolution of the BTZ.

Doubly-plunging folds in the Talladega thrust sheet (Columbiana syncline) have an northeast-southwest orientation and are co-axial with the northeast-southwest trending Kelley Mountain and Fourmile Creek anticlines in the underlying Yellowleaf thrust sheet (the footwall of the Talladega fault) (Plate 1). The co-axial traces of the Kelley Mountain and Fourmile Creek anticlines, and the Columbiana syncline, are interpreted as recording the same deformation event, in which the Talladega thrust sheet, and the underlying Yellowleaf thrust sheet, were folded synchronously. The Talladega fault, however, also truncates the limbs of the Kelley Mountain and Fourmile Creek anticlines in the Talladega footwall; the fault cuts across the formation contacts on both limbs and around the plunging ends of the doubly plunging anticlines (Plate 2 [Locations 29, 30, 31, and 32]). This map relationship between the Talladega fault, and the underlying Yellowleaf thrust sheet, indicates that the Kelley Mountain and Fourmile Creek anticlines were formed during displacement on the Yellowleaf fault, and some of the structural relief of the Kelley Mountain and Fourmile Creek anticlines predates emplacement of the Talladega thrust sheet. The truncation of the Kelley Mountain and Fourmile Creek anticlinal limbs by the Talladega fault, indicates that the Talladega fault was emplaced after the initial movement of the Yellowleaf fault. Co-axial folding of the Talladega thrust sheet (Columbiana syncline) and the Yellowleaf thrust sheet (Kelley Mountain and Fourmile Creek anticlines) indicates late slip on the Yellowleaf thrust fault after emplacement of the Talladega thrust sheet with consequent re-folding of the Yellowleaf and Talladega thrust sheets. The outcrop geometries indicate that the Yellowleaf fault was emplaced prior to the Talladega fault, in opposition to the break-forward deformation sequence of thrusting. The Talladega fault was emplaced and renewed break-forward movement on the Yellowleaf fault refolded the Yellowleaf and Talladega thrust sheets.
The Yellowleaf thrust fault ends to the southwest along strike in the BTZ (Plate 2 [Location 26]). The Dry Creek thrust fault is an en-echelon fault that terminates to the northeast along strike in the BTZ (Plate 2 [Location 34]). The en-echelon nature of the Yellowleaf-Dry Creek system and the opposing, along-strike displacement vectors, indicate that the Yellowleaf-Dry Creek system is kinematically related along a lap joint displacement transfer zone (Dahlstrom, 1969) and the Yellowleaf-Dry Creek system is interpreted as a single kinematic unit. The Talladega thrust fault parallels and does not truncate any structures in the trailing part of the Dry Creek thrust sheet; there is no definitive evidence of thrust sequencing for the Dry Creek fault (Plate 2 [Location 36]). However, the en-echelon relationship between the Yellowleaf and Dry Creek faults, and the interpretation of a displacement transfer zone kinematically linking the two faults, suggests that the complicated kinematic sequence interpreted for the Yellowleaf fault may also be viable for the Dry Creek fault.

The trailing edge of the Helena hanging wall is folded into the Coosa synclinorium, which contains smaller-scale folds within the larger Coosa fold-envelope (Plate 2 [Locations 23, 24, 25, accommodation fold]. The strike of the Yellowleaf fault is parallel to the trend of the Coosa synclinorium, but truncates the leading limb of an unnamed, second-order syncline within the Coosa fold envelope (Plate 2 [footwall of Location 27]). The strike of the Dry Creek fault is parallel to the strike of the trailing limb of an accommodation anticline at the up-plunge termination of the Coosa synclinorium in the BTZ (Plate 1). Map patterns indicate that the trailing limb of the accommodation anticline is connected to a trailing syncline cored in upper Knox Group rocks. The Dry Creek fault dissects the syncline as an out-of-syncline thrust, exposing lower Knox Group rocks in the synclinal core. The lower Knox Group rocks were structurally elevated in the Dry Creek hanging wall. These map relationships indicate that the Dry Creek fault truncates a pre-existing fold in the Helena thrust sheet, implying that the Dry Creek fault is younger than the syncline it truncates. The cross cutting relationships of the Helena and Yellowleaf-Dry Creek thrust sheets indicates that the Yellowleaf-Dry Creek thrust sheets were emplaced after the emplacement and folding of the Helena thrust sheet. The kinematic unity of the Yellowleaf-Dry Creek system also supports an interpretation that the Dry Creek fault should also have been
emplaced after the Helena thrust sheet. The timing of Helena emplacement, with respect to the Yellowleaf-Dry Creek system, is contrary to the timing predicted by a break-forward sequence. The Yellowleaf-Dry Creek faults are interpreted as being break-back faults with respect to the Helena thrust sheet.

The Cahaba synclinorium in the Jones Valley thrust sheet has a large plunge that terminates to the northeast of the BTZ, in the Anniston transverse zone. The up-plunge termination of the Cahaba synclinorium is expressed as a bend from northeast-strike in the Jones Valley frontal ramp to northwest-strike in a lateral ramp (Thomas, 2001). The entire Paleozoic succession, from the Conasauga to the Pottsville formations, is exposed in the northwest-striking lateral ramp of the synclinorium. The Helena fault truncates the lateral ramp and the entire Paleozoic succession (Thomas, 2001). This pattern indicates that the Helena thrust fault cut through the lateral ramp after the ramp was emplaced with the Jones Valley thrust sheet and the fault-related folding of the Cahaba synclinorium. Southwest along strike, in the BTZ, the Helena fault truncates a trailing flat of the Jones Valley thrust sheet, exposed in the Pottsville Formation at the present erosional surface (Plate 1). Because the Helena fault is parallel to the ramp syncline in the Jones Valley hanging wall, the map relationships in the BTZ do not clearly illustrate a kinematic sequence of the Jones Valley and Helena faults. The break-back kinematic relationship of the Helena thrust fault, however, evidenced at the up-plunge termination of the Cahaba synclinorium, must be consistent to the southwest along strike in the BTZ.

The Jones Valley fault truncates a folded Opossum Valley hanging wall and a faulted and folded Blue Creek hanging wall. In the BTZ, the Jones Valley fault is parallel to the trend of the medial syncline of the Birmingham anticlinorium, truncates the trailing limb of a northeast-plunging Conasauga Formation-cored anticline (Plate 2 [southwest of Location 15]), and truncates the northwest-striking lateral ramp at the southwest end of the Opossum Valley fault (Plate 2 [Location 10]). The Jones Valley fault is parallel to the trailing limb of the Blue Creek syncline in the Blue Creek hanging wall. In the Blue Creek thrust sheet, two unnamed transverse faults are truncated southwest of the BTZ by the Jones Valley fault (Plate 2 [southwest of Location 8]). The map trace of the transverse faults is straight and linear, which is interpreted as a
steeply dipping, non-folded fault plane. Steep-, non-folded fault planes cutting through the trailing limb of the Blue Creek syncline indicate that the faults cut through the syncline after folding. Cross-cutting relationships between the transverse faults and the Jones Valley fault indicate that the Jones Valley fault cuts through the Blue Creek trailing limb after its formation. The truncation of the northeast-plunging anticline in the Opossum Valley hanging wall, the Opossum Valley lateral ramp, and the Blue Creek transverse faults, indicate that the Jones Valley fault is a back-break fault that formed after the emplacement and deformation of the Opossum Valley and Blue Creek thrust sheets.

On the basis of observations described in the preceding paragraphs, the kinematic sequence of thrust sheet emplacement in the BTZ does not fit the typical break-forward deformation plan. Interpretation of cross-cutting relationships on the BTZ geologic map indicate that the Opossum Valley and Blue Creek faults are the oldest faults in the BTZ. Progressively younger thrust sheets were emplaced towards the orogenic hinterland; the Jones Valley, Helena, Yellowleaf-Dry Creek and Talladega faults form in succession, each thrust sheet truncating the hanging wall of previously emplaced thrust sheets. This pattern indicates that the BTZ was emplaced in an out-of-sequence, or break-back, deformation plan (Hossack, 1985). Timing of the formation of the Sequatchie anticline may be later than the emplacement of the Opossum Valley and Blue Creek thrust sheets; data do not constrain timing of Sequatchie deformation.

