5-2018

Structural Geology of the Caddo Gap Area, Ouachita Mountains, Arkansas

Martin Messmer
messmerml@jacks.sfasu.edu

Structural Geology of the Caddo Gap Area, Ouachita Mountains, Arkansas

STRUCTURAL GEOLOGY OF THE CADDO GAP AREA, OUACHITA MOUNTAINS, ARKANSAS

By

Martin Lee Messmer, Bachelor of Science

Presented to the Faculty of the Graduate School of

Stephen F. Austin State University

In partial Fulfillment

Of the Requirements

For the Degree of

Master of Science

STEPHEN F. AUSTIN STATE UNIVERSITY

May, 2018

STRUCTURAL GEOLOGY OF THE CADDO GAP AREA,

OUACHITA MOUNTAINS, ARKANSAS

By

Martin Lee Messmer, Bachelor of Science

APPROVED:

Dr. Chris Barker, Thesis Director

Dr. R. LaRell Nielson, Committee Member

Dr. Melinda Faulkner, Committee Member

Dr. I-Kuai Hung, Committee Member

Pauline Sampson, Ph.D.
Dean of Research and Graduate Studies

ABSTRACT

The Caddo Gap quadrangle is located on the southern margin of the Benton Uplift, the orogenic core of the Ouachita Mountains. Recent field mapping focused on delineating stratigraphic and structural relationships in the southern part of the quadrangle to improve existing reconnaissance-scale maps of the area. New structures were discovered that provide further information about the structural evolution of the Ouachita fold and thrust belt.

Field work included mapping the three informal members (Lower, Middle and Upper) of the Arkansas Novaculite. Major folds within the study area include the Nelson Mountain Anticline and two synclinal folds ("South Caddo Mountain" and "Arrowhead Mountain") where south-dipping Novaculite has been folded around very sharply in map view, resulting in a "fishhook." The backthrust interpretation for Strawn Mountain (Haley et al., 2009) was found to be more structurally complex than previously proposed.

Analysis of the Nelson Mountain Anticline shows it is steeply inclined and gently plunging: the calculated mean axial plane (n = 104) is 276°, 78°SW (N84°W, 78°SW) and mean fold axis is 22°, 101° (22°, S79°E), similar to the reconnaissance-scale findings of Evansin (1976). Two fishhook folds, both located at the west ends of east-west ridges of Arkansas Novaculite, have similar geometries. The mean axial planes are 290°, 71°SW (N70°W, 71°SW) and 289°, 81°SW (N71°W, 81°SW) and average fold axes are 37°, 125° (37°, S55°E) and 40°, 117° (40°, S63°E).

Previously unmapped, northeast-trending strike-slip faults in the Arkansas Novaculite were discovered on the east-west "South Ridge" immediately south of and adjacent to the South Caddo Mountain fold. This style of faulting differs significantly from previous regional interpretations (Haley et al., 2009) which instead show South Caddo Mountain juxtaposed against the north side of the South Ridge by thrust faulting. Field mapping found no evidence for thrust faulting on South Caddo or Arrowhead Mountains.

An alternative hypothesis is that late-stage, northwest-directed compression formed left-lateral strike-slip tear faults that cut obliquely through the regional structures of the Caddo Mountains. This style of faulting better explains the fishhook drag folds and the strike-slip faults on the South Ridge, with Strawn Mountain backthrusts accommodating the northwest-directed compression on the north limb of the Nelson Mountain Anticline.

ACKNOWLEDGMENTS

Dr. Chris Barker, of the Department of Geology at Stephen F. Austin State University, supervised and reviewed this thesis study, assisted with field work and provided many useful discussions concerning this study. My thanks go also to thesis committee members Dr. R. LaRell Nielson and Dr. Melinda Faulkner of the Department of Geology, and Dr. I-Kuai Hung, Professor of GIS of the College of Forestry and Agriculture at SFA.

I would like to thank Robert Davidoff (retired) and Catherine Kilgore, Chief of the Division of Minerals Evaluation, U.S. Department of Interior for their support throughout this study. I also appreciate the support of Bekki White, Director and State Geologist, and Doug Hanson, Geologist, of the Arkansas Geological Survey.

Much appreciation goes to the Clingman-Jones Family Association who generously allowed access to their private land holdings. My thanks go also to Daniel Goodwin, Attorney, of Gill Ragon Owen, P.A., Little Rock, Arkansas, for coordinating permission to access lands owned by SPHS Holdings, LLC. I greatly appreciate the help of Chad Moore and Tom Moore of Caddo Gap, Arkansas, who kindly provided me access, guidance, and use of their all-terrain vehicle to map their private land holdings within the study area.

And a special thanks and love to my family, especially my wife, Jessica Messmer, for their patience, encouragement and support during this study.

TABLE OF CONTENTS

LIST OF FIGURES

Total number of figures: 90

CHAPTER 1

Introduction

Purpose and Objectives

Much of the Ouachita Mountain physiographic province in Arkansas (Figure 1.1) has been mapped at regional to reconnaissance (1:500,000 to 1:100,000) scale, but only a few 7.5 minute USGS quadrangles in the area have been mapped and published at detailed (1:24,000) scale (Arkansas Geological Survey, 2014). Many quadrangles still lack detailed, field-based geologic mapping, and therefore have not been structurally analyzed in a comprehensive manner (Doug Hanson, Geologist, Arkansas Geological Survey, personal communication, March 2015).

One such quadrangle is the USGS Caddo Gap 7.5-minute quadrangle (Figure 1.1), named for the village of Caddo Gap, Arkansas (and thereby indirectly for the Caddo Indians). This quadrangle lies on the southern margin of the Benton Uplift, the orogenic core of the Ouachita Mountains, where Paleozoic strata have undergone intense compression and deformation as a result of the Ouachita Orogeny during the formation of Pangea (Arbenz, 1989; Arbenz, 2008).

There is no published, readily available 1:24,000 geologic map of the Caddo Gap quadrangle. This quadrangle was covered by the Arkadelphia 30'x60' (1:100,000-scale) geologic map (Haley et al., 2009), but much of that project was done using aerial photography with limited field checking (Doug Hanson, personal communication, April 2016).

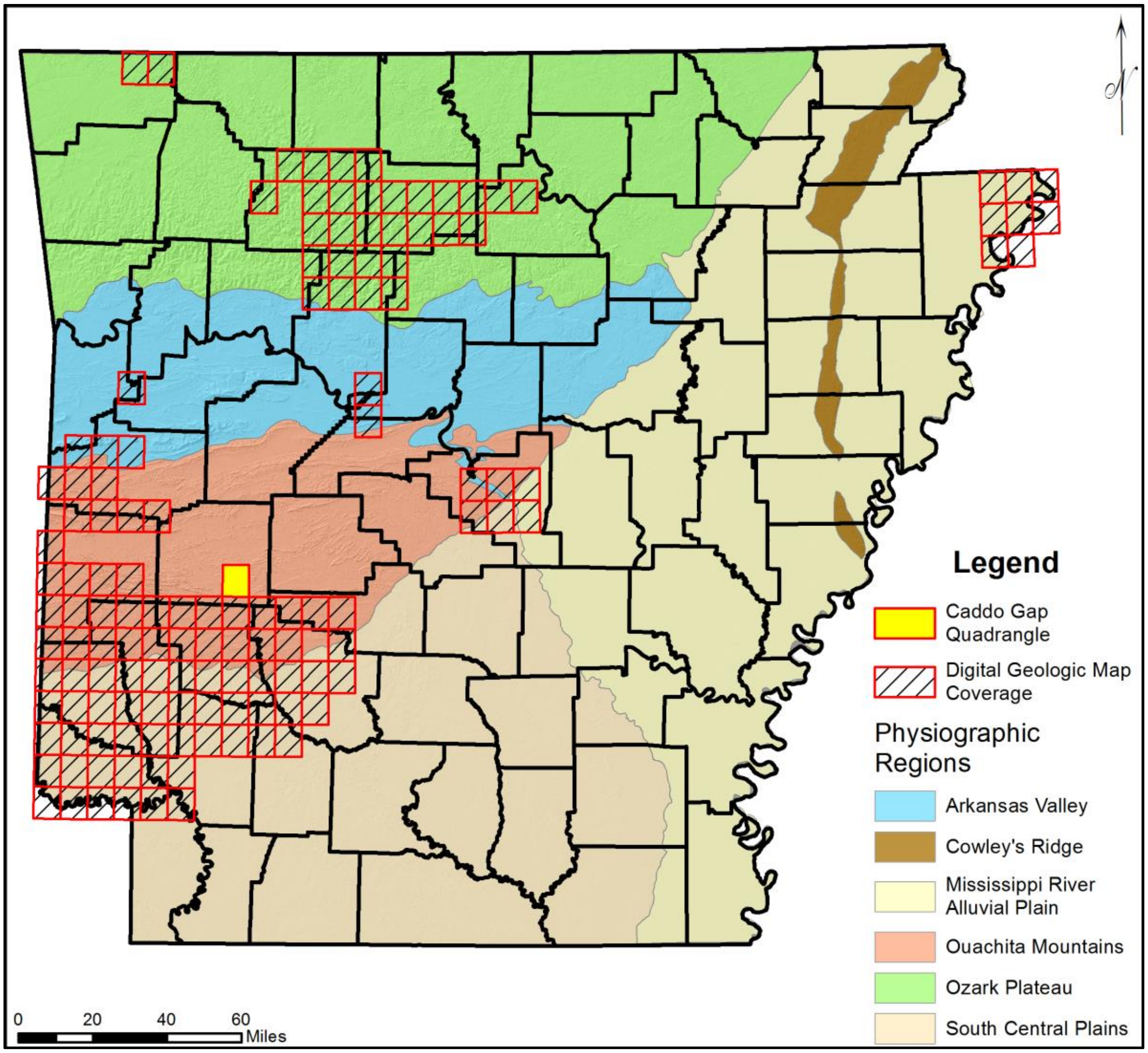


Figure 1.1. Physiographic regions of Arkansas showing available digital geologic map coverage (modified from Arkansas Geological Survey, 2014). Note the lack of published 1:24,000-scale geologic maps within the Ouachita Mountains (light red region). The Caddo Gap quadrangle is highlighted by the yellow-filled box.

None of the published maps of the Caddo Gap area show more than a few scattered strike and dip measurements. An unpublished field worksheet for the Caddo Gap quadrangle obtained from the Arkansas Geological Survey suggests that field checking within the quadrangle was limited to a handful of measurements taken along major highways and roads (Haley and Stone, 1991). Field mapping in greater detail, undertaken during this study, has revealed previously unmapped faults and folds that provide evidence for updated structural interpretations. Smaller structures have been identified and should improve existing regional maps and aid in interpreting the structural evolution and tectonic history of this mountain range.

A primary objective of this study was to compile a 1:12,000 scale geologic map of the southern part of the Caddo Gap quadrangle using detailed field work and Geographic Information Systems (GIS). The study area covers approximately 15 square miles of the Caddo Mountains, a subsidiary range of the Ouachitas. This study also included structural analysis of the field data collected to determine the styles of deformation and timing of the tectonic evolution of the Ouachita Mountains.

Previously unreported strike-slip faulting was found in this area as a result of detailed field mapping. This strike-slip fault system was found on an east-west trending novaculite ridge of the Caddo Mountains. This study describes the kinematics and timing of folding and faulting within this region.

Structural analysis objectives also included correlation of the observed features with the tectonic evolution of the local Caddo Mountain range and with the regional structural framework of the Benton Uplift. Results and interpretations were compared and contrasted with other structural studies of the Ouachita Mountains, especially those of nearby areas.

Location

The study area is located in southeastern Montgomery County, Arkansas, within the southernmost portion of the USGS 7.5-minute Caddo Gap quadrangle (Figure 1.2). It is bounded by latitudes 34.3750°N to 34.4063°N, and longitudes 93.6250°W to 93.5000°W, covering roughly 15 square miles. Most of the lands within the study area, especially the mountain ridges and surrounding slopes, are owned and managed by the U.S. Forest Service and were therefore accessible for field mapping. However, physical access over most of the study area was very difficult due to the lack of improved roads and trails. Thick undergrowth made some areas virtually inaccessible. On some of the south-facing slopes, thorny vines completely covered the native undergrowth and smaller trees, rendering access and mapping extremely difficult. Areas clear cut in the past were also essentially impassable due to dense overgrowth of berry vines and shrubs.

While the ridges in the area are part of the Ouachita National Forest, the surrounding valleys and flat-lying areas are usually private. Where possible, permission was obtained from those landowners in areas where bedrock exposures would likely be prominent. Access roads maintained by private landowners proved invaluable in reaching certain parts of the study area and for data collection.

The small community of Caddo Gap (pop. <100) is located in the southwestern portion of the study area, approximately three quarters of a mile from the geographic feature called Caddo Gap, which is where the south-flowing Caddo River has cut a narrow gorge through an east-west ridge of the Caddo Mountains. This locale is well-known among geologists for its excellent road cut exposures of about 900 stratigraphic feet of the Arkansas Novaculite along Arkansas State Highway 8. The outcrop has been studied extensively over the past 100 years (Miser and Purdue, 1929; Hass, 1951; Evansin, 1976; Sholes, 1977; Zimmerman, 1984; Philbrick, 2016). In the remainder of this report, the term “Caddo Gap” will refer to the geographic feature, not the town. The town of Glenwood, Arkansas is located about 6 miles south of the study area (Figure 1.3).

*Figure 1.2. Map showing location of the Caddo Gap and nearby quadrangles. The study area (**red** outline) covers the southern portion of the Caddo Gap quadrangle (ESRI, 2017).*

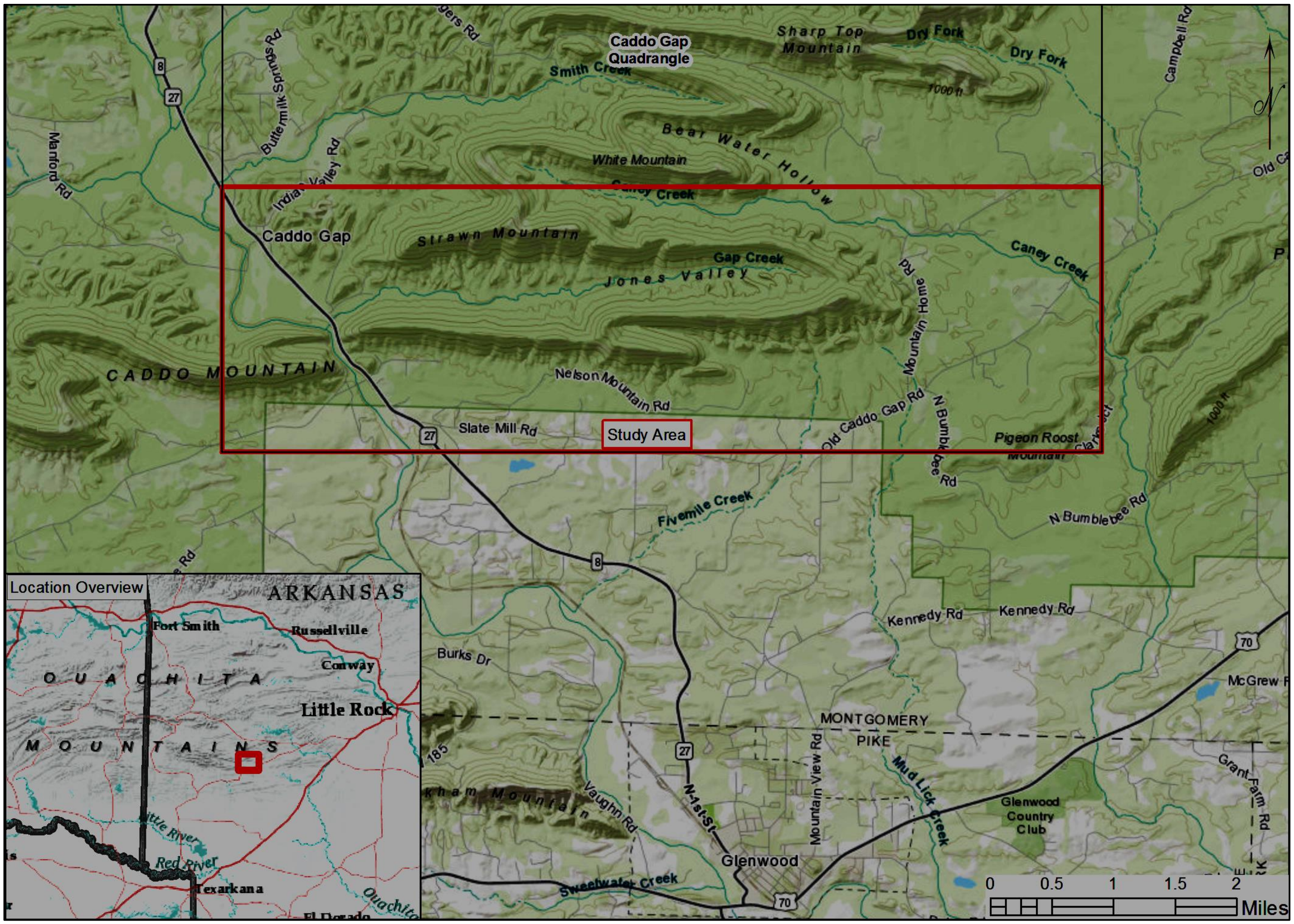


Figure 1.3. *Topographic map of the study area (**red** outline) in the southern Ouachita Mountains. Black lines represent the Caddo Gap Quadrangle (ESRI, 2017).*

The elevation in the study area ranges from 590 feet above mean sea level along the Caddo River valley to 1,574 feet at the summit of Strawn Mountain in the northern part of the study area (Figure 1.4) for a total relief of 984 feet. Nelson Mountain reaches an elevation of about 1,486 feet in the eastern portion of the study area. An un-named peak of about 1,420 feet lies near the junction of the south limb of the Nelson Mountain Anticline and the southern-most ridge of the Caddo Mountains (Figure 1.4). For the purposes of this study, this peak is referred to as "South Caddo Mountain." Another un-named peak with an elevation of about 1,325 feet is located about 1 mile due west of Strawn Mountain (Figure 1.4) and is referred to as "North Caddo Mountain" in this study. A third un-named peak in the very southwest corner of the study area, with an elevation of about 1,250 feet, is referred to as "Arrowhead Mountain" in this study (after the Arrowhead Campground located nearby on the Caddo River where the author often stayed during this study).

The Caddo Mountains are characterized by long, narrow ridges with steep slopes and winding crests, forming a major drainage barrier that is cut by the Caddo River in the study area. Small tributary streams occupy the intervening strike valleys and form a trellis drainage pattern. Gap Creek flows westward through Jones Valley and drains into the Caddo River, while Caney Creek occupying the valley between Strawn Mountain and White Mountain to the north flows eastward before turning due south along the eastern edge of the study area (Figure 1.5). The un-named stream valley on the northwest side of North Caddo Mountain is referred to as "Bean Creek" after the Bean Creek Cabins (on private land) through which the creek passes. The Caddo River, a tributary to the

Ouachita River, flows towards the south-southeast through the southwestern part of the study area.

The climate of the study area consists of hot, humid summers and mild winters. Temperatures can reach over 100 degrees Fahrenheit in the summer while the average winter low temperatures usually approach freezing (The Weather Channel, 2013). Average annual precipitation is around 56 to 58 inches (NOAA, 1997). The dense vegetation and forests supported by the high rainfall and relatively long summer growing period makes field work difficult. Usually only the most resistant formations such as fine grained novaculite and chert units are exposed. Weaker formations such as clay-rich shales typically develop a thick soil cover and overburden, but may be exposed in road cuts and stream gullies with steep cut banks.

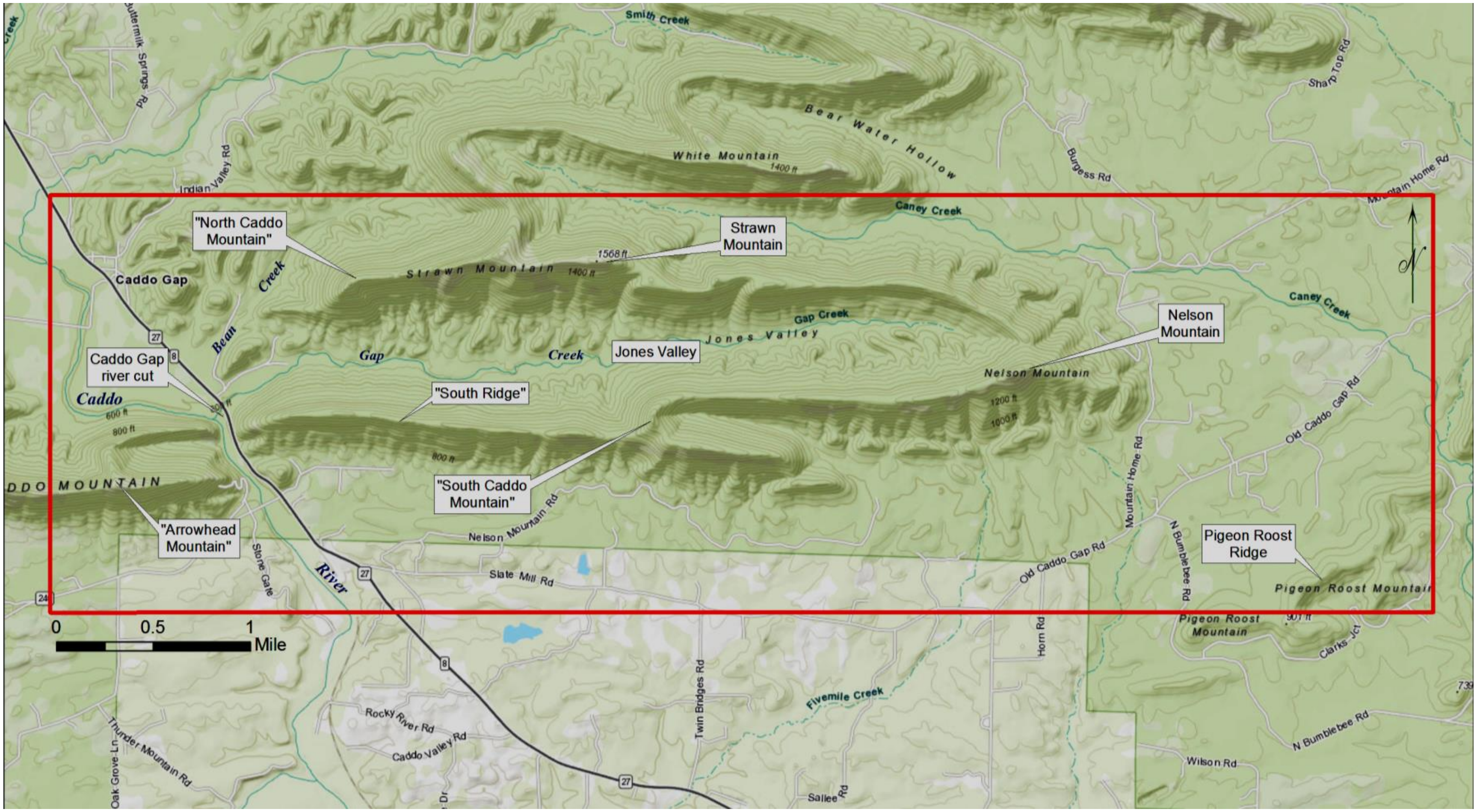


*Figure 1.4. Detailed topographic map of the study area (**red** outline) with major mountains and features labeled (modified from ESRI, 2017).*

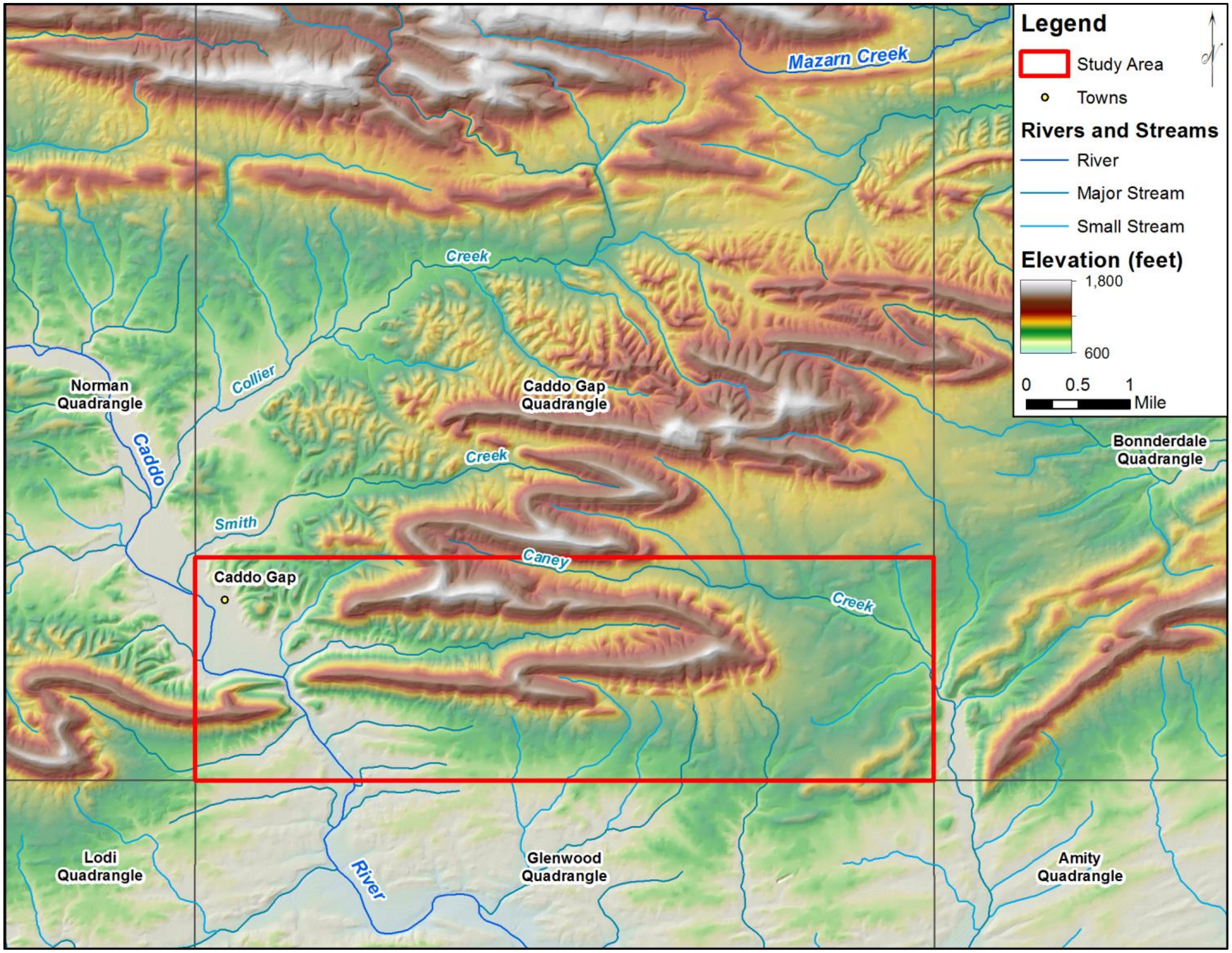


Figure 1.5. Digital elevation map of the study area (USGS, 2000); study area shown by ***red*** *outline.*

Methodology

Introduction

Initial study efforts consisted of background and literature research, particularly on works about the Caddo Gap road cut and nearby areas. Field work was then conducted in the southernmost part of the USGS Caddo Gap 7.5 minute quadrangle (Figure 1.5) using topographic maps kindly provided by the Arkansas Geological Survey. Enlarged digital base maps of the study area, including USGS topographic contours, were also created using ESRI's ArcGIS software. The area was mapped at a scale of 1:12,000 to show geologic detail. Field work was completed during multiple 2-6 day field visits during the winter and spring months of 2016 and 2017 (Figure 1.6; Figure 1.7). After the completion of field mapping, digital maps were created in ArcGIS to show the locations where data was collected. Finally, a geologic map and a pair of cross-sections were made showing the structural trends of the study area. Field locations and data are listed in Appendix A.

Field Work

During field work, locations were determined primarily by GPS devices and were plotted on topographic maps. A Garmin handheld GPSMAP 64s was initially used to record latitude and longitude coordinates. Later, locations were recorded using a cell phone application US Topo Map Pro (developed by ATLOGIS Geoinformatics GmbH & Co. KG). This tool provided more efficient data entry, backup, and retrieval. The application also provided a variety of base maps (many of which could be cached for use offline in low signal areas), and high resolution Google Earth aerial photography. These features were very useful for navigation in the field.

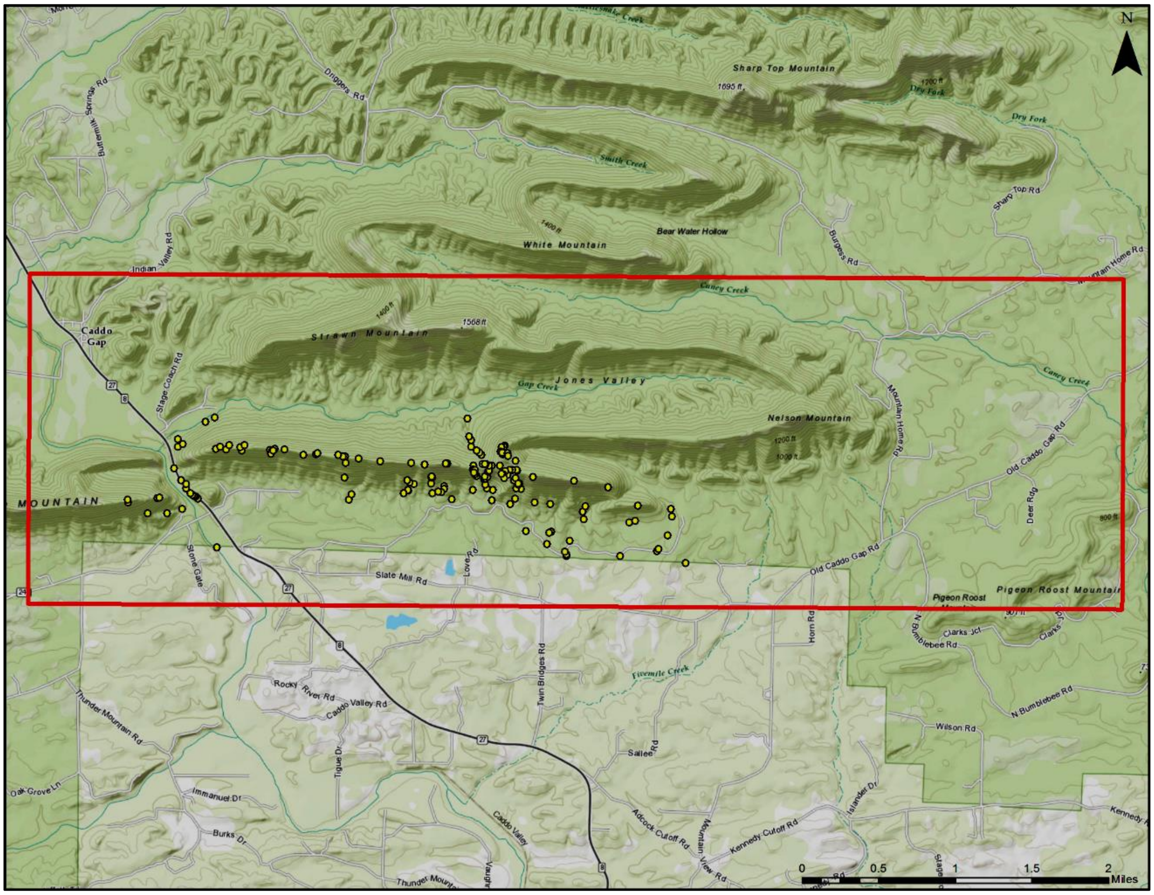


Figure 1.6. Location map of 2016 field Stops (yellow dots). Most of the Stops are located along the southern ridge extending east-west across the field area. These locations are described in Appendix A.