In a break-back deformation plan, the basal decollement is interpreted as propagating forelandward; major thrust faults formed above the basal decollement and broke from the foreland back towards the hinterland with time (Milici, 1975; Perry, 1978; Boyer and Elliot, 1982). Although the BTZ thrust faults do exhibit the characteristics of break-forward thrusts; namely cutting up stratigraphic section in the transport direction and emplacing older over younger rocks; the BTZ thrust faults also cut through earlier structures in their respective footwalls (Morley, 1988). On the basis of the evidence presented in this section, a break-back deformation sequence is used to model the kinematic history of the Alleghanian allochthon in the BTZ.
Kinematic History of BTZ interpreted from Strike-Perpendicular Cross Section A

Introduction

Strike-perpendicular cross section A is used to elucidate the regional kinematic history of the BTZ, and a part of strike-perpendicular cross section B is used to elucidate the local kinematic history of the Concord and McCalla parts of the BTZ. Cross section B encompasses the more detailed strike-perpendicular cross section 6 on the 1:24,000-scale Concord and McCalla geologic map (Plate 13) and is used to model local kinematic history for that reason. The kinematic models derived from cross section A focus on the kinematic relationship between the Opossum Valley and Jones Valley thrust sheets in particular, and the kinematic models derived from cross section B focus on the relationship between the Blue Creek and Jones Valley thrust sheets. The Helena, Yellowleaf, Dry Creek and Talladega thrust sheets maintain the same kinematic relationships in both cross sections A and B and therefore are modeled in the Regional Kinematic History section utilizing only cross section A.

Kinematic Interpretation

The palinspastic restoration of the BTZ along the line of cross section A has an undeformed line length of 542,000 ft (165,200 m) (Plate 24 part A). The restoration of cross section A shows the location of the Birmingham basement fault system in the BTZ, grabens 1 and 2 and basement faults 1, 2, and 3 as they are defined in Chapter 7. Seismic reflection profiles and deep wells indicate that the Paleozoic cover strata varies in the BTZ. The Rome and Conasauga Formations (unit 1) triple in thickness in graben 1 and double in thickness in graben 2 of the Birmingham basement fault system (Plate 24, part A). Unit 1 has an approximate thickness of 3,000 ft (915 m) northwest of the Birmingham basement fault system, and increases to approximately 10,000 ft (3,050 m) in graben 1. Rome-Conasauga thickness decreases to approximately 3,000 ft (915 m) above the horst block separating grabens 1 and 2 and thickens farther southeast to approximately 7,500 ft (2,290 m) in graben 2. Knox Group (unit 2) thickness varies across the thrust belt; unit 2 thicknesses decrease from approximately 4,000 ft (1,220 m) northwest of the Birmingham basement fault system to approximately 2,000 ft (610 m) over basement fault 1 and the northwestern part of graben 1 (Plate 24, part A). Unit 2
thicknesses increase to the southeast from 2,000 ft (610 m) to approximately 4,000 ft (1,220 m) over basement fault 2. In the southeastern part of the BTZ, another decrease in unit 2 thickness ranges from 4,000 ft (1,220 m) over basement fault 3 to approximately 3,000 ft (914 m) over graben 2 (Plate 24, part A). The Chickamauga to Fort Payne succession (unit 3) thins uniformly southeastward across the thrust belt; from approximately 1,200 ft (365 m) northwest of graben 1 to approximately 1,000 ft (300 m) over graben 2. The Floyd to Pottsville rocks (unit 4) thicken over grabens 1 and 2, varying from thicknesses of approximately 1,870 ft (570 m) in the northwestern part of the BTZ (Birmingham anticlinorium) to approximately 5,800 ft (1,770 m) in the Cahaba and Coosa synclinoria (Thomas, 1986, 1995).

Initial emplacement of the Alleghanian allochthon proceeded with translation of units 1 though 4 over the basal decollement horizon in the lower part of unit 1 (Plate 24, part A). The basal decollement ramps shallowly up section in unit 1 across the allochthon, from the Chilhowee Group in the southeastern part of the thrust belt, to the Rome Formation in the mid-section of the allochthon, to the Conasauga Formation in the northwestern thrust belt. On the basis of the break-back deformation interpretation discussed in the Outcrop Indicators section of this chapter, initial failure of the allochthon is interpreted as occurring in graben 1, with initiation of the Bessemer mushwad in the incipient-Opossum Valley hanging wall (Plate 24, part B).

The deformed cross-sectional representation (Plate 24, part I) of the Bessemer mushwad, and the overlying Paleozoic succession, is an asymmetrical (northwest-verging), thrust-faulted antiform. The antiform structure contains a 17,000 ft (5,150 m), internally deformed, ductile core (unit 1) capped by 2,000 to 4,000 ft (610 to 1,220 m) of competent carbonate and 3,070 ft (935 m) of interlayered competent and weak rocks (Plates 3, 4, and 24 (part I)). The ductile core is interpreted as the Bessemer mushwad, and the folded competent and interlayered mechanical units overlying the ductile core comprise the Birmingham anticlinorium. The Bessemer mushwad-Birmingham anticlinorium structure is flanked on either side by asymmetrical (northwest-verging) synclines; the Blue Creek and Cahaba synclines (Plate 24, part C). The 2,000 to 4,000 ft (610 to 1,220 m) competent carbonate layer (unit 2) capping the mushwad core (unit 1) is broken by the Opossum Valley and Jones Valley faults,
splaying from the upper mushwad detachment horizon (Plate 24, parts E and F). Antiformal structures formed at the tip line of detachment faults cored by a thick ductile units, and mantled by thick, faulted competent layers are modeled as detachment folds (Mitra, 2002); the Bessemer mushwad/Birmingham anticlinorium system is interpreted as a detachment fold broken by the Opossum Valley and Jones Valley faults.

Growth of detachment folds are initiated as a response to a large competence strength contrast between weak detachment horizons and competent rocks overlying the detachment horizon (Mitra, 2002). The Bessemer mushwad is interpreted as having been initiated in this fashion. Separation of weak unit 1 from competent unit 2 along a passive detachment near the top of unit 1 permitted the emplacement of a large volume of ductile rocks above the basal decollement without conservation of shortening between unit 1 and overlying units 2 through 4. The injection of large volumes of unit 1 between the basal decollement and the upper detachment horizon permitted the formation of a detachment anticline (incipient Bessemer mushwad), so that the growing anticlinal core uplifted overlying units 2 though 4 (incipient Birmingham anticlinorium) (Plate 24, part B). Continued growth of detachment folds is accommodated by the cannibalization of ductile rocks from adjacent synclines (Mitra, 2002); ductile unit 1 rocks are interpreted as having migrated from the core of the Cahaba syncline into the Bessemer detachment anticline (Plate 24, parts B to F). The Bessemer detachment anticline increases in amplitude and wavelength at the expense of the adjacent Cahaba syncline. The deformed-state cross section A (Plates 3 and 24, part I) models the basal decollement underlying the Cahaba synclinorium as dipping northwest (Plate 24 [decollement ramp 2]) over basement fault 2 to a deeper structural position than is modeled in the palinspastic restoration of the decollement horizon at a depositional stratigraphic level (Plate 24, part A). The removal of ductile rock from the Cahaba syncline footwall is interpreted as resulting in the down warping of the syncline into graben 1, forcing the deepening of the basal decollement into stratigraphically lower parts of the Conasauga Formation (Plate 24, part B to F). Downward buckling of the Cahaba synclinorium initiated propagation of the decollement into graben 1 through lower parts of the Conasauga stratigraphy towards basement fault 1 (e.g. Ramsay, 1992; Thomas, 2001) (Plate 24, part B). Decollement ramp 1 is interpreted from
seismic reflection lines as being over basement fault 1 (Plate 24, part F) and connecting the decollement flat in graben 1 with a decollement flat above the horst block bounding graben 1 to the northwest (Plate 24, part C). The decollement ramp is interpreted as the result of stress concentration at basement fault 1, which presents a southeast-dipping impediment to the northwest-directed allochthon stress field (Wiltschko and Eastman, 1983, 1988). The overturned limb of the Blue Creek syncline is modeled in deformed-state cross section A as being part of the Birmingham-Cahaba fold train. Continued growth of the Bessemer detachment fold, and propagation of unit 1 rocks from graben 1 onto the northwestern horst block via decollement ramp 1, provided a mechanism for the development of a tectonic wedge of unit 1 forward of the leading limb of the detachment fold (Plate 24, part C). The overturned Blue Creek trailing limb is interpreted as having been formed during the growth of the Bessemer detachment fold and emplacement of the tectonic wedge above the northwestern horst block (Plate 24, part C to F).