A Brunton Compass was used for taking field measurements such as strike and dip of bedding, measuring orientations of slickenlines/slickensides, measuring fault planes, fold axial planes, and other structural data. Hand samples were collected for reference during the study.

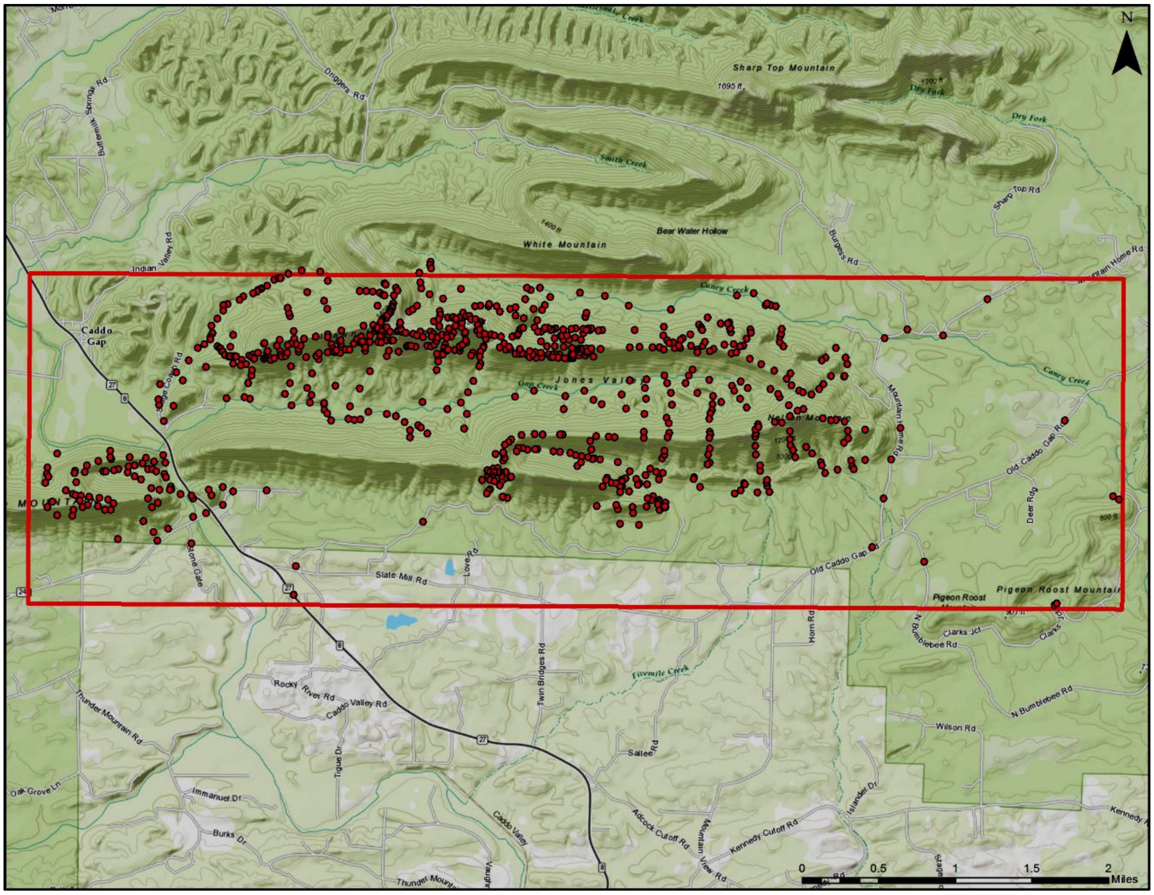


*Figure 1.7. Map showing locations of field Stops in 2017 (**red** dots). These locations are listed in Appendix A (ESRI, 2017).*

<u>*GIS Mapping and Analysis*</u>

Geographic Information Systems (GIS) is a very useful tool for compiling and mapping geologic data in the digital domain. ESRI's ArcGIS software was used to compile the data collected in this study and construct a digital geologic map for analysis and presentation. By compiling the data into a geodatabase, the data can be checked for quality control against other georeferenced layers while also providing more efficient data storage, backup, map production, editing, and digital distribution.

Field notes and paper maps were used in the field to record data and collect information, sketches and notes on the geology of the study area. Latitude and longitude coordinates for each location were recorded using GPS receivers. The latitude/longitude coordinates and notebook data were then entered into a Microsoft Excel spreadsheet and imported into ArcGIS. Quadrant measurements of strike and dip and plunge and bearing were converted into right hand rule for importing into both ArcGIS (ESRI, 2017) and Stereonet 9 (Allmendinger, 2013). This also provided a valuable quality control check of the data. Other information entered into the table included the type of feature measured (bedding, fault, lineation, etc.), the geologic formation in which the measurement was made (and the member of the Arkansas Novaculite if in that formation) and field notes. This table is summarized in Appendix A.

The Excel spreadsheet was then imported into ArcGIS and the data plotted as points on USGS topographic base maps (NED, 2016) and high resolution aerial photography (EFS GeoTechnologies, 2010). The data were appropriately symbolized using the ESRI Geology character marker style. Line feature classes including contacts, faults and map-scale fold axes from the field maps were drawn in ArcMap and stored in a geodatabase using the Universal Transverse Mercator (UTM) Zone 15N Coordinate System with North American Datum (NAD) 1983.

Polygons of the geologic formations were then drawn by tracing the contact and fault line features and also stored in the geodatabase. All feature classes constructed in GIS (contacts, faults, fold hinge lines and polygons) were given proper attributes such as fault or fold name (if applicable), type and location (concealed, inferred or observed).

Finally, topographic profiles of the cross section lines were interpolated from the USGS 10 meter digital elevation model of the area using the 3D Analyst extension in ArcMap. Cross sections were drawn by hand as construction in GIS is difficult.

Overall, the detailed geologic map produced in this study improved upon the regional scale map of Haley et al. (2009) by more accurately locating the faults through South Caddo Mountain and Arrowhead Mountain. It also better delineated the complexity of the backthrust faults forming Strawn Mountain Ridge. The high concentration of bedding measurements and float observations in the Arkansas Novaculite made it possible to map out the 3 informal members and improve structural analysis. Finally, a geodatabase of this map, including symbology, attributes and annotations can be stored and distributed electronically in today's ever-growing digital age.

By plotting all the field data in ArcGIS and comparing with a variety of base maps on the fly, quality control checks and analysis of the data were performed with more efficiency. Detailed aerial photography (some with up to 1 foot resolution) proved very useful for identifying outcrop trends. Questionable data could be compared against topography, aerial photography and surrounding data points to test the data. This was useful in areas where outcrops were very sparse due to the thick soil and forest cover. Data for an individual formation could be turned on or off to compare trends across formations and topographic features, such as selecting just those bedding measurements from the Arkansas Novaculite in the fishhook folds for importing into Stereonet 9.

The data were also compared against topography and aerial photography for proper location within a geographic feature or geologic formation. For instance, a suspect

Lower Novaculite outcrop with slickenlines and tension fractures at Stop 497 on the north side of Strawn Mountain was thought to be a possible major fault location during field work. However, comparison with topography, other surrounding measurements (recorded in the Stanley Shale) and inspection of detailed aerial photography (showing in-place Novaculite outcrops were located much higher uphill) indicated this location was outside the Lower Novaculite trends and was probably a large block that was not in place. This improved the detailed mapping and interpretation of the fault zones on the north side of Strawn Mountain.

Structural Analysis

Field data such as strike and dip of beds, bearing and plunge of folds, slickenlines and fault plane data were analyzed and plotted on Stereonet 9, a stereonet program created by Richard W. Allmendinger at Cornell University. This program aided in the plotting and analysis of the data recorded in the study area and for interpretation of various structures.

Previous Works

As discussed previously, the narrow gap or gorge formed by downcutting of the Caddo River through the Caddo Mountains provides an excellent series of outcrops and road cuts of the Arkansas Novaculite that are easily accessible for examination and study. An old railroad grade on the east side of the Caddo River and below the highway road cut offers additional exposures for study (Zimmerman, 1984). Many previous studies on the mineralogy, petrography, stratigraphy, and structural geology of the Arkansas Novaculite have been undertaken at this location.

One of the first geologic maps produced in the region covering the study area was by Miser and Purdue (1929) who reported on the topography, stratigraphy, structure, and minerals of the early De Queen and Caddo Gap 30'x30' topographic maps (the Caddo Gap 7.5' quadrangle comprises the northeast corner of the Caddo Gap 30'x30' topographic map). They reported that the rocks of the Ouachita Mountains ranged from Cambrian to Pennsylvanian in age with an aggregate thickness of 25,000 feet. They also discussed the stratigraphy and structure of the Arkansas Novaculite at Caddo Gap and divided the formation in 3 members: a Lower Novaculite member, a Middle Chert and Shale member, and an Upper Novaculite member.

Buthman (1982) mapped in detail the northern halves of the Norman and Caddo Gap quadrangles (Figure 1.5; Figure 1.8) and reported on the fold styles, geometry, and fault characteristics of the Early and Middle Ordovician rocks exposed in this area. Some of his cross sections indicate low-angle thrusts have been folded (Figure 1.8), suggesting multiple phases of deformation. His field evidence for a northwest-trending tear fault along the Caddo River suggests older folds and faults have been deformed by later phases of deformation with a change in the direction of compression. He interpreted up to four phases of folding and fault evolution in the Ordovician rocks (Buthman, 1982).

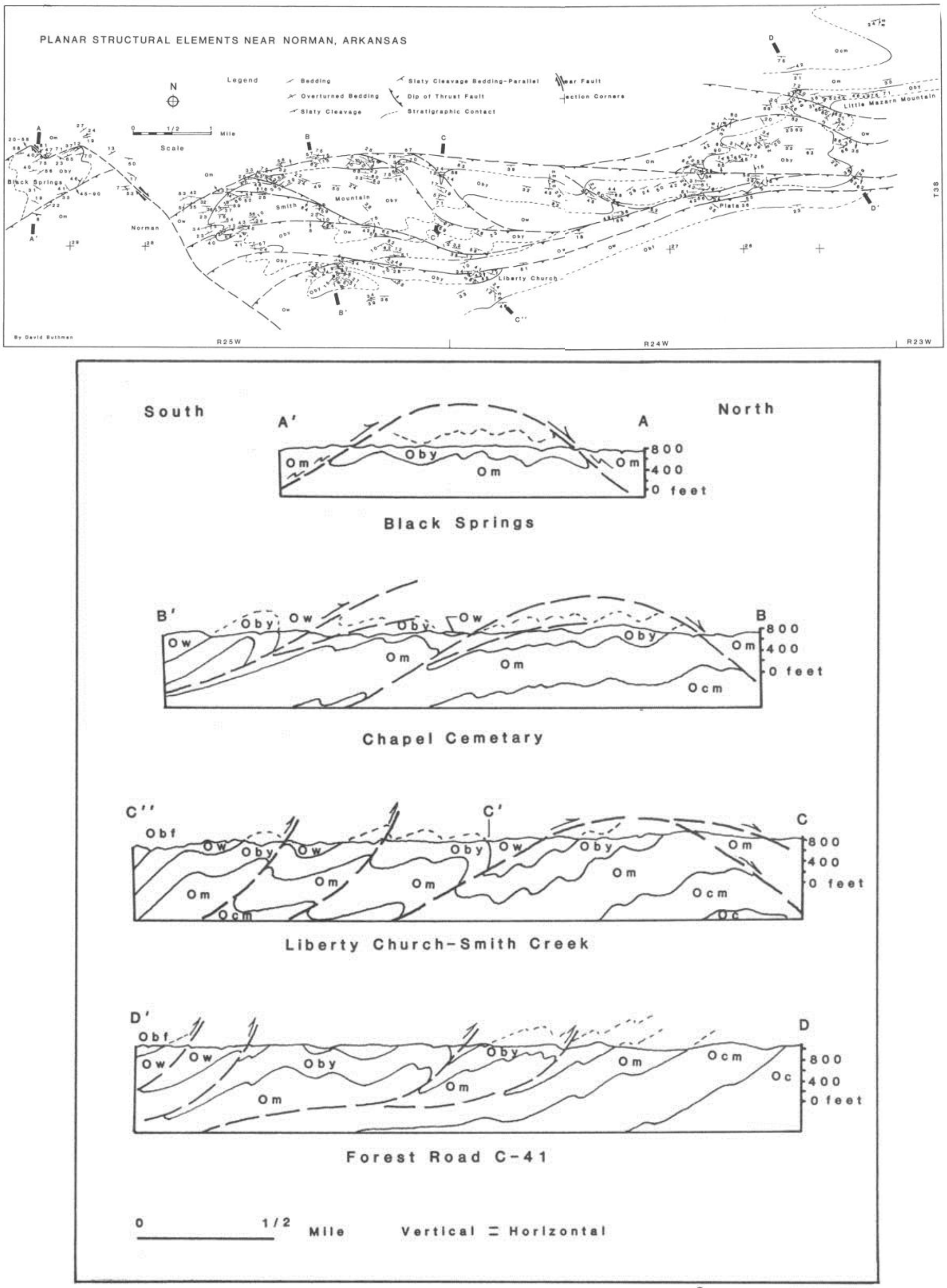


Figure 1.8. Geologic map (top) and cross sections (bottom) of the northern portion of the Caddo Gap quadrangle by Buthman (1982).

Evansin (1976) mapped the geology from Caddo Gap southward, past the town of Glenwood, including the eastern end of the Cossatot Mountains and South Fork Valley (Figure 1.9, Figure 1.10 and Figure 1.11). Most of this field mapping appears to have been concentrated in the South Fork Valley and eastern Cossatot Mountains, because very few field measurements were reported from the Caddo Mountains beyond the area adjacent to Caddo Gap (Figure 1.10). His structural analysis of the Nelson Mountain Anticline (Figure 1.9) used bedding plane attitudes (n = 25) inferred from topographic interpretation. The data suggested a vertical, east-southeast striking axial plane (102°, 90°; N78°W; 90°) with a gently plunging axis of about 07°, 102° (07°, S78°E) (Evansin, 1976).