The Opossum Valley fault is modeled in the deformed-state cross section A as branching from the upper detachment of the Bessemer mushwad and displacing the upper strata of unit 1 and units 2 though 4 (Plates 3 and 24, part I). Detachment-fold models (Mitra, 2002) interpret fracturing of the competent units overlying detachment-fold cores as evolving into thrust faults by progressive migration of the fracture tip in two directions, down section to branch with the detachment horizon and up section to accommodate further amplitude increase in the detachment fold. Increase in the amplitude of the Bessemer detachment fold is interpreted as generating fractures in unit 2 and initiating the incipient-Opossum Valley fault (Plate 24, part C). Down-dip migration of the incipient-Opossum Valley fault is interpreted as occurring per Mitra’s (2002) detachment fold model, with the difference being that the incipient-Opossum Valley fault branched with the upper detachment of the Bessemer mushwad, not with the basal decollement (Plate 24, part C and D). The upper detachment of the Bessemer mushwad is modeled in deformed cross section A as branching with the basal decollement across strike to the southeast. Kinematically, the Opossum Valley fault is therefore interpreted as branching with the basal decollement via the upper detachment horizon of the Bessemer detachment fold. Branching of the incipient-Opossum Valley
fracture tip line with the detachment surface is interpreted as the conversion of the incipient-Opossum Valley fault to an allochthon thrust fault accommodating foreland-directed tectonic stress. Propagation of the Opossum Valley fault up stratigraphic section is also interpreted as accommodating allochthon stress, as well as facilitating uplift and growth of the Bessemer mushwad. Shortening of the Opossum Valley fault is decoupled from that of the underlying detachment fold core. Total amount of displacement on the Opossum Valley fault is measured at 4,607 ft (1,404 m). The total amount of shortening (measured as the difference in amount of allochthon propagation between parts D and E of Plate 24), accounting for the formation of the Bessemer detachment fold and movement along the Opossum Valley fault, is measured at approximately 2,598 ft (792 m) (Plate 24, part E).

The Jones Valley thrust fault is interpreted in deformed-state cross section A (Plates 3 and 24, part I) as truncating the shared limb of the medial syncline and trailing anticline of the Birmingham anticlinorium and branching from the upper detachment of the Bessemer mushwad (Plate 24, parts E and F). An incipient-Jones Valley fault is interpreted as having been initiated in the same fracturing event that created the incipient-Opossum Valley fault; however, on the basis of the geologic map patterns discussed in the Outcrop Indicators section of this chapter, the Jones Valley thrust fault is interpreted as cutting through the Opossum Valley hanging wall after emplacement of the Opossum Valley thrust sheet (Plate 24, part F). The incipient Opossum Valley and Jones Valley faults may have formed at the same relative time; however, propagation is interpreted as having occurred on the Opossum Valley fault initially, followed by propagation of the Jones Valley fault at a later time. Development of the incipient Jones Valley fault into an allochthon thrust fault is interpreted as having occurred in the same fashion as the Opossum Valley fault, with bi-directional propagation of the incipient-Jones Valley fault tip-lines. Downward propagation continued to the branch point with the upper detachment of the Bessemer mushwad, and upward propagation occurred with continued emplacement of the Alleghanian allochthon and growth of the Bessemer detachment fold. The Jones Valley fault is interpreted as having formed to accommodate shortening originally maintained by the Opossum Valley fault.
The Bessemer detachment fold is emplaced above the basement fault 1 horst block as a tectonic wedge, forming the trailing overtuned limb of the Coalburg syncline (Plate 24, parts C and D). Propagation of the basal decollement into the foreland is interpreted as occurring during emplacement of the Bessemer tectonic wedge. The decollement terminates to the northwest, transferring displacement into the core of the Sequatchie anticline. There are no upper-age constraints on the timing of decollement propagation into the foreland. Forelandward decollement propagation did not precede emplacement of the Bessemer tectonic wedge and the fracturing of the Opossum Valley and Jones Valley faults; however, decollement propagation may have occurred during later emplacement of the Helena, Yellowleaf or Talladega thrust sheets. The amount of displacement on the Jones Valley fault is measured at 20,475 ft (6,240 m). At this stage of allochthon formation, cumulative allochthon shortening was approximately 34,757 ft (10,593 m) (Plate 24, part B).

Continued growth of the Bessemer mushwad reached a critical limit where stress could no longer be effectively translated through the ductile duplex and shortening must have been accommodated by other means. In the BTZ, further shortening of the allochthon was accommodated by the Helena fault breaking back in the Jones Valley hanging wall, hinterlandward of the trailing edge of the mushwad (Plate 24, part G). The Helena fault did not incorporate any of the mushwad in its hanging wall. The Helena fault also did not have the mushwad in its immediate footwall, which was instead the trailing part of the Jones Valley thrust sheet (Plate 24, part G). The amplitude and wavelength of the mushwad are interpreted as having controlled the configuration of the Jones Valley thrust sheet and the location of the Helena frontal ramp in graben 1 (Plate 24, part G). The two duplexes in units 1 and 2 of the Helena hanging wall may be interpreted as accommodating stresses not easily propagated by displacement along the Helena fault proper. The proximity of the Helena fault to the Bessemer mushwad indicates that the mushwad impeded stress propagation in proximal thrust sheets, regardless of whether the mushwad was part of the individual thrust sheet anatomy. The along-strike shape of the mushwad is also interpreted as having impacted along-strike behavior of the Helena thrust sheet in the BTZ, which shall be discussed in the section titled Local Kinematic History. The amount of
displacement along the Helena fault is approximately 37,406 ft (11,401 m). Estimated total amount of allochthon shortening at this point in the kinematic history is 124,545 ft (37,961 m) (Plate 24, part G).

The geologic map trace of the Yellowleaf thrust fault suggests that the fault was emplaced after the Helena thrust fault. The Yellowleaf fault maintained a lower detachment at the top of unit 1 in graben 2, and ramped to an upper detachment along the top of unit 3 above basement fault 3, duplicating part of unit 1 and units 2 to 4 on the upper level detachment horizon (Plate 24, part H). Cross-cutting relationships described in the Outcrop Indicators section of this chapter indicate that the Yellowleaf thrust sheet was folded into the Fourmile Creek and Kelley Mountain anticlines prior to emplacement of the Talladega thrust sheet. Propagation of the Yellowleaf fault from its restored location in graben 2, over basement fault 3, to rest over the horst separating grabens 1 and 2 is interpreted as a cause of folding of the Yellowleaf thrust sheet and forming the Fourmile Creek and Kelley Mountain anticlines (Plate 24, part H). The leading limb of the Fourmile Creek anticline is located in the leading edge of the Yellowleaf thrust sheet and is a hanging-wall ramp cutting up section from unit 1 to unit 3 in the Fourmile Creek forelimb (Plate 24, part H). This geometric relationship implies that the Fourmile Creek anticline is a fault-bend fold in the Yellowleaf hanging wall (Plate 24, part H). The Kelley Mountain anticline is a ramp anticline related to a frontal splay in the trailing part of the Yellowleaf thrust sheet (Plate 3), where the thrust sheet drapes over basement fault 3 in the subsurface. The draping of the Yellowleaf thrust sheet over basement fault 3 further deformed the Yellowleaf hanging wall, including the Kelley Mountain ramp anticline and an unnamed trailing syncline (Plate 24, part H). Total estimated displacement on the Yellowleaf thrust fault is 63,113 ft (19,236 m). The amount of shortening for the entire allochthon at this point is approximately 167,988 ft (51,202 m) (Plate 24, part H).