Based on analysis of fold, fault, and fracture data, Evansin (1976) interpreted that the Caddo Mountains underwent at least two, possibly three phases of tectonic folding, but under a constant and relatively uniformly-directed compressional regime. The first was mesoscopic folding with north dipping axial planes and consistent axial plunge to the ESE at about 45°. These folds were then refolded by apparent northeast-directed compression. The estimated axial plane of this macroscopic folding was N45°W, 80°NE; this folding may be represented by the northwest-trending folds in the Arkansas Novaculite ridge between Strawn Mountain and White Mountain (Evansin, 1976).

However, the Nelson Mountain Anticline (NMA) appears to have been unaffected by this second phase of northeast-directed compression as the NMA is presently oriented about an east-west axis. Evansin suggested the NMA either formed concurrently or after the second phase of folding. This raises the question: why does the NMA have an east-west orientation while the macroscopic folds in the Novaculite to the north (Figure 1.5) trend more northwest-southeast?

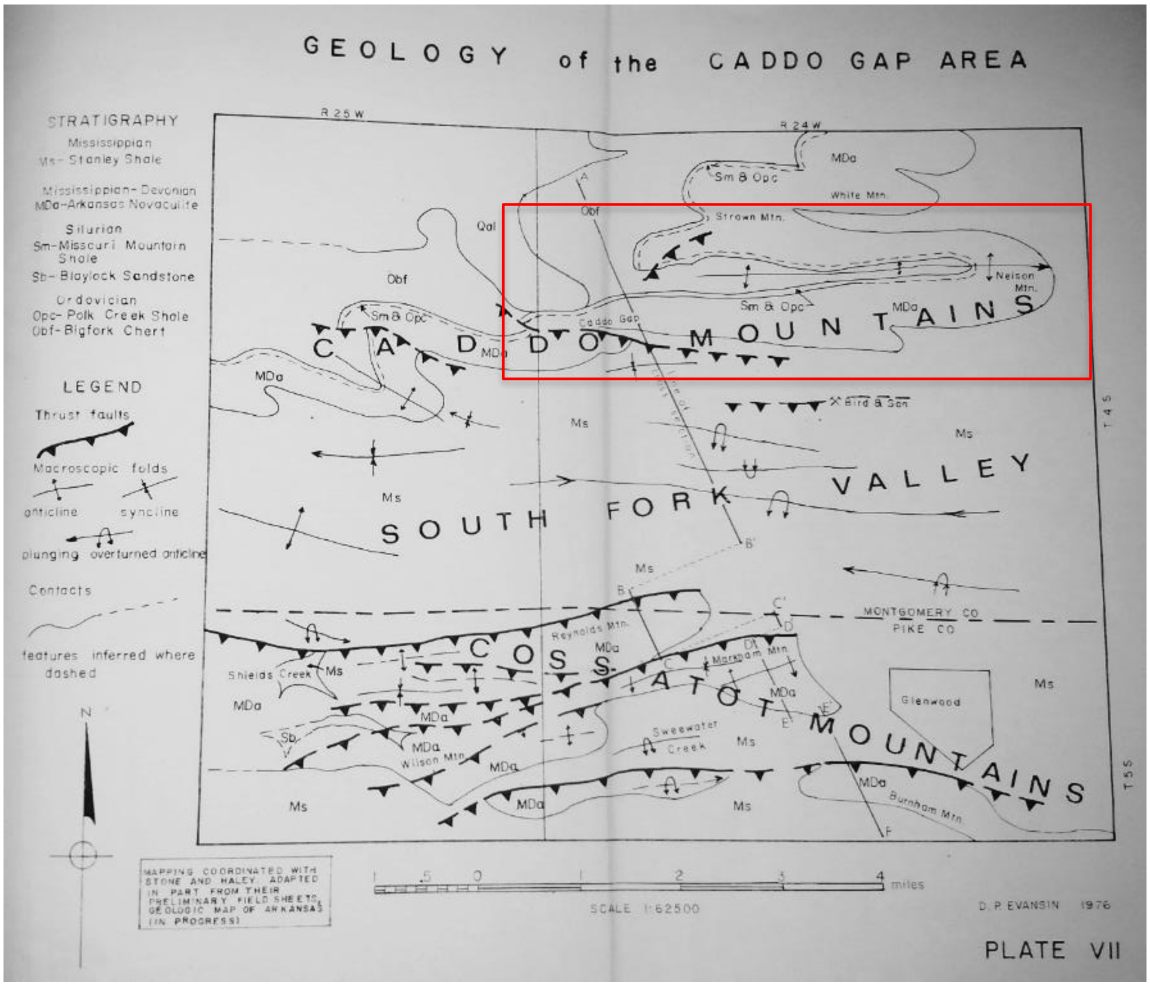


*Figure 1.9. Structural geology map (photo) of the Caddo and Cossatot Mountains between Caddo Gap and Glenwood, Arkansas (modified from Evansin, 1976). The study area of this report is shown approximately by the **red** box.*

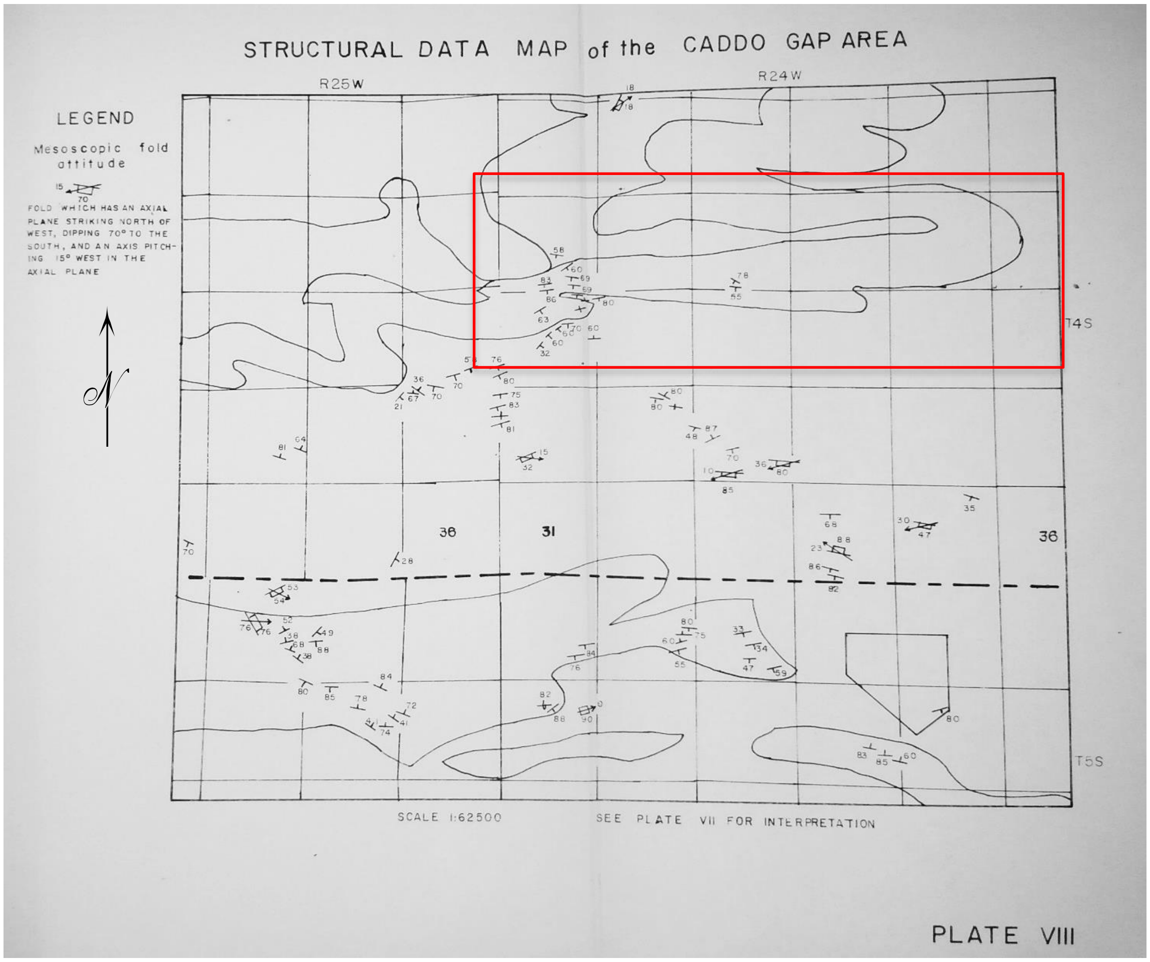


Figure 1.10. Structural data collected in the Caddo and Cossatot Mountains by Evansin (1976). The study area of this report is shown approximately by the red box.

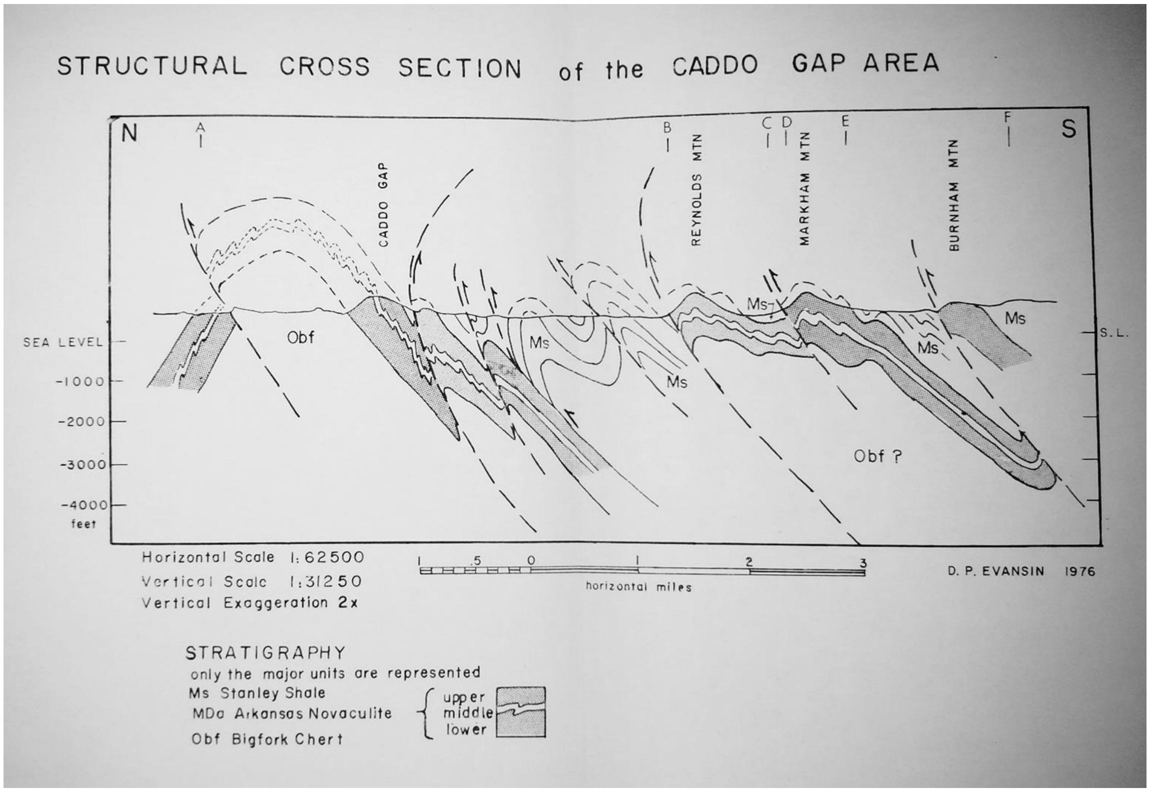


Figure 1.11. Structural cross section from Caddo Gap to Glenwood, Arkansas (from Evansin, 1976).

Sholes (1977) made a detailed stratigraphic and petrographic study of the Arkansas Novaculite across Arkansas and Oklahoma, subdividing the road cut at the Caddo Gap into 5 members: a Lower Chert and Shale member, a Lower Novaculite member, a Middle Chert and Shale member, an Upper Novaculite, and an Upper Chert and Shale member.

Zimmerman (1984) published a short paper on the Arkansas Novaculite exposures at Caddo Gap (Figure 1.12), discussing the origin of folds and faults exposed along the highway road cut. He suggested the folds in the Novaculite probably formed during a “single deformative event” as the rocks were transported northward during the Ouachita orogeny.

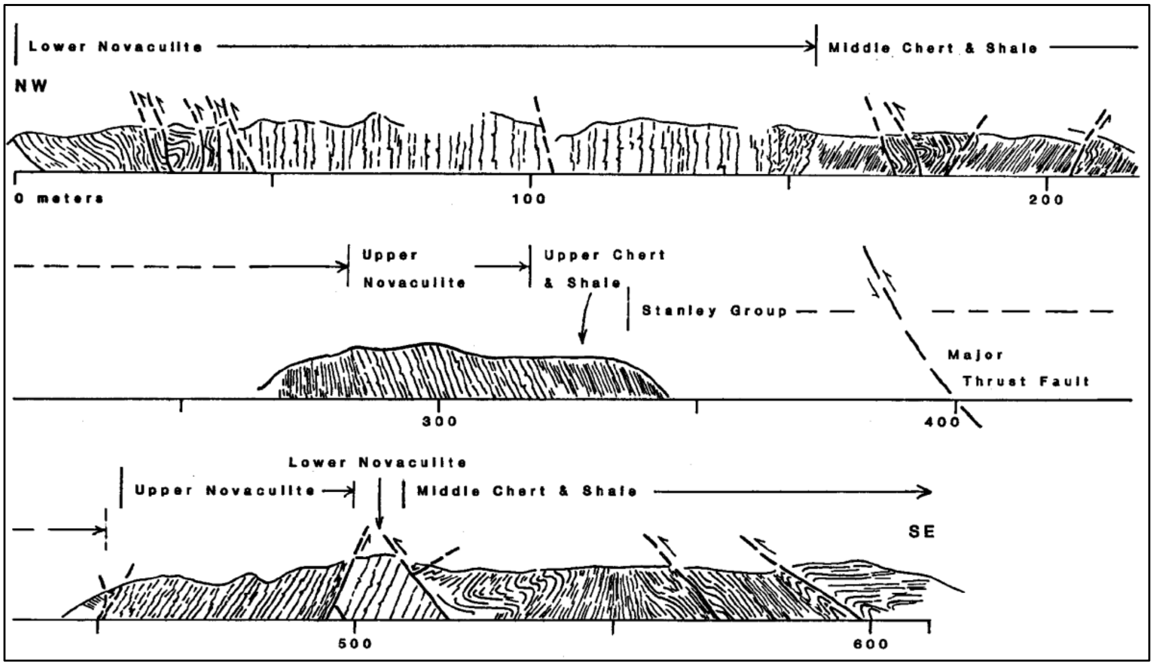


Figure 1.12. Simplified cross section of the Caddo Gap road cut through the Arkansas Novaculite. This figure was completed prior to highway construction, which altered the length but not the surface of the exposed sequence (from Zimmerman, 1984).

The study area was covered by the 1:100,000 scale geologic map of the Arkadelphia 30'x60' quadrangle (Haley et al., 2009) as shown in Figure 1.13. As mentioned previously, much of this mapping was done using interpretation of aerial photography with limited field checking (Haley and Stone, 1991). Field checking within the quadrangle was limited to a few measurements taken along major highways and roads (Figure 1.13). No field data were reported on the major Novaculite ridges or intervening valleys.

Keng (2011) collected field data on bedding, joints, folds, faults, and other structural fabrics in the Arkansas Novaculite to construct cross sections and interpret the deformational history and evolution of folds in the western Caddo Mountains near Mosquito Gap, located about 20 miles west of the study area. She interpreted north-dipping faults and south-verging folds on the southern part of the Benton Uplift as backthrusts instead of overturned fold-and-thrust structures (Figure 1.14).

Philbrick (2016) compiled a detailed geochemical study using X-ray defraction and mass spectrometry of Arkansas Novaculite samples gathered from the Caddo Gap highway road cut.

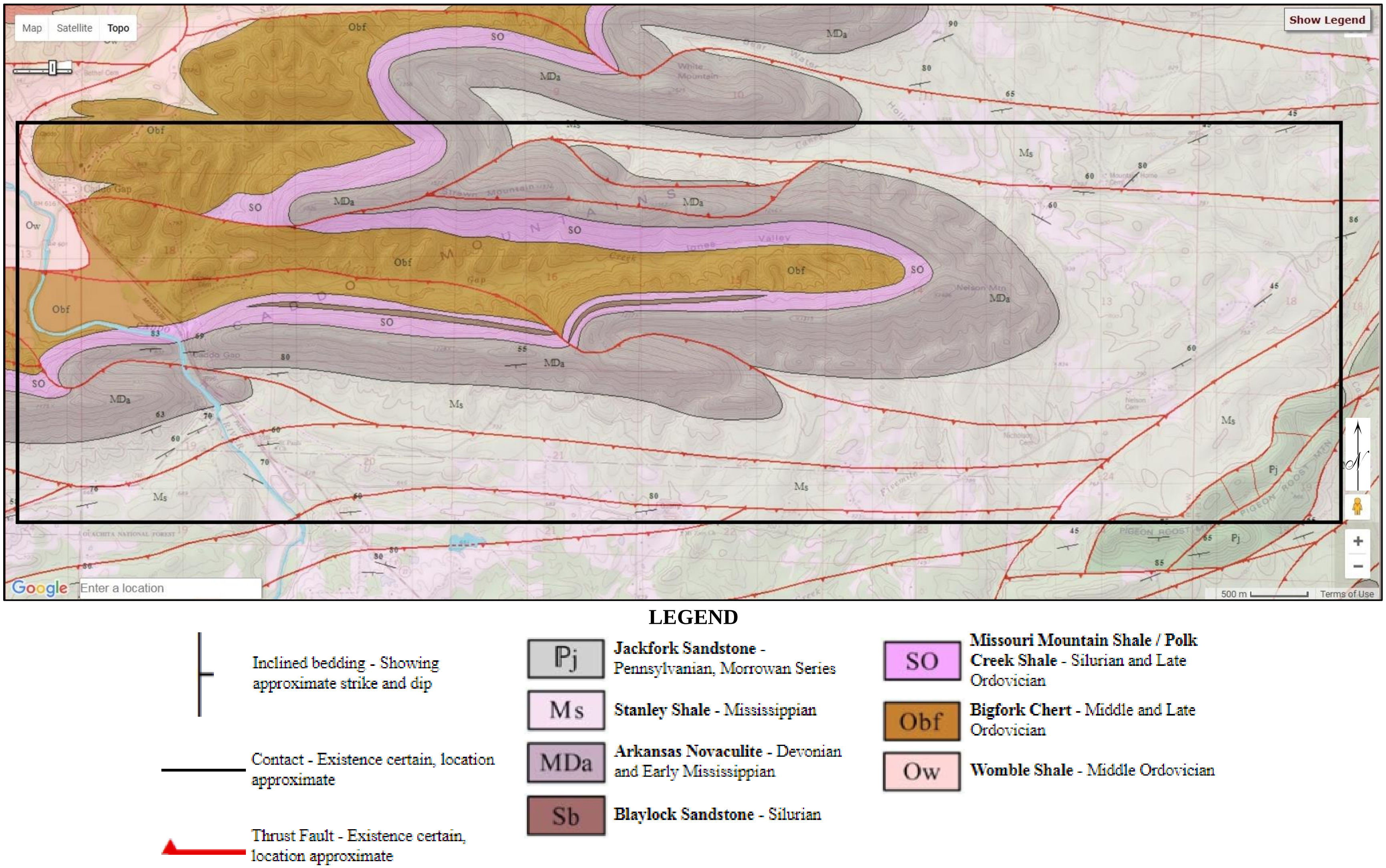


Figure 1.13. 1:100,000-scale simplified geologic map of the study area (black outline) (modified from Haley et al., 2009; Arkansas Geological Survey, 2017).

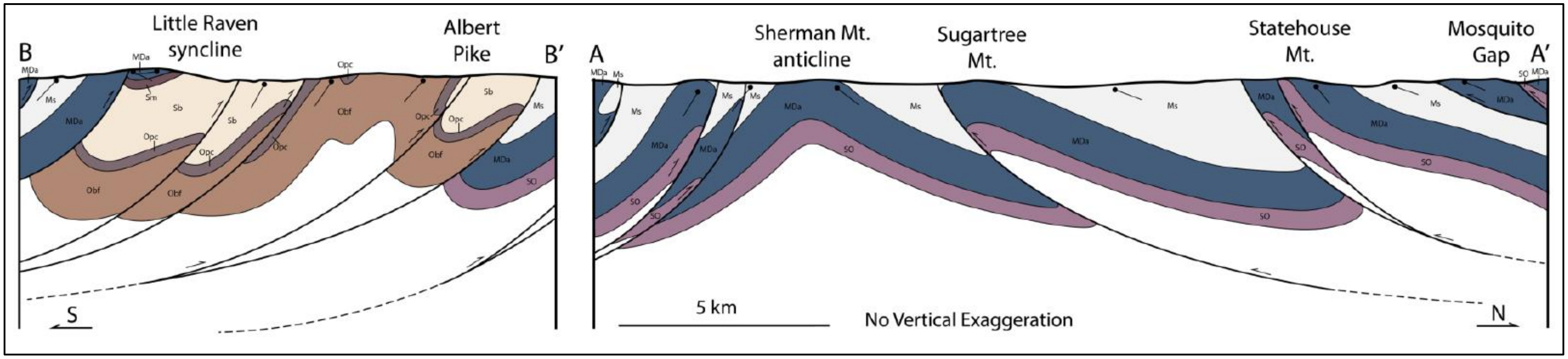


Figure 1.14. Cross section interpretation of the western Caddo Mountains near Mosquito Gap, Arkansas. The Sherman Mountain ancticline in the southern part of A-A' represents a triangle zone where vergence direction changes from south-vergent in the north to north-vergent in the south. North-dipping structures in A-A' are interpreted as south-vergent backthrusts in an accretionary wedge (from Keng, 2011).

CHAPTER 2

Stratigraphy

Introduction

The Benton Uplift is cored by rocks that range from Upper Cambrian through Lower Mississippian (Figure 2.1). These rocks are often referred to as the "Ouachita facies" as they were deposited in the Ouachita Basin, an open to restricted marine basin that existed in the early Paleozoic south of the present-day Ouachita Mountains (Lowe, 1975). The oldest rocks exposed in Arkansas, the Upper Cambrian – Lower Ordovician Collier Shale, are found in the Crystal Mountains located about 5 miles north of the study area (Haley et al., 1993; Haley et al., 2009). There are no known exposures of in-place Precambrian rocks in Arkansas.

The uplift is flanked by syn- to post-tectonic rocks of Mississippian and Pennsylvanian age. The study area is comprised of Middle Ordovician through Upper Mississippian strata (Figure 2.2). A small ridge of Lower Pennsylvanian-age rocks intersects the southeastern corner of the study area. The Arkansas Novaculite forms the bulk of the exposures in the study area due to its resistance to weathering.

Igneous rocks present in the region include Cretaceous lamprophyres near the town of Murfreesboro about 25 miles to the southwest, and the Magnet Cove intrusive complex about 45 miles to the east (Howard, 2007; Howard and Chandler, 2007). There are no igneous rocks exposed within the study area. The closest reported igneous rocks to the study area are two small, northeast-trending dikes of lamprophyre on the eastern end of Pigeon Roost Mountain (Haley et al., 2009), about 5 miles east of the study area.

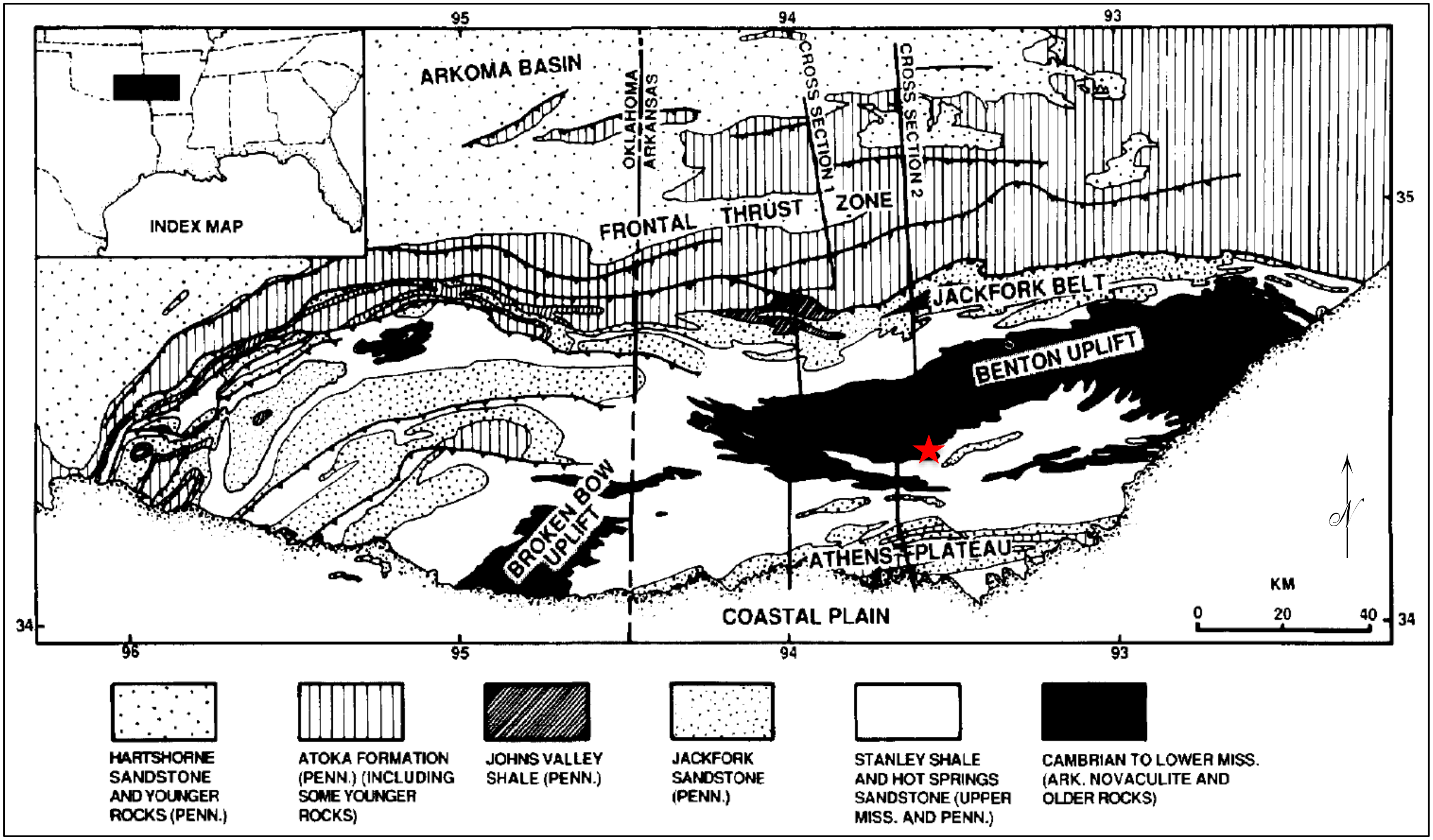


Figure 2.1. Structural provinces of the Ouachita fold belt and their associated rock units (from Blythe, 1988). Study area shown by red star.

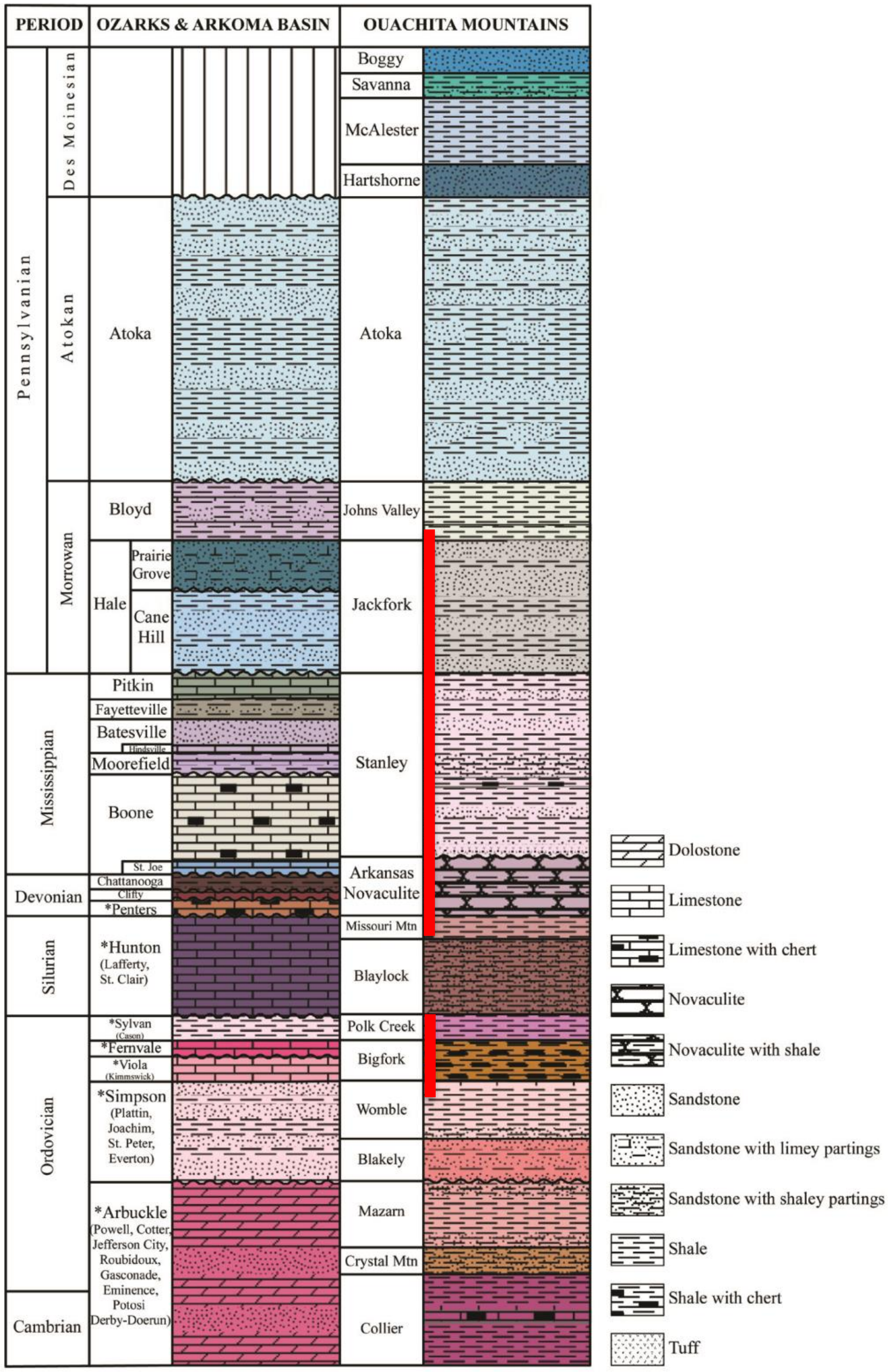


Figure 2.2. Stratigraphic correlation between the Ozark Uplift/Arkoma Basin and Ouachita Mountain regions in Arkansas (Godo et al., 2011). Red bars indicate those formations present in the study area.