Cross-cutting relationships discussed in Outcrop Indicators section of this chapter indicate that the Talladega fault was emplaced later than the Yellowleaf thrust sheet. The Talladega fault is interpreted as having ramped from the basal decollement in graben 2 and having cut up section from unit 1 of the Helena thrust sheet, truncating the trailing edge of the Yellowleaf thrust sheet and cutting up section from unit 1 to the
contact between units 2 and 3 in the Yellowleaf hanging wall (Plate 24, part I). A very small Talladega flat is located at the unit 2-unit 3 contact, and the Talladega fault cuts up section farther northeast from the base of unit 3 into unit 4. The Talladega fault maintains an upper-level detachment in unit 4, truncating the Kelley Mountain and Fourmile Creek anticlines in the underlying Yellowleaf thrust sheet (Plate 24, part I). The upper-level detachment of the Talladega fault plunges northwestward at the crest of the Fourmile Creek anticline, forming the Columbiana syncline in the Talladega thrust sheet (Plate 24, part I). The Talladega fault remains in unit 4 and breaches the erosional surface to the northwest of the outcrop trace of the Columbiana syncline. After the emplacement of the Talladega fault, both the Yellowleaf and Talladega thrust sheets were deformed by folds related to five small-scale faults splaying from the upper level detachment horizon of the Yellowleaf fault (Plate 24, part I, shown as incipient faults). One of these small-scale faults shortens the Kelley Mountain anticline along its trailing limb, tightening the anticline and folding the overlying Talladega thrust sheet (Plate 24, part I, fault U). A back thrust, the Shelby Valley fault, tightens the Fourmile Creek anticline and the Columbiana syncline. These small-scale faults deform both thrust sheets and are the youngest observable structures related to emplacement of the Alleghanian allochthon of the BTZ. The amount of displacement of the Talladega fault cannot be determined, because of the lack of shared cut-offs between the two thrust sheets; the Yellowleaf thrust sheet contains Valley and Ridge stratigraphy, the Talladega thrust sheet contains Piedmont stratigraphy. The amount of allochthon displacement in the BTZ is therefore calculated only to the emplacement of the Yellowleaf thrust sheet.

**Palinspastic Maps of the Bessemer Transverse Zone**

**Introduction**

Three palinspastic maps were generated from the two 1:100,000-scale, balanced and restored cross sections traversing the BTZ. The maps display six of the seven thrust sheets (minus the Talladega thrust sheet) comprising the BTZ at three stratigraphic levels; one map each for the top of the Cambrian Conasauga Formation (unit 1) (Plate 10), the top of the Cambrian-Ordovician Knox Group (unit 2) (Plate 11), and the top of
the Mississippian Fort Payne Chert (unit 3) (Plate 12). Also shown on the palinspastic maps are the traces of basement faults 1, 2, and 3 (Plates 10, 11, and 12).

The maps were constructed using the line-length restorations for the top of each stratigraphic unit. The leading and trailing cut-offs of each thrust sheet were restored along the line of each BTZ cross section. The along-strike trace of each frontal and trailing thrust sheet edge was correlated between the two BTZ cross sections and extended to intersect three additional balanced and restored cross sections constructed on each side of the BTZ; cross section 15 to the northeast of the BTZ and cross sections 16 and 17 to the southwest of the BTZ (Thomas and Bayona, in press). The construction of the palinspastic maps permitted correlation of the lateral edges of each thrust sheet.

The geometry of the BTZ thrust sheets remains consistent between the palinspastic maps. The en-echelon distribution of the Blue Creek and Opossum Valley thrust sheets is unvaried from the top of Conasauga palinspastic map, to the top of Knox and top of the Fort Payne maps (Plates 10, 11, and 12). One lateral edge (cross-strike link 4) is mapped between the Opossum Valley and Jones Valley thrust sheets. The position of the lateral ramp remains consistent; however, the length of the lateral edge decreases up section (Plates 10, 11, and 12). The Jones Valley thrust sheet maintains two trailing lateral edges. One edge is shared with the Helena thrust sheet, which is an oblique ramp in all three palinspastic maps (Plates 10, 11, and 12). The other Jones Valley lateral edge is a lateral ramp shared with an unnamed thrust sheet mapped modeled in cross section 17 (Plates 10, 11, 12) (Thomas and Bayona, in press). The Jones Valley-unnamed lateral edge also maintains a consistent geometry in all three palinspastic maps. The Helena trailing edge is bordered by the Yellowleaf-Dry Creek system (Plates 10, 11, and 12). An embayment in the Helena trailing edge (at the triple point boundary between the Helena-Yellowleaf-Dry Creek thrust sheets) is more convex up stratigraphic section (Plates 10, 11, and 12). The convexity of the trailing Helena edge is an oblique ramp with the Yellowleaf fault in the Knox palinspastic map (Plate 11). On the Fort Payne palinspastic map, the oblique ramp borders both the Yellowleaf and Dry Creek thrust sheets (Plate 12). The Talladega thrust sheet is not
modeled in the palinspastic maps because of the lack of trailing Talladega cut-off points.

Basement fault 1 is located underneath the palinspastic restoration of the Opossum Valley and Blue Creek thrust sheets on all three maps (Plates 10, 11 and 12). A divergent fault splays from basement fault 1. Seismic reflection profiles indicate that the two faults present along cross section A have differing displacements; the northwestern fault has a very small displacement and the southeastern fault has a displacement of approximately 7,500 ft (2,286 m). The southeastern fault with the large displacement is interpreted as basement fault 1 and the northwestern fault with the small displacement is interpreted as the divergent splay. The branch point for basement fault 1 and the divergent splay is located between the branch point of the Opossum Valley and Blue Creek faults and the lateral ramp of the Opossum Valley thrust fault (Plates 10, 11, and 12). Basement faults 2 and 3 underlie the palinspastic location of the Jones Valley and Helena thrust sheets on all three maps (Plates 10, 11, and 12). There is a mapped dextral offset on both basement faults underneath the Jones Valley thrust sheet (Plates 10, 11, and 12) (Thomas and Bayona, in press). The dextral offset of the basement faults is directly aligned across strike from a lateral edge between the Jones Valley thrust sheet and an unnamed thrust sheet along the southwestern trailing edge of the Jones Valley thrust sheet (Plates 10, 11, and 12). The Jones Valley-Helena thrust sheets share a large oblique lateral edge overlying basement faults 2 and 3; however, there is no offset in the basement faults underlying the Jones Valley-Helena oblique ramp. Seismic data are not available to interpret whether basement faults exist under the palinspastic locations of the Yellowleaf and Dry Creek thrust sheets.

**Local Kinematic History of the Bessemer Transverse Zone**

The Blue Creek, Opossum Valley and Jones Valley thrust faults crop out in the Concord and McCalla 7.5’ quadrangles. A rejoining splay of the Opossum Valley fault, and the McAshan Mountain back thrust, are also mapped in the two quadrangles (Plate 13). The kinematic relationship between the Opossum Valley and Jones Valley faults has been discussed in the section of this chapter titled, *Regional Kinematic History of the Bessemer Transverse Zone*. The kinematic relationship between the Opossum Valley and Jones Valley faults remains consistent in the Concord-McCalla area and will
not be discussed in this section. The Blue Creek thrust sheet in the Concord and McCalla 7.5’ quadrangles contains the trailing limb of the Blue Creek syncline. The synclinal limb in the trailing Blue Creek hanging wall is truncated to the southwest along strike by the Opossum Valley splay, the Opossum Valley fault, and the Jones Valley fault (Plate 13). The kinematic relationship between the Blue Creek fault, and the Opossum Valley and Jones Valley faults, will be discussed in this section. The kinematic relationships between the Opossum Valley splay, the McAshan Mountain back thrust, and the cross-strike links connecting all of the above-mentioned structures will be analyzed.