The following descriptions of the rocks within the study area are primarily from Miser and Purdue (1929) and from the Arkansas Geological Survey's "Stratigraphic Summary of the Arkansas River Valley and Ouachita Mountains" website at URL http://geology.arkansas.gov/geology/strat_arkvalley_ouachita.htm.

Womble Formation

The Arkansas Geological Survey (2017) describes the Womble Formation as: "mostly black shale with thin layers of limestone, silty sandstone, and some chert. The sandstones are dark-gray, compact, fine-grained, and occasionally conglomeratic; they are generally present in the lower part of the formation. Dense, blue-gray limestones usually occur near the top of the formation in thin to medium beds. Black chert also is present as thin layers at the top of the formation. Large milky quartz veins often fill fractures in the formation. Graptolite and conodont fossils have been noted from the Womble Shale. The formation rests conformably on the underlying Blakely Sandstone and ranges from 500 to 1,200 feet in thickness; its thickness cannot be estimated exactly as the formation has been intensely deformed."

The Womble Formation is rarely exposed in the study area and was only found at exposures along the Caddo River (north of Caddo Gap) and along Bean Creek (Figure 2.3) and Gap Creek (Jones Valley), all in the western part of the study area (Figure 1.4). The base of the formation was not observed. Graptolites were observed in field samples from the study area. Thin, blue-gray limestones, with very strong effervescence to hydrochloric acid, were found in the Bean Creek exposures near the contact with the overlying Bigfork Chert. In Jones Valley, the Womble sometimes had a charcoal or soot-like texture when handled.

Figure 2.3. Womble shale beds exposed in the channel of Bean Creek (hammer for scale, Stop 255).

Bigfork Chert

The Bigfork Chert, named for its type section near the village of Bigfork in Polk County, Arkansas, consists of “thin-bedded, dark-gray, cryptocrystalline chert interbedded with varying amounts of black siliceous shale, calcareous siltstone, and dense, bluish-gray limestone. The cherts normally occur in thin to medium beds and are usually highly fractured. The interbedded siliceous shales occur in thin to thick sequences and are often pyritic. Limestones occur mostly as interbeds in the chert and typically weather to soft brown layers. Fossils are rare, but fragments of brachiopods, crinoids, sponges, conodonts, and graptolites have been reported; graptolite fauna suggest a Middle Ordovician age” (Arkansas Geological Survey, 2017).

The contact between the Bigfork Chert and the underlying Womble Shale is conformable. The contact between the Bigfork and the overlying Polk Creek Shale is also conformable, as the Bigfork gradually increases in shale thickness with a corresponding decrease in chert content (Miser and Purdue, 1929). The Bigfork in Arkansas ranges in thickness from about 450 feet in the northern Ouachitas to about 750 feet in the southern Ouachitas (Arkansas Geological Survey, 2017).

The Bigfork Chert is poorly exposed in the study area and forms hummocky hills and knobs in Jones Valley and the area surrounding Bean Creek. Only one possible limestone locality was observed within the Bigfork in the study area. The formation is often chaotically folded and deformed (Figure 2.4).

Figure 2.4. Intense folding in the Bigfork Chert along Gap Creek in Jones Valley at Stop 773 (hiking pole for scale, about 4 feet in length).

Polk Creek Shale

The Polk Creek Shale, named for exposures in Polk Creek about 10 miles west of the study area, is composed of "black, sooty, fissile shale with minor black chert and traces of gray quartzite and limestone. Graptolites are common in most of the shales in the formation and have been dated as Late Ordovician" (Miser and Purdue, 1929). The Polk Creek Shale rests conformably on the Bigfork Chert. Its thickness ranges from about 50 to 225 feet in the Ouachita Mountains (Arkansas Geological Survey, 2017).

Exposures were extremely rare in the study area. The few suspected exposures, all in stream gullies, were always highly weathered to clay and mud. Likewise, its true thickness in the study area could not be determined.

Blaylock Sandstone

The Blaylock Sandstone, named for exposures on Blaylock Mountain, consists of "fine- to medium-grained sandstone of tan, dark-gray, or greenish color, interbedded with dark-colored to black, fissile shale in the southern Ouachita Mountains. The sandstones are usually thin-bedded, but some intervals consist of fairly thick beds. The sandstones tend toward wacke with small amounts of plagioclase, zircon, tourmaline, garnet, leucoxene, and mica. The shales, which may dominate thick sequences, are usually dark-gray and micaceous" (Arkansas Geological Survey, 2017). Fossils are rare: only graptolites and a few trace fossils have been reported which were assigned an age of Lower Silurian" (Miser and Purdue, 1929). The unit rests conformably on the Polk Creek Shale (Figure 2.2). The formation ranges from as much as 1,500 feet thick in the Cossatot Mountains (Weber, 1986), but thins dramatically to the north (near the study area) where it is frequently represented by only 5 to 20 feet of olive-gray shale (Miser and Purdue, 1929; Roths, 1988; Arkansas Geological Survey, 2017).

Miser and Purdue (1929) had mapped a narrow outcrop band of Blaylock on the north side of the Caddo Mountains on the slope facing Jones Valley (Figure 1.13); however, it was not observed during this field study. According to Evansin (1976) per personal communication with Charles Stone and Boyd Haley of the Arkansas Geological Survey, these sandstones may occur near the top of the Polk Creek Shale and should be considered part of that formation. Roths (1988) also reported that the Blaylock Sandstone was absent in the Caddo Mountains near Mosquito Gap. Thus, the Blaylock Sandstone is considered absent from the study area.

Missouri Mountain Shale

The Missouri Mountain Shale, named for exposures in the Missouri Mountains about 15 miles west of the study area, is "a shale interbedded with various amounts of conglomerate, novaculite and sandstone. The shales are usually gray, green, black, or red and weather to buff, green, yellow or reddish-brown" (Arkansas Geological Survey, 2017). Originally named the Missouri Mountain Slate (Miser and Purdue, 1929), the formation has undergone regional metamorphism and has been altered to slate in most places, but may still be shale at others, as observed throughout most of the study area.

Few if any identifiable fossils have been found in the Missouri Mountain Shale. It has been assigned an age of Silurian based on stratigraphic relationships (Misch and Oles, 1956; Park and Croneis, 1969). The formation rests conformably on the Blaylock Sandstone to the south and on the Polk Creek Shale in the northern part of its outcrop range (near the study area). It reaches a maximum of about 300 feet in thickness. Miser and Purdue (1929) reported a thickness of about 50 feet at Caddo Gap.

At Mosquito Gap in the Missouri Mountains, several prospect pits were quarried into the "slate" (Figure 2.5) to test its use as roofing material, but the quality proved to be too low (Doug Hanson, personal communication, April 2016). During field mapping, several small abandoned pits dug into the Missouri Mountain Shale were discovered on the northeast side of the Caddo Gap road cut, about 200 feet due east off the highway. Here, the Missouri Mountain is more slaty and red-maroon in color like at Mosquito Gap. Abandoned mining and loadout structures were also present. No information could be found in the literature as to when this operation was active or how much material was removed, but it has been abandoned for some time. The prospect pits offer the best exposures of the Missouri Mountain Shale in the study area.

The Missouri Mountain Shale is rarely exposed elsewhere aside from occasional stream gully exposures and as float, often in overturned tree stumps. As it is poorly exposed like the underlying Polk Creek Shale, mapping the contact between the two formations is very difficult. Therefore, the Polk Creek and Missouri Mountain Shales are mapped together (label SOu) in this study as was done in previous mapping efforts (Miser and Purdue, 1929; Haley et al., 1993; Haley et al., 2009).

Figure 2.5. Missouri Mountain Shale at an abandoned quarry at Mosquito Gap, Arkansas (hammer for scale). This location is about 10 miles west of the study area.

Arkansas Novaculite

The Arkansas Novaculite overlies the Missouri Mountain Shale and is a prominent ridge former in the Ouachita Mountains because of its resistance to weathering (Figure 2.6). Novaculite is a fine-grained, hard sedimentary rock that is composed of microcrystalline to cryptocrystalline quartz; like quartz it breaks with a conchoidal fracture (Sholes, 1977; Keller et al., 1985). Numerous hypotheses have been proposed for its sedimentary origin and environment of deposition over the last 100 years (Purdue, 1909; Miser and Purdue, 1929; Park and Croneis, 1969; Sholes, 1977; Beaty, 1989; Philbrook, 2016) but this study focused on the structural history of the formation.

The Novaculite was first divided into three members consisting of lower and upper novaculite members separated by a middle chert and shale member (Miser, 1917; Miser and Purdue, 1929). Sholes (1977) refined this number to five members as shown in Figure 2.7 and described in detail the type section exposed at the Caddo Gap road cut (Figure 1.12). These members are called, in ascending order, the Lower Chert and Shale Member, the Lower Novaculite Member, the Middle Chert and Shale Member, the Upper Novaculite Member, and the Upper Chert and Shale Member. The Caddo Gap type section is approximately 900 feet thick (Sholes, 1977; Zimmerman, 1984).

Because the Lower and Upper Chert and Shale Members are poorly exposed throughout the study area, this study used the informal 3-member subdivision of the Arkansas Novaculite. The members of the Arkansas Novaculite are described in the following sections.

Lower Chert and Shale Member

The Lower Chert and Shale Member is conformable with the underlying Missouri Mountain Shale (Sholes, 1977) and is relatively thin compared with the rest of the formation. At Caddo Gap it has a thickness of approximately 23 feet, but thins to 10 feet or less regionally, and is composed of thin-bedded, lenticular chert beds with local conglomerate and quartz sandstone beds. Medium-grained, mature to supermature chert-rich quartz sandstone beds up to one half foot thick are found in the Lower Chert and Shale Member near Hot Springs, Arkansas. The chert is spiculitic, but radiolaria are rare (Sholes, 1977). This member was mapped with the Lower Novaculite Member in this study given its thinness and poor exposure in the field area.

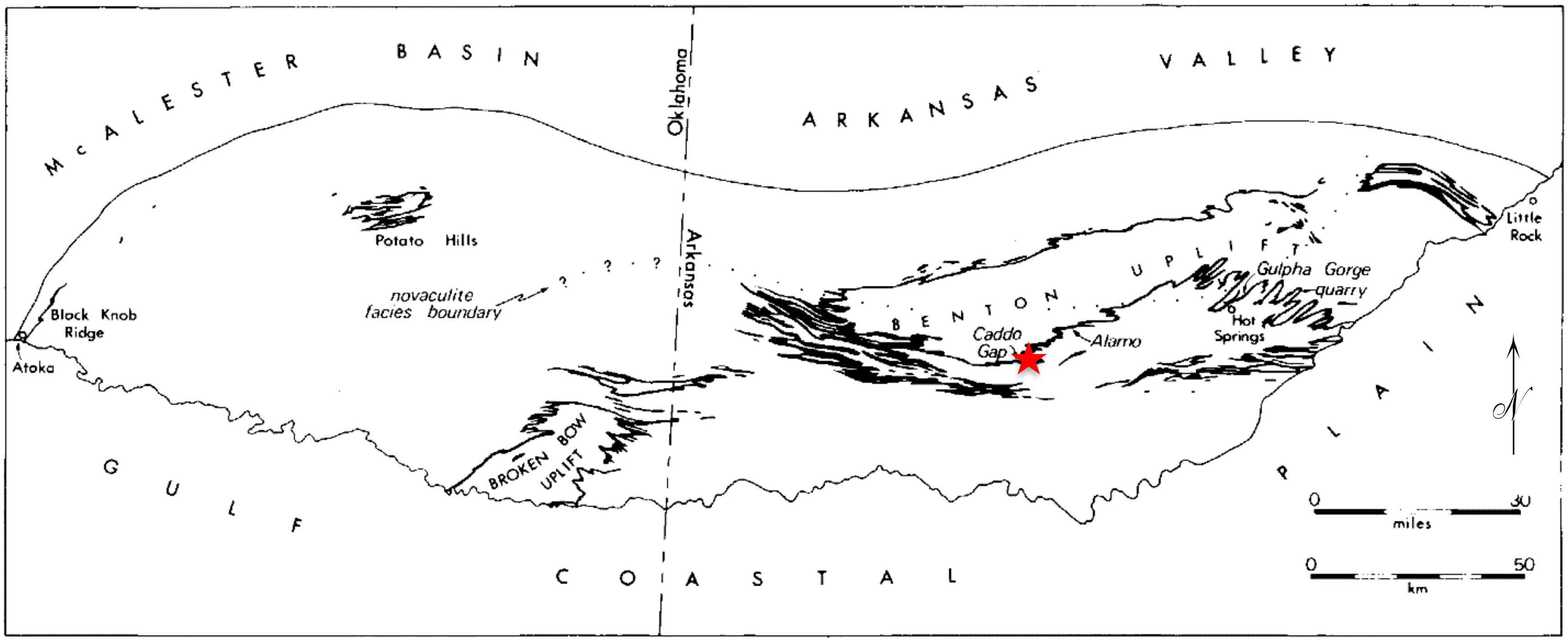


Figure 2.6. Regional outcrop map of the Arkansas Novaculite (black) in the Ouachita Mountains of Arkansas and Oklahoma (modified from Lowe, 1976). Approximately location of study area shown by ***red*** *star.*

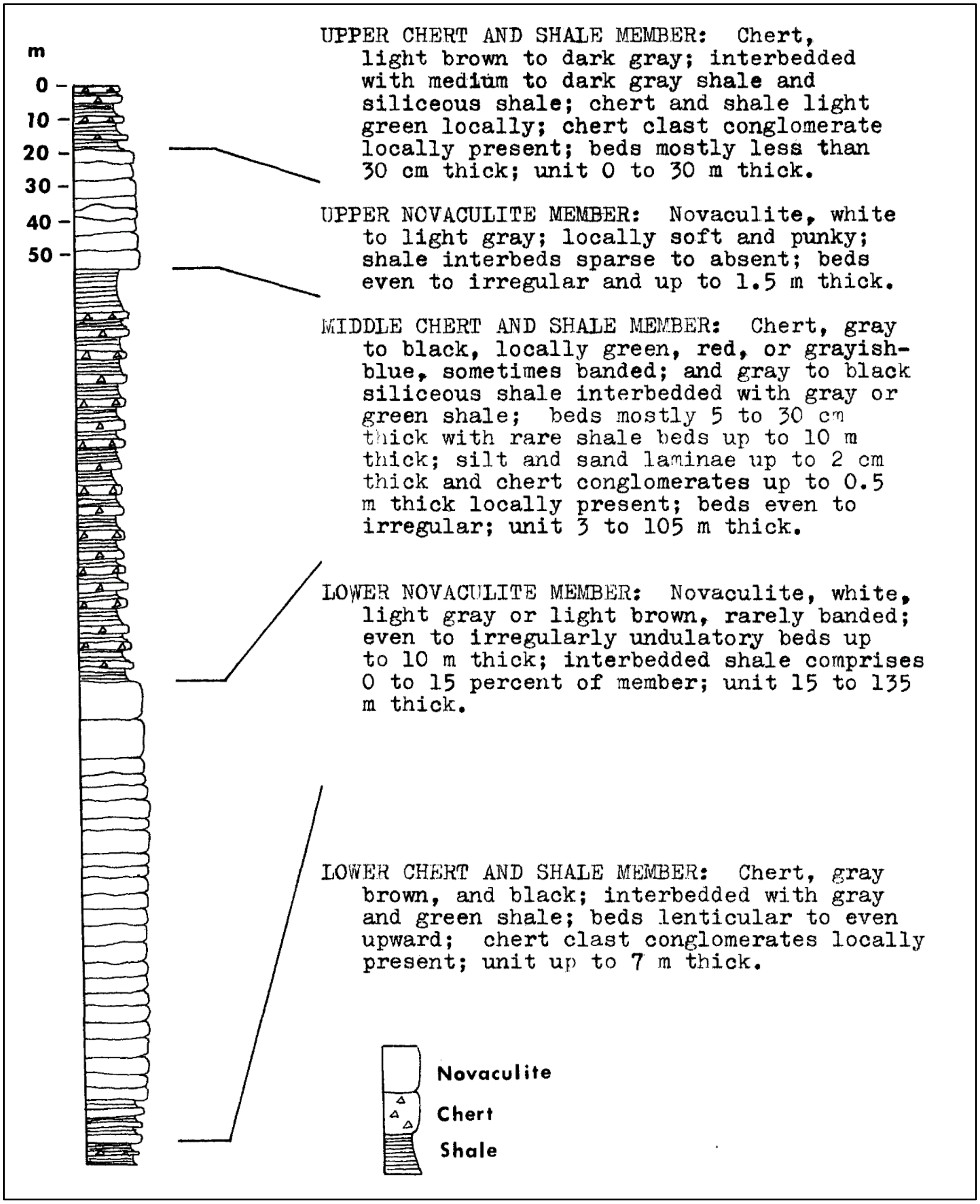


Figure 2.7. Generalized stratigraphic column of the Arkansas Novaculite, Caddo Gap, Arkansas (from Sholes, 1977).