As outlined in Chapter 6, cross-strike links in the Concord and McCalla 7.5’ quadrangles are grouped into the Concord and McAshan Mountain cross-strike link (CSL) zones. The Concord CSL zone contains cross-strike links 1, 2, and 3 and is divided into three sections. Each section of the Concord CSL zone is bound by the Blue Creek thrust fault to the northwest, the Opossum Valley and/or Jones Valley faults to the southeast, and individual cross-strike links to the northeast or southwest of each section (Plate 13). The McAshan Mountain CSL zone contains cross-strike links 4, 5, 6, and 7, the southwest part of the McAshan Mountain back thrust, and the Jones Valley fault (Plate 13). The kinematic relationships of the cross-strike links in these zones aid in elucidating the kinematic relationships between the Blue Creek, Opossum Valley, and Jones Valley thrust faults and permits interpretation of how the CSL zones transfer displacement between the thrust faults of the BTZ.

**Outcrop Indicators of Local Kinematic History**

The Blue Creek fault truncates the leading limb of the Blue Creek syncline. One hanging-wall frontal ramp (Plate 14 [Location 5]) and two hanging wall flats (Plate 14 [Locations 6 and 7]) are present in the Parkwood and Pottsville formations along the Blue Creek fault trace (sections 2 and 3). Thrust fault ramps propagating in an undeformed footwall are modeled as maintaining fault-bend or fault-propagation anticlines in the hanging wall. A syncline in the Blue Creek hanging wall, the Blue Creek fault cutting down stratigraphic section across cross-strike link 2, and the Blue Creek fault cutting up stratigraphic section across cross-strike link 3 in the hanging wall suggest that the Blue Creek fault truncates a deformed footwall (Plate 13). The Blue
Creek syncline is the deformed footwall of the Blue Creek fault. The geologic map geometry of the Blue Creek fault indicates that the Blue Creek syncline is older than the Blue Creek fault.

The en-echelon map distribution of the Blue Creek and Opossum Valley thrust faults and the opposite vector displacements of both faults (Opossum Valley tends to zero displacement at a lateral ramp to the southwest along strike, Blue Creek tends to zero displacement at the Opossum Valley branch point to the northeast along strike in the Bessemer 7.5’ Quadrangle) (Plate 2 [Location 1]) indicates a lateral-ramp displacement transfer zone exists between these two thrust faults. The Opossum Valley and Blue Creek thrust sheets are interpreted as a single kinematic unit connected by the lateral-ramp displacement transfer zone. The Opossum Valley fault is interpreted as having been emplaced at the same time as the Blue Creek fault.

The Jones Valley fault truncates the trailing limb of the Blue Creek syncline to the southwest along strike; cutting through the Copper Ridge Dolomite along the trailing edge of the McAshan Mountain back thrust footwall and cutting up section from the Copper Ridge to the Red Mountain formation at cross-strike link 6 (Plate 13). As discussed in the previous paragraphs, the Blue Creek synclinal limb is not a structural feature formed during emplacement of the Blue Creek thrust sheet. The Blue Creek fault truncates the pre-existing Blue Creek syncline. Truncation of the Blue Creek synclinal limb by the Jones Valley fault suggests that the Jones Valley fault is younger than the Blue Creek syncline and in turn is younger than the Blue Creek fault that truncates the syncline.

Concord CSL Zone

Section 1

A rejoining splay of the Opossum Valley fault is mapped in section 1 of the Concord CSL (Plate 13). The rejoining splay truncates small-scale folds in the trailing Blue Creek thrust sheet; the southwest-plunging West End anticline at cross-strike link 7 and the trailing limb of an unnamed, northeast-plunging anticline to the southwest along strike (Plate 14 [Locations 9, 15, and 16]). The northeast striking folds in section 1 are mapped as sharing the trailing Blue Creek synclinal limb, implying that the
northeast striking folds are part of the Blue Creek syncline-Birmingham anticlinorium fold train. The folds are not related to emplacement of the Blue Creek thrust sheet, but are interpreted to be part of the fold system truncated by the Blue Creek fault. As such, the truncated folds in section 1 do not indicate a break-back deformation sequence between the Blue Creek fault and the Opossum Valley rejoining splay; but indicate that both faults cut through a deformed footwall when they were emplaced as a single kinematic unit.

Section 2

The McAshan Mountain back thrust is present in section 2 ([Plate 14] [fault labeled MBT]). The back thrust branches with cross-strike link 1 at the northeastern boundary of section 2 and is truncated along strike to the southwest by cross-strike link 2 ([Plate 13]). The McAshan Mountain back thrust, and both cross-strike links, shorten the up-plunge termination of the Blue Creek syncline. The McAshan Mountain back thrust and two splays are parallel to the strike of stratigraphic contacts in the synclinal trailing limb. Timing of back thrust emplacement with respect to the folding of the Blue Creek syncline is unclear in the geologic map expression of the back thrust. Map geometries do not indicate if the back thrust was folded by the Blue Creek syncline, or if the back thrust is a post-folding stucture.

Cross-strike links 1 and 2 exhibit a straight map trace across topography, truncating and offsetting the Blue Creek syncline perpendicular to the axial plane ([Plate 13]). The linear cross-strike link map traces indicate that the faults were not folded by the Blue Creek syncline, but post-date folding. Cross-strike links 1 and 2 branch from the Blue Creek fault at high angles, but are not mapped as displacing the thrust fault. Map evidence of the kinematic sequencing of the cross-strike links with the Blue Creek fault is not clear. Cross-strike link 1 branches with the McAshan Mountain back thrust across strike. The geometry of the branch point does not elucidate the relative timing of faulting; neither fault cross cuts the other. Cross-strike link 2 truncates and offsets the McAshan Mountain back thrust; cross-strike link 2 is therefore interpreted as post-dating emplacement of the back thrust. Cross-strike link 2 branches with the Opossum Valley rejoining splay. Cross-strike link 2 and the rejoining splay are not displaced by
the other, the branch point geometry of the cross-strike link and the rejoining splay do not elucidate the kinematic relationship between the two faults.

**Section 3**

Section 3 is unique in that it is the juncture between the Concord and McAshan Mountain CSL zones, and it is truncated by two different thrust faults along the strike of its trailing edge ([Plate 13](#)). The Opossum Valley fault truncates the northeast trailing edge of section 3 in the Concord CSL zone ([Plate 13](#)). The Jones Valley fault truncates the southwest trailing edge of section 3 in the McAshan Mountain CSL zone, southwest of the Opossum Valley lateral ramp (cross-strike link 4) ([Plate 13](#)). The Opossum Valley fault truncates the stratigraphy of “the Knot”, as defined in Chapter 8, in a footwall ramp ([Plate 14](#) [Location 10]), truncates the Blue Creek trailing limb in a Chickamauga Limestone FSP ramp, and terminates at the lateral ramp that is cross-strike link 4 ([Plate 13](#)). The Jones Valley fault truncates the Blue Creek trailing limb in a footwall FSP ramp in the Copper Ridge Dolomite ([Plate 13](#)).

The trailing Blue Creek synclinal limb is shortened in section 3 by the McAshan Mountain back thrust. The back-thrust hanging wall and footwall are interpreted as plunging underneath the lateral ramp of the Opossum Valley thrust sheet. The back thrust and its related components are interpreted as extending underneath the Opossum Valley thrust sheet and emerging along strike to the north in “the Knot”. “The Knot” is a fault-bounded succession exposing the same rocks that crop out in the McAshan Mountain back-thrust footwall to the southwest, the Fort Payne and Red Mountain formations ([Plate 13](#)). The outcrop exposure in “the Knot” also contains the Hartselle Sandstone, which pinches out to the southwest along strike, north of cross-strike link 4 ([Plate 14](#) [Location 11]). The Hartselle Sandstone is not present in the stratigraphic succession in the McAshan Mountain back-thrust footwall to the southwest of cross-strike link 4 ([Plate 13](#)).