Lower Novaculite Member

The Lower Novaculite Member is approximately 394 feet thick at Caddo Gap but varies between 115 and 443 feet across the region (Lowe, 1976). Lowe provided a detailed stratigraphic and petrographic analysis of this member in Arkansas, and subdivided the member into 5 informal beds (Figure 2.8), with the basal bed consisting of the Lower Chert and Shale Member of Sholes (1977), based on lithology and stratigraphic position of finely-laminated couplets interpreted as varves. These informal subdivisions are, in ascending order, the Chert-and-Shale subdivision, the Calcareous Novaculite, the Translucent Novaculite, the Massive Novaculite (Figure 2.9), and the Breccia subdivision (Figure 2.10). Two types of varves, terrigenous and calcareous, are present throughout the member with the calcareous variety more common in the calcareous and massive Novaculite subdivisions (Lowe, 1976).

The age of the Lower Novaculite Member has been debated as there are only rare fossils within the member. Honess (1923) found a single Devonian-age fossil specimen in the Lower Novaculite on Bog Springs Mountain in Oklahoma.

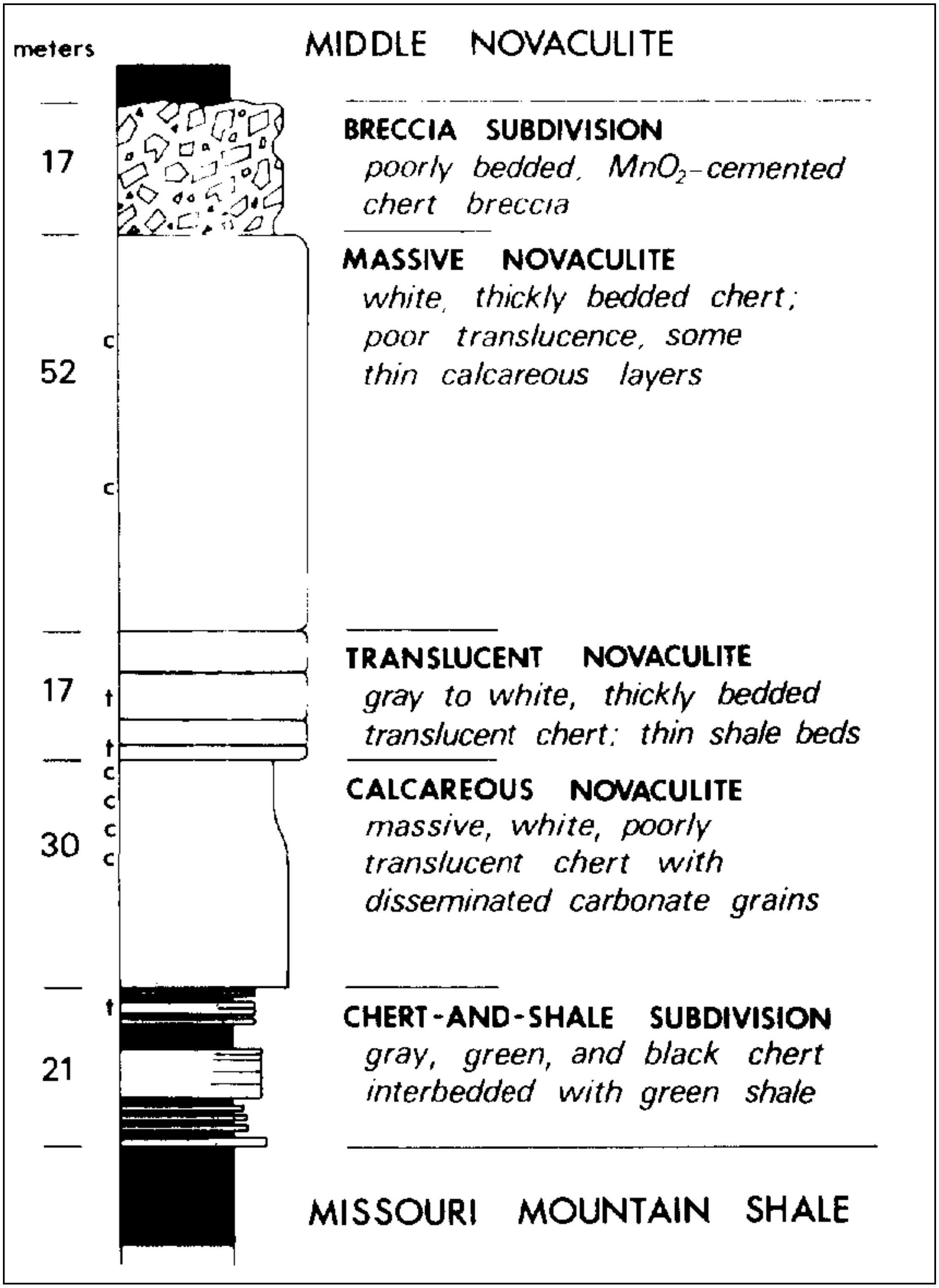


Figure 2.8. Stratigraphic subdivisions of Lower Novaculite Member at Caddo Gap, Arkansas. Shale shown in black, chert in white: t, terrigenous couplets, c, calcareous couplets (from Lowe, 1976).

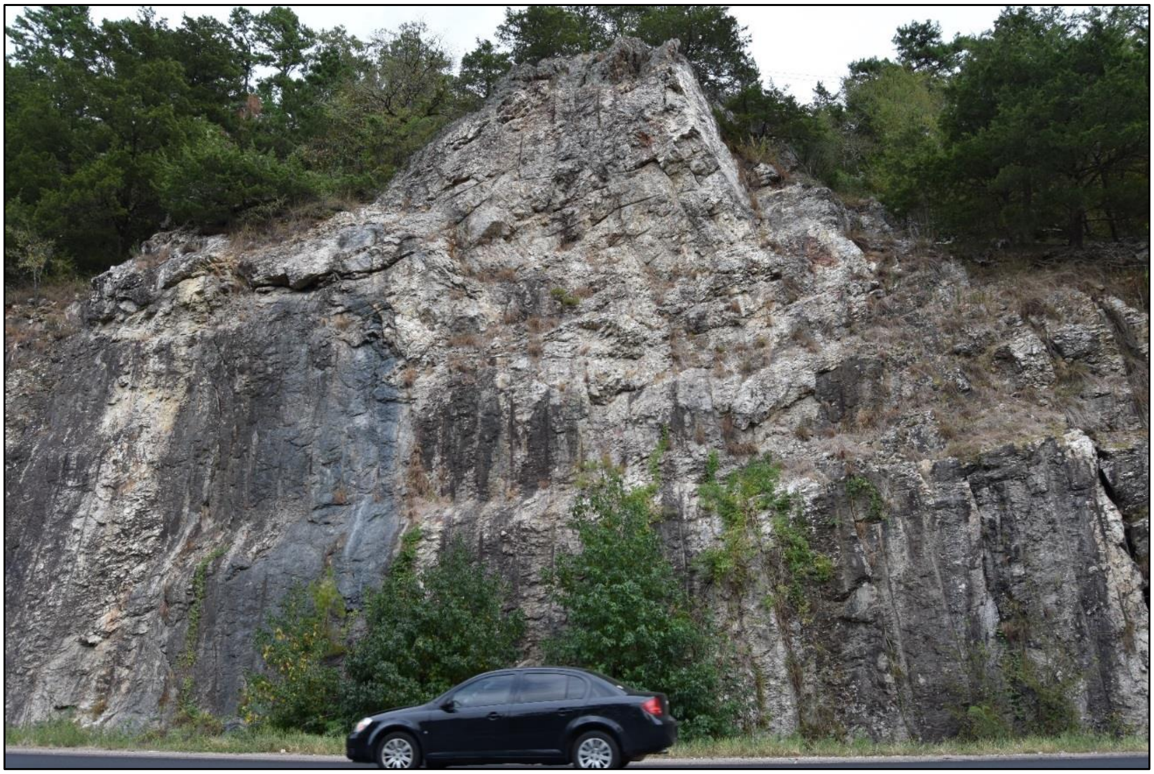


Figure 2.9. Massive ridge-forming Lower Novaculite at the northern end of the Caddo Gap road cut. Passing car for scale; north is to the left.

Figure 2.10. Contact between Lower Novaculite breccia subdivision (left) and Middle Chert and Shale Member (right) at the northern section of the Caddo Gap road cut. North is to the left.

<u>*Middle Chert and Shale Member*</u>

The Middle Chert and Shale Member is about 360 feet thick at the Caddo Gap road cut (Figure 2.7) and is composed of alternating black, siliceous, organic clay-rich shale and thinly bedded (1 to 6 inches), argillaceous, radiolarian-bearing chert (Park and Croneis, 1969). Most beds are less than 1 foot thick (Figure 2.10), although shale beds up to 30 feet thick are present locally (Sholes, 1977). The chert beds are predominately gray to black in color, but may be green, red, or gray-blue locally. The Middle Member thins towards the west in Arkansas. Rounded to well-rounded silt and sand quartz laminations up to 4 cm thick are found in the Middle Member, and these may display sedimentary structures such as cross-laminations, cross-bedding and grading (Park and Croneis, 1969;

Lowe, 1977; Sholes, 1977). Conglomerates of coarse sand to fine gravel chert clasts in beds up to 1.5 feet thick are also found in the Middle Member. The black shales and chert are indicative of their high organic (sapropelic) carbon content (Lowe, 1977). Radiolaria ghosts, sponge spicules, and non-siliceous spore capsules are abundant in the Middle Member. Hass (1951) placed the Devonian-Mississippian boundary about 28 feet below the top of the Middle Chert and Shale Member.

Sholes (1977) reported that conodonts from the Middle Member are age-equivalent to conodonts from the Woodford and Chattanooga Formations to the west and north, respectively, which are interpreted to be marine shales. Sholes suggested the environment of deposition for the Middle Member was a deep marine basin under anoxic conditions. Lowe (1977) interpreted the alternating shale and chert layers with their grading, cross-lamination, and flat-lamination structures as marine turbidites.

The Middle Chert and Shale Member displays a number of folds in exposures along the Caddo Gap road cut (Figure 1.12; Figure 2.11). The member is poorly exposed in the field as it is highly fractured and contains a larger percentage of shale. It is most often observed in stream channels, cut banks and abandoned logging roads.

Figure 2.11. Faulted and folded Middle Chert and Shale beds at the southern end of the Caddo Gap road cut on Highway 8 (Stops 3-4). Note the intense folding and deformation within this member compared with the parallel planar bedding shown in Figure 2.10. Northwest is to the left.

Upper Novaculite Member

The Upper Novaculite Member (Figure 2.7) is about 118 feet thick at the Caddo Gap road cut (Evansin, 1976; Sholes, 1977) but reaches a maximum thickness of 180 feet at Hot Springs, Arkansas. It consists of white to light grey, generally massive, radiolaria-bearing beds up to 5 feet thick (Figure 2.12). Shale interbeds are especially sparse and sedimentary structures are rare. Sponge spicules and pellets are present locally (Sholes, 1977). It varies in thickness regionally, but overall it thins rapidly to the north and south, and gradually to the west. Abundant carbonate rhombs and cavities are present in the Upper Novaculite and X-ray investigation of the carbonate component has shown it is commonly rhodochrosite (Park and Croneis, 1969). The Upper Novaculite is known for its relatively higher carbonate content relative to the rest of the formation. Weathering dissolves the carbonate and forms a tripolitic texture often seen in surface exposures that resembles pumice (Godo et al., 2011); this characteristic significantly aided in identifying the member during field mapping. The Upper Novaculite is also famous for the production of whetstones, especially in the area around Hot Springs (Evansin, 1976; Sholes, 1977).

The Upper Novaculite Member, because it is more resistant to weathering than the underlying Middle Chert and Shale Member, often forms subtle flatirons or knolls (Figure 1.5) where it dips moderately (30 to 60 degrees). Flatiron development is much less pronounced where dips exceed 70 degrees as the Lower Novaculite Member provides more topographic control at steeper dips.

Figure 2.12. Upper Novaculite beds (with prominent bedding-parallel slickenlines) on the north limb of Nelson Mountain Anticline (Stop 584). Brunton for scale.

Upper Chert and Shale Member

The Upper Chert and Shale Member (Figure 2.7) is about 50 feet thick in Arkansas and increases in thickness westward (Sholes, 1977). It is comprised of interbedded gray to brown chert and gray shale, with shale generally making up 50 percent or more of the member, especially as it grades upward (conformably) into the siliceous shales of the overlying Stanley Group. Beds are typically less than 1 foot thick. Radiolaria are abundant (Sholes, 1977).

Sholes (1977) reported that chert conglomerate beds occur sporadically at the top and upper part of this member and are laterally discontinuous, and therefore are not a reliable marker bed. However, numerous locations of float and in-place outcrops of angular, poorly sorted, coarse sand to coarse pebble chert conglomerate beds, up to 6 feet thick near the Novaculite-Stanley contact were found during field mapping (Figure 2.13). This may indicate the conglomerate beds are more laterally continuous than once thought, and may represent an unconformity between the Novaculite and Stanley Group.

Figure 2.13. Black, 1-2 ft thick, medium to coarse pebble chert conglomerate on north limb of Nelson Mountain Anticline (Stop 675). Hammer for scale.

Stanley Shale

The Stanley Shale is composed of dark gray to black shale interbedded with fine-grained siltstone and sandstone (Figure 2.2). A sandstone member, the Hot Springs Sandstone, is found near the base of the sequence; it is up to 200 feet thick in the area around Hot Springs but thinner elsewhere (Arkansas Geological Survey, 2017). An equivalent thin conglomerate or breccia occurs at the base of the unit in many other places. This breccia, discussed previously, was observed in place at several locations in the study area, and often as float in streams and creek beds near the break in the slope.

Stratigraphically minor amounts of tuff, chert, bedded and vein barite, and conglomerate have also been noted in various parts of the sequence throughout the Ouachita Mountains. Silty sandstones in units other than the Hot Springs Sandstone Member of the Stanley Shale are normally found in thin to massive beds separated by thick intervals of shale. The tuffs (Hatton Tuff Lentil and others) are generally restricted to the lower part of the Stanley Shale (Arkansas Geological Survey, 2017); these are best developed in southeastern Oklahoma and western-most Arkansas. Shaulis et al. (2012) age dated the stratigraphically-lowest tuff in the Stanley, the Beaver's Bend Tuff, at 328.5±2.7 Ma.

The true thickness of the Stanley Formation is unknown due to intense folding, faulting, deformation, and post-tectonic erosion. Estimates have varied from 3,500 feet to over 10,000 feet (Arkansas Geological Survey, 2017). In the study area, it is found primarily in the valley areas on the south, east, and north of the Nelson Mountain Anticline. Exposures are limited to road cuts, creek beds, and steep cut banks.

Jackfork Sandstone

The Pennsylvanian-age Jackfork Sandstone is only present within the southeastern corner of the study area where it forms Pigeon Roost Ridge (Figure 1.4). This topographic feature extends northeast and southwest into the Bonnerdale and Glenwood quadrangles, respectively (Figure 1.5). Haley and Stone (1994) described the Jackfork as "thin to massive-bedded, fine to coarse-grained, brown, tan, or bluish-gray quartzitic sandstone with subordinate brown silty sandstones and gray-black shale." The Jackfork is conformable with the underlying Stanley Shale and ranges in thickness from 3,500 to 6,000 feet (Arkansas Geological Survey, 2017).

As it only forms a sliver of the study area, and the larger portions of Pigeon Roost Ridge lie outside the field area, it was only mapped at reconnaissance scale in this study. The Jackfork was observed at Stops 939 and 940, about 2,000 feet west of Caddo Pond on the north side of Caddo Pond Road. Bedding here strikes between N38°E and N45°E and dips moderately (43° to 61°) to the southeast. The Jackfork consisted of brown (weathered) to dark gray (fresh), very hard, quartzitic, moderately sorted, very fine grained quartz sandstone.

CHAPTER 3

Regional Geology

Introduction

The Late Precambrian to Early Cambrian breakup of the supercontinent Rodinia (Figure 3.1) left crustal weaknesses and a series of promontories and embayments (basins) along the southern margin of Laurentia which would influence later tectonic events (Thomas, 2011). Passive margin conditions developed in the region by the Late Cambrian and persisted through the Devonian.

In the Mississippian, a compressional event began along the southern margin of Laurentia as the Iapetus Ocean closed and exotic landmasses were accreted to converging continents. This event culminated with the Ouachita orogeny, a continent-continent collision of Laurentia with northern South America, in the Middle to Late Pennsylvanian during the assembly of Pangea. The resulting arcuate Ouachita Mountains (Figure 3.2) were superimposed on the irregular southern margin of Laurentia, forming complex structures on both regional and local scales. The Ouachita Mountains extended through present day Alabama, Arkansas, Oklahoma, northern Louisiana, east Texas, and into west Texas as the Marathon Fold Belt (Figure 3.2).

During the breakup of Pangea in the Mesozoic, the Ouachita hinterland underwent subsidence due to extensional tectonics and the mountain belt was subsequently eroded and, in some areas such as east Texas, buried. Surface exposures of the orogen are now limited to the Ouachita Mountains of west-central Arkansas and southeastern Oklahoma (Figure 3.2) and in the Marathon Uplift of west Texas.

The rest of the Ouachita orogenic belt, including the entire hinterland, is buried under Gulf Coastal Plain sediments of Cretaceous and Tertiary age in eastern Texas, northern Louisiana, and southern Arkansas (Arbenz, 1989). Subsurface information, primarily from oil, gas, and minerals exploration and geophysical surveys, is crucial to understanding the buried segments of the Ouachita orogen. The Sabine and Monroe basement uplifts in the subsurface of northern Louisiana may represent remnant parts of the buried Ouachita hinterland (Viele and Thomas, 1989; Ewing, 2009).

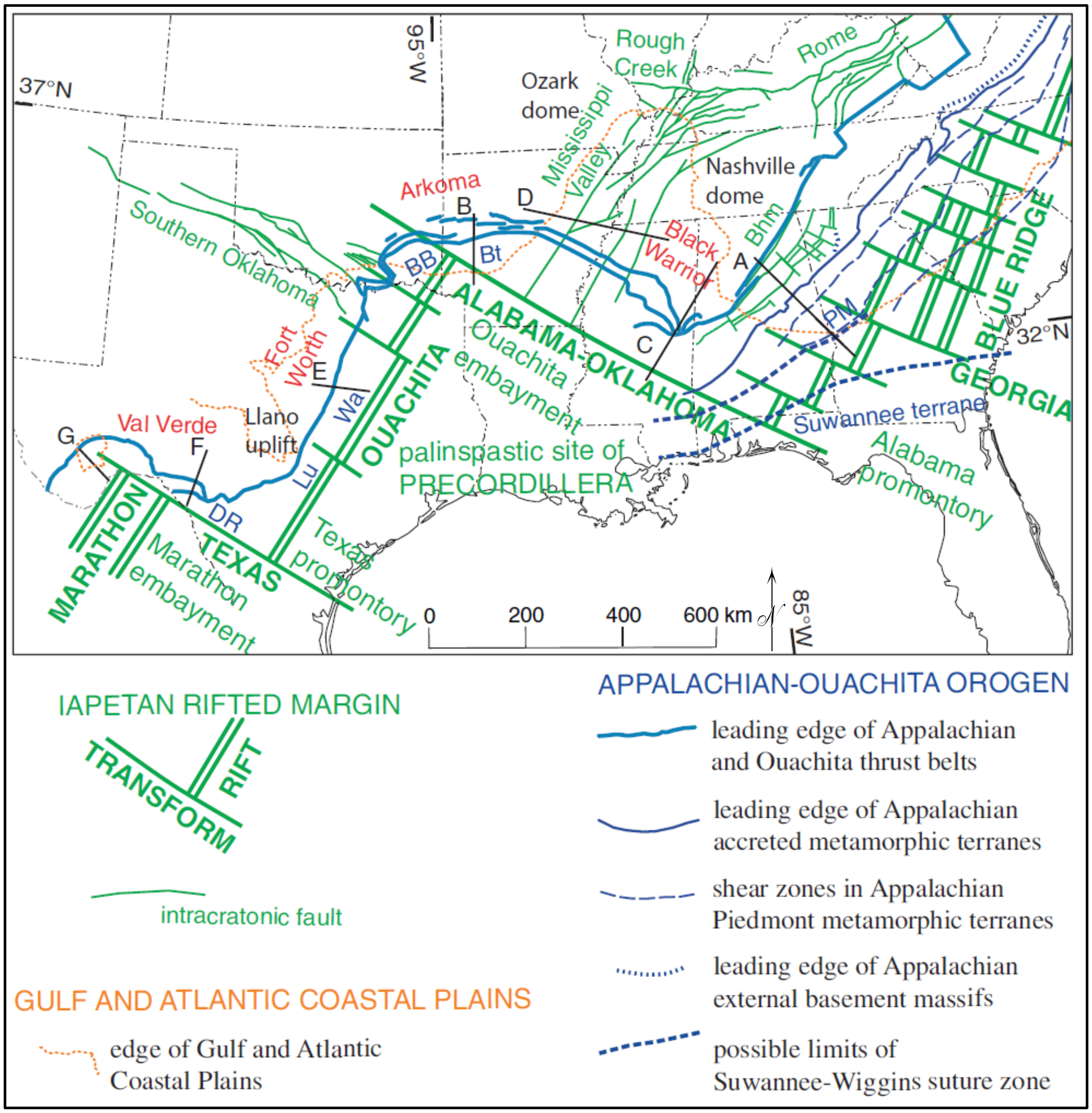


Figure 3.1. Palinspatically-restored Iapetan rifted margin of southern Laurentia, synrift intracratonic basement faults, and leading edges of superimposed Ouachita and Appalachian thrust belts (modified from Thomas, 2011). Note the similarity of the Late Paleozoic Ouachita thrust belt trends with respect to the Late Precambrian-Early Cambrian rift structures.

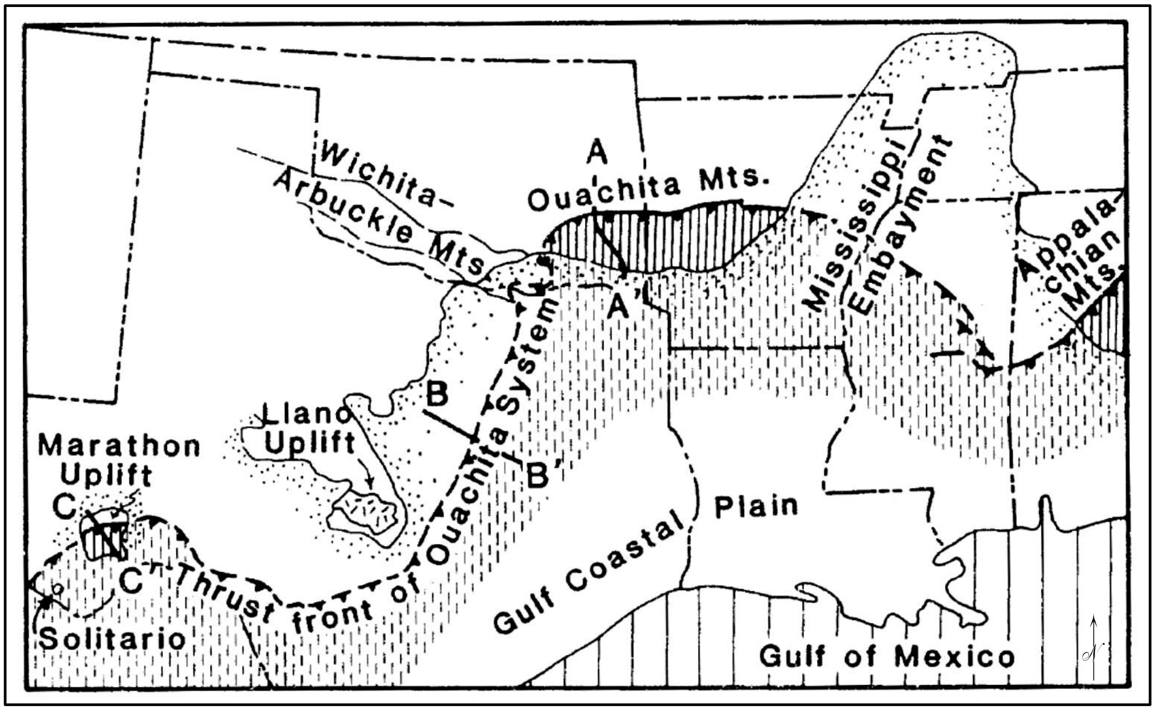


Figure 3.2. Outcrop and subsurface trends of the Ouachita orogen from Alabama to west Texas (from Arbenz, 1989). Small dot patterns: northern margin of Cretaceous-Tertiary cover; tight vertical lines pattern: outcrop regions of the Ouachita system; dashes: subcrop region of Ouachita system.

Precambrian History

It has been postulated that in the Early Neoproterozoic (approximately 1 Ga to 750 Ma) all or most of the continents came together and formed a large supercontinent called Rodinia. The Grenville (1.1 to 1.0 Ga) basement rocks of eastern and southern Laurentia are thought to have been accreted to Laurentia along convergent boundaries with other continents during assembly of Rodinia. These rocks ultimately formed the basement rocks for much of the Ouachita Mountains (Figure 3.3; Figure 3.4).

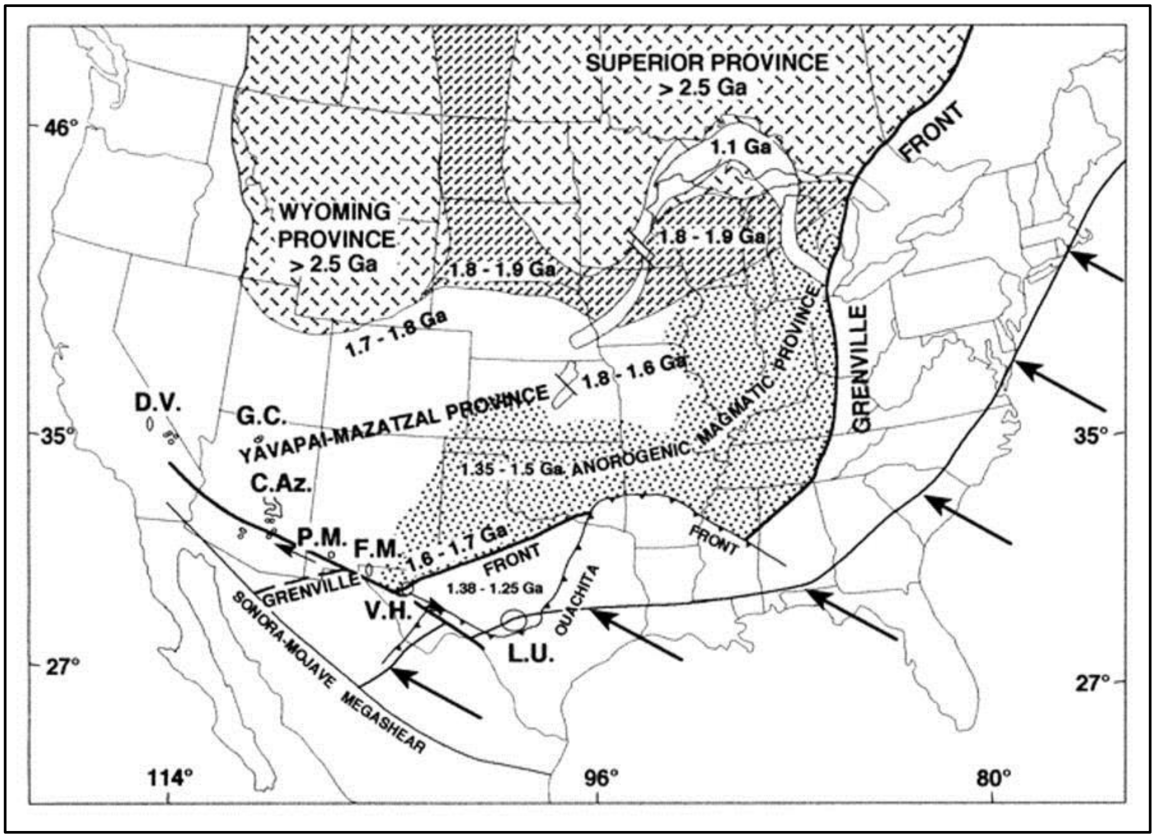


Figure 3.3. Precambrian basement-age provinces of Laurentia outlining the Grenville orogenic front. Location of Mesoproterozoic exposures at Llano (L.U.), Van Horn (V.H.), and Franklin Mountains (F.M.) in Texas are shown in relation to the Grenville orogenic belt (from Bickford