Cross-strike link 3 splays from the Blue Creek fault and truncates the hinge and trailing limb area of the Blue Creek syncline. The Paleozoic stratigraphic framework varies across the Concord CSL zone. The competent Hartselle Sandstone pinches out between cross-strike links 2 and 3; 160 ft (48 m) of quartzose sandstone in the Concord 7.5° Quadrangle thins to the southwest along strike to pinch out in the McCalla 7.5°
Quadrangle (Plate 13). Cross-strike link 3 is a steep, unfolded transverse fault that differs from the other cross-strike links in the Concord CSL zone in that it translates displacement into a Floyd Shale-cored anticline. The tip line of cross-strike link 3 is located in the Floyd Shale and does not extend into the Fort Payne Chert capping the shale core of the anticline (Plate 14 [Location 23]). The outcrop width of the Floyd Shale on either side of cross-strike link 3 is wider than Floyd outcrop mapped a distance away from the cross-strike link. Dip measurements in the Floyd Shale on either side of cross-strike link 3 are consistent at an average 53° (Plate 13), indicating that the increase in outcrop pattern width is not the result of a change in the dip of the unit. The outcrop width of the Floyd Shale is interpreted to be the result of thickening of the stratigraphic unit. A tectonically thickened weak unit forming the core of an anticline with a competent unit bounding the weak core is interpreted as a detachment fold (Mitra, 2002). Transfer of displacement along cross-strike link 3 is interpreted as forming a detachment fold in the Floyd Shale, which folded the McAshan Mountain back-thrust, the back-thrust footwall, and caused the northeast- to north-strike change in the back-thrust hanging wall and footwall (Plate 14 [Location 13]). The pinchout of the Hartselle Sandstone in the Concord CSL zone is interpreted as the removal of an important competent unit from a predominantly weak multilayer stratigraphic succession. The lack of a competent horizon is interpreted as initiating a change in the geometry of the cross-strike links in the Concord CSL zone.

McAshan Mountain CSL Zone

Cross-strike links 4, 5, and 6 are northwest-striking transverse faults in the Concord and McCalla 7.5’ quadrangles. Cross-strike link 4 is the lateral ramp terminating the Opossum Valley thrust sheet (Plate 13). Cross-strike link 5 is the northeastern transverse fault that is a footwall splay of the Jones Valley fault exposing the Copper Ridge Dolomite (unit 2) on the surface (Plate 13). Cross-strike link 6 is another transverse fault that is also a footwall splay of the Jones Valley fault. Cross-strike link 6 accommodates a dextral offset in the strike of the Jones Valley fault (Plate 13).

All of the cross-strike links in the McAshan Mountain CSL zone have straight map traces across the topography of the two quadrangles. The faults are interpreted as
steeply dipping, non-folded transverse faults that truncate the leading edge of the Opossum Valley thrust sheet (cross-strike link 4) and truncate the trailing edge of the Blue Creek thrust sheet (cross-strike links 5 and 6).

Cross-strike link 4 truncates the northeast-plunging, unnamed folds in the Opossum Valley thrust sheet, the McAshan Mountain back thrust, and the Copper Ridge to Fort Payne stratigraphy in the McAshan Mountain back-thrust footwall. This map geometry suggests that cross-strike link 4 is younger than the McAshan Mountain back thrust. Cross-strike link 4 branches with the Opossum Valley fault to the northwest and branches with the Jones Valley fault to the southeast. The northeast-plunging, unnamed folds in the Opossum Valley thrust sheet are interpreted as having formed during emplacement of cross-strike link 4 and the Opossum Valley thrust sheet. Folding of the Opossum Valley thrust sheet after the emplacement of cross-strike link 4 would have resulted in folding of the cross-strike link. The straight map trace of cross-strike link 4 precludes an interpretation of a folded cross-strike link. Cross-strike link 5 truncates the Copper Ridge through Fort Payne stratigraphy of the McAshan Mountain back thrust (Plate 14 [Location 18]). Cross-strike link 6 truncates the Copper Ridge to Red Mountain stratigraphy of the McAshan Mountain back thrust footwall (Plate 14 [Location 19]). Cross-strike links 5 and 6 branch with the McAshan Mountain back thrust to the northwest and branch with the Jones Valley fault to the southeast. The geometry of the branch points do not indicate a timing relationship between the respective faults. However, the truncation of the McAshan Mountain stratigraphy by the cross-strike links implies that the cross-strike links are younger than the McAshan Mountain back thrust.

**Local Kinematic History Interpreted from Strike-Perpendicular Cross Section 6**

Strike-perpendicular cross section 6 is used to elucidate the kinematic history of the Blue Creek, McAshan Mountain back thrust, and Jones Valley thrust faults in the Concord and McCalla 7.5’ quadrangles.

The palinspastic restoration of the Blue Creek thrust fault and the McAshan Mountain back thrust in cross section 6 has an undeformed line length of 46,500 ft (14,175 m) (Plate 25, part A). The restoration of cross section 6 shows the location of
basement fault 1 of the Birmingham basement fault system underlying the Concord and McCalla 7.5’ quadrangles, the northwestern part of graben 1, and decollement ramp 1, as defined in Chapter 7 (Plate 25, part A).

The kinematic history in the Concord and McCalla 7.5’ quadrangles begins with the emplacement of the Alleghanian allochthon by translation of units 1 though 4 over the basal decollement horizon. As described in the Regional Kinematic History of the Bessemer Transverse Zone, detachment folding in weak unit 1 initiated the Bessemer mushwad, uplifting the multilayer stratigraphy overlying the ductile detachment fold core, and fracturing the competent units (unit 2) within the multilayer succession (Plate 25, part B). Growth of the detachment fold uplifted and draped the overlying stratigraphy into antiforms and synforms, creating the Blue Creek syncline-Birmingham anticline-Cahaba synclinorium fold train. Fracturing of competent units in the uplifted stratigraphy is interpreted as having formed the incipient Blue Creek and Jones Valley faults. The Bessemer mushwad propagated forelandward of graben 1 along an out of syncline fracture, the incipient Blue Creek fault. The Blue Creek fault is in the structural position of the Opossum Valley fault to the northwest along strike. Propagation of the incipient-Blue Creek fault down section to branch with the basal decollement horizon is interpreted to have formed decollement ramp 1 and provided a kinematic path for forelandward propagation of the Bessemer detachment fold (Plate 25, part C). Displacement on the Blue Creek fault is small and is interpreted at approximately 4,000 ft (1,220 m). The limited displacement on the Blue Creek fault suggests that allochthon stress was not resolved by a large displacement on the Blue Creek fault but by additional folding of the Bessemer mushwad and continued folding of the Blue Creek syncline and fracturing of the overlying competent units (incipient McAshan Mountain and Jones Valley faults). Initiation of the McAshan Mountain back thrust is interpreted as an accommodation structure formed during tightening and folding of the mushwad and the Blue Creek syncline in the hanging wall of the Blue Creek fault (Plate 25, part D). Continued folding of the Bessemer mushwad steepened the McAshan Mountain back thrust and the Blue Creek synclinal limb to steep and almost vertical dips (Plate 25, part E). Fractures in the competent unit overlying the
detachment fold core were activated as the Jones Valley fault when displacement could no longer be propagated along the folded McAsran Mountain back thrust.

**Palinspastic Maps of the Concord and McCalla 7.5’ Quadrangles**

Three palinspastic maps were developed from the seven 1:24,000-scale balanced and restored cross sections traversing the Concord and McCalla 7.5’ quadrangles. The maps display the Blue Creek, McAsran Mountain back thrust, and Opossum Valley thrust sheets at three stratigraphic levels; the top of the Cambrian Conasauga Formation (Plate 26), the top of the Cambrian Copper Ridge Dolomite (Plate 27), and the top of the Mississippian Fort Payne Chert (Plate 28). Also shown on the palinspastic maps are the traces of basement fault 1 and a diverging splay. Of particular interest on the palinspastic maps of the Concord and McCalla 7.5’ quadrangles is the evolution of the cross-strike link geometry at different stratigraphic levels.

The maps were constructed using the line-length restorations for the top of the three units. The leading and trailing cut-offs for each thrust fault were restored along the lines of all seven restored cross sections. The along-strike traces of the frontal and trailing edges of each thrust sheet were correlated between the seven cross sections. The construction of the palinspastic maps also permitted correlation of the lateral edges of each thrust sheet.

Basement fault 1 is located underneath the palinspastic restoration of the Opossum Valley and Blue Creek thrust sheets on all three maps (Plates 26, 27, 28). As discussed in the *Palinspastic Maps of the Bessemer Transverse Zone* section of this chapter, a divergent fault splays from basement fault 1. Comparison of displacement amounts on both faults led to interpretation of the southeastern fault as basement fault 1 and interpretation of the northwestern fault as the diverging splay. The branch point for basement fault 1 and the diverging splay is located between the branch point of the Opossum Valley and Blue Creek faults and the lateral ramp of the Opossum Valley thrust fault (Plates 26, 27, 28).

At the upper Conasauga contact, cross-strike links 4, 5, and 7 are present between the Blue Creek, Opossum Valley and Jones Valley thrust sheets (Plate 26). Cross-strike link 4 is the northeast-striking Opossum Valley lateral ramp. Cross-strike
link 5 is a transverse fault on the footwall splay of the Jones Valley fault. Cross-strike link 7 is the northwestern transverse fault of the Opossum Valley rejoining splay. The cross-strike links of the McAshan Mountain CSL zone are interpreted as splaying from the basal decollement with the Opossum Valley and Jones Valley (cross-strike link 4) and Blue Creek and Jones Valley (cross-strike link 5) thrust sheets that they connect. Cross-strike links 4 and 5 are interpreted as fundamental components of thrust sheet formation, not accommodation structures facilitating shortening during deformation.

The Concord cross-strike links are mapped at the upper contact of the Copper Ridge Dolomite (Plate 27), but not at the base of the unit (Plate 26). Cross-strike links 1, 2, and 3 are mapped as part of the Blue Creek thrust sheet and the McAshan Mountain back-thrust sheet. Cross-strike link 1 is interpreted from the palinspastic map as having formed with the McAshan Mountain back thrust as the back thrust changed strike from northeast to northwest to branch with the Blue Creek thrust fault (Plate 27). Incipient cross-strike link 2 is present on the Copper Ridge map as part of the McAshan Mountain back thrust system. Back-thrust splay 2, as defined in Chapter 8, is also present on the Copper Ridge map. Northeast striking splay 2 branches with the McAshan Mountain back thrust at cross-strike link 1 and terminates along strike at incipient cross-strike link 2. Cross-strike link 2 is shown on the Copper Ridge palinspastic map as a change in the strike of splay 2 from northeast to northwest. This implies that cross-strike link 2 is splay 2, not a separate fault truncating splay 2. On the geologic map of the Concord 7.5 Quadrangle, cross-strike link 2 truncates the McAshan Mountain back thrust and its footwall structures (Plate 13). The geologic map relationships, used in conjunction with the palinspastic map interpretations, imply multiple episodes of displacement on cross-strike link 2. Initially, cross-strike link 2 formed with the emplacement of the back thrust splay. Cross-strike link 2 was later reactivated, with tip line extension along northwest strike, and truncated the McAshan Mountain back thrust and structures in the McAshan Mountain back thrust footwall. On the geologic map of the Concord and McCalla quadrangles, cross-strike link 2 terminates at a branch point with the Opossum Valley rejoining splay (Plate 13).
Cross-strike link 3 is mapped on the Copper Ridge upper contact as a northwest-striking transverse fault branching with the Blue Creek fault to the northwest and the McAshan Mountain back thrust to the southeast (Plate 27).

McAshan Mountain cross-strike links 4 and 5, and cross-strike link 7 are present on the Copper Ridge map. Changes in the geometry of the cross-strike links are not evident from the Conasauga map to the Copper Ridge map (Plates 26 and 27).

The Concord CSL zone is present on the Fort Payne palinspastic map (Plate 28). McAshan Mountain back-thrust splay 1 is mapped on the Fort Payne upper contact (Plate 28). Splay 1 branches from cross-strike link 1, extends southwestward along strike and branches with cross-strike link 2. The inclusion of splay 1 into the cross-strike link 2 system lengthens the map trace of the cross-strike link. Cross-strike link 3 varies in geometry from its expression on the Copper Ridge map in that it does not branch with the McAshan Mountain back thrust on the Fort Payne map (Plate 28). As evidenced on the geologic map of the Concord and McCalla quadrangles, the fault transfers its displacement into the overlying Floyd Shale, forming a Floyd Shale detachment fold as discussed in the Concord CSL Zone section of this chapter (Plate 13).

The cross-strike links of the McAshan Mountain CSL zone are all present on the Fort Payne palinspastic map. Changes in the geometry of the cross-strike links are not evident from the Copper Ridge map to the Fort Payne map (Plates 27 and 28).

**Controls on the Location of the Bessemer Transverse Zone**

**Introduction**

The alignment of several cross-strike links into the BTZ has been evidenced in this dissertation for the Alleghanian thrust belt of Alabama. Previous research (Thomas, 1990) has shown that the systematic alignment of cross-strike links into transverse zones implies some primary control on the location of transverse zones in allochthons. Alternative hypotheses regarding controls on transverse zone placement include:

1. Controls external to the allochthon (sub-decollement basement structures)
2). Controls within the allochthon (basement-rooted faults in the cover strata; drape folds in the cover strata over basement faults; stratigraphic variations in the cover strata, especially in the decollement horizon).


This section considers which of these factors control the origin and location of the cross-strike links that form the Bessemer transverse zone in the Alleghanian allochthon of Alabama.

**Controls External to the Allochthon**

An allochthon, or thrust belt, is interpreted as an internally deformed mass of rock that has been translated as in internally non-cohesive whole, on one regional sole fault, or basal decollement, away from the orogenic core towards the foreland basin. Rocks and structures in the allochthon extend down to the basal decollement and do not extend underneath the basal allochthon detachment. Structures located underneath the basal decollement of the allochthon are separate from the allochthon and may consist of igneous or metamorphic basement rocks, sedimentary rocks associated with pre-allochthon basins, or older thrust belt zones from earlier orogenic events. Sub-allochthon structures are separate from the geometric and kinematic allochthon in question; however, sub-allochthon structures may impact geometric and kinematic evolution of the allochthon, through the re-activation of previous structures. The presence of variable sub-allochthon sedimentary packages may serve as later basal decollement horizons for the allochthon. Variations in sub-allochthon sedimentary packages and/or facies changes will impact the geometry of the basal decollement and in turn affect the geometry of the allochthon.

Sub-decollement basement structures do exist beneath the Alabama Alleghanian allochthon. A regional basement fault system, the Birmingham basement fault system, underlies the BTZ (Plates 3, 4, 10, 11, and 12). As outlined in Chapter 7, the Birmingham basement fault system underneath the BTZ contains two grabens (graben 1 and graben 2), three basement faults (basement fault 1, basement fault 2, basement fault 3) and two horst blocks (the northwestern, foreland boundary of graben 1 and the horst-
block separating graben 1 and graben 2). The basement faults are located underneath displacement transfer zones, along the transport path of lateral ramps and underneath oblique ramps in the thrust sheets of the BTZ. Basement fault 1, and the splay diverging from it, underlies the Blue Creek-Opossum Valley lateral ramp displacement transfer zone. The branch point of basement fault 1 and the diverging splay is located between the Blue Creek-Opossum Valley branch point and the Opossum Valley lateral ramp (Plates 10, 11, 12, 26, 27, and 28).

A lateral ramp is modeled between the Jones Valley thrust sheet and an unnamed thrust sheet on the palinspastic maps of the BTZ (Plates 10, 11, and 12). When the thrust sheets are retrodeformed in the palinspastic map of the BTZ, the lateral ramp is translated parallel to allochthon propagation direction to rest along the northwest-southeast linear trend of the dextral offsets in basement faults 2 and 3 of the Birmingham basement fault system (Plate 10, 11, and 12).

The oblique ramp between the Jones Valley and Helena thrust sheets palinspastically restores above the map traces of basement faults 2 and 3 (Plates 10, 11, and 12); however, there is no offset of, or branch point between, basement faults 2 and 3 at this location.

Wiltschko and Eastman (1988) provide a model where basement faults disrupt the allochthon stress field and initiate ramps (frontal, lateral, or oblique) in thrust sheets. As discussed above, the palinspastic maps of the BTZ elucidate the geometric relationship of the cross-strike links in the Opossum Valley, Jones Valley, and Helena faults with respect to the underlying basement faults. The basement faults of the Birmingham fault system are interpreted as having controlled the formation of the cross-strike links between the Blue Creek and Opossum Valley thrust sheets, the Jones Valley and unnamed thrust sheets, and the Jones Valley and Helena thrust sheets.

**Controls within the Allochthon**

Drape folding in the Paleozoic cover strata (Plates 3 and 4) has been interpreted as a response to basement-fault reactivation during the Mississippian-Pennsylvanian, prior to Alleghanian orogenesis (Thomas, 1986; Ferrill, 1989; Thomas, 1995). The drape fold discussed in Thomas (1986) and Ferrill (1989) is located above basement
fault 1 of the Birmingham basement fault system in the BTZ. The palinspastic restoration of the Jones Valley thrust sheet in the BTZ places the leading edge of the thrust sheets in the core of the drape fold (Plate 3). The glide horizon for the Jones Valley fault ramps from the upper detachment of the Bessemer mushwad and is located above basement fault 1, in the leading limb of the drape fold (Plate 3). This implies that drape-fold geometry may affect thrust-glide-horizon location (Thomas, 1990). In the BTZ, the drape fold is interpreted as affecting the location of the glide horizon of the Jones Valley fault, correlation cannot presently be made between the drape fold and BTZ cross-strike links.

Stratigraphic variations within the decollement-host horizon are presented by Thomas (1990) as a cross-strike link control within the allochthon. Unit 1 thickness in the BTZ triples in grabens 1 and 2. The increase in thickness of unit 1 in graben 1 facilitated the development of the Bessemer mushwad. The greater thickness of unit 1 permits the gradual accretion of the weak material into the core of the mushwad, controlling the amplitude and wavelength of the ductile duplex. As discussed in the *Regional Kinematic History* section of this chapter, the Blue Creek syncline, Birmingham anticlinorium, and Cahaba synclinorium are the result of growth of the Bessemer mushwad. Variations in the geometry of these structures are a result of folding by the underlying mushwad. The Blue Creek, Opossum Valley, and Jones Valley faults were also initiated from growth of the Bessemer mushwad. As modeled in transverse zone cross section D (Plate 6), along-strike changes in the geometry of these faults are results of the irregular shape of the foreland edge of the underlying mushwad. The glide horizon of the McAshan Mountain back thrust appears draped over the lateral expression of apparent thickness change in the mushwad because cross section D (Plate 6) is oblique to the curvilinear foreland edge of the mushwad. Cross-strike link 4, the Opossum Valley lateral ramp, is also located above a lateral change in mushwad geometry (Plate 6). Cross-strike link 7, the northeast lateral ramp of the Opossum Valley rejoining splay also is at a location of lateral variation in the foreland mushwad edge (Plate 6). The geometry of the Blue Creek syncline changes laterally because of apparent thickness changes in the Bessemer mushwad (Plates 3 and 4). The McAshan Mountain back thrust shortens the Blue Creek syncline as a mechanism to accommodate
synclinal tightening. The cross-strike links of the McAsahan Mountain back thrust (Concord CSL zone) are modeled as accommodation mechanisms for shortening of the Blue Creek syncline and of the McAsahan Mountain back thrust. Thickness variations of one unit in the Bessemer allochthon are interpreted as being responsible for the creation of three major thrust faults, one back thrust, and one cross-strike link zone.

**Combinations of Stratigraphic Variations and Sub-Decollement Structures**

As illustrated in the preceding sections, the controls on the locations of cross-strike links in the BTZ are not primarily localization of structures by sub-allochthon structures. Neither are the controls primarily a result of stratigraphic variations in unit 1 of the stratigraphic framework. Sub-decollement structures and stratigraphic variations in the allochthon both exhibit fundamental controls on the BTZ cross-strike links. The Concord CSL zone and the McAsahan Mountain back thrust are the result of the thickness and geometry changes in the unit 1 fill of graben 1 and the impact of these changes on the style of structures (ductile duplexes and folds) in the subsurface. Influence exerted from basement faults affects the location of the Blue Creek-Opossum Valley lateral ramp displacement transfer zone, including cross-strike link 4; the location of the Jones Valley-unnamed thrust sheet lateral ramp; and the location of the Jones Valley-Helena oblique ramp.

The presence of the basement fault system underneath the Alabama allochthon is interpreted as the mechanism for providing accommodation space for the deposition of approximately 7,000 ft (2,130 m) of unit 1. The controls on the localization and formation of cross-strike links in the BTZ are interpreted as a combination of pre-existing basement structures and variations of stratigraphy in the allochthon.

**Discussion**

As discussed in the *Regional Kinematic History* section of this chapter, the Alleghanian allochthon in the BTZ is interpreted as an out-of-sequence thrust system (Morley, 1988). The first thrust sheets emplaced in the BTZ were the Opossum Valley and Blue Creek sheets. Progressive break-back deformation occurred in the Opossum Valley-Blue Creek hanging wall, resulting in the sequential emplacement of the Jones Valley, Helena, Yellowleaf-Dry Creek, and Talladega thrust faults. Current models of
break-back deformation sequences imply that initial forelandward propagation generates a large detached sheet, the hanging wall of which is subsequently fractured and deformed as orogenesis proceeds (Wissing et al., 2003). The emplacement of the large thrust sheet is modeled as a response to tectonic stress applied to multilayer stratigraphic frameworks in which a large competency contrast is present between a weak decollement horizon and a competent overlying layer that is the “strut” (Rich, 1934) of the stratigraphic framework. Large competency contrasts support the emplacement of a large coherent thrust sheet towards the foreland with break-back thrusting as a mechanism accommodating strain within the thrust system (Wissing et al., 2003).

Stratigraphic variations in the weak basal decollement horizon are also modeled by Wissing et al. (2003) as factors promoting thrust-sheet emplacement. Increases in thickness of the basal decollement horizon also promote detachment fold formation (Mitra, 2002) as allochthon propagation proceeds. The 7,000 ft (2,133 m) abrupt increase in weak-layer thickness across the syn-sedimentary basement fault system plays an important role in the development of the Alleghanian allochthon and the creation of a detachment fold in unit 1. The presence of basement fault 1 in the Birmingham basement fault system is interpreted as a stress concentrator (Wiltschko and Eastman, 1983), that in addition to the stratigraphic thickness and facies changes (Miller and Fuller, 1954; Woodward, 1988) promoted the development of the detachment fold. Continued mushwad evolution, with the formation of the Opossum Valley, Blue Creek, and Jones Valley thrust faults is interpreted as reaching a state where stress could no longer be propagated through the allochton. Additional break-back deformation, with the formation of the Helena, Yellowleaf-Dry Creek, and Talladega faults was needed to maintain allochthon propagation.

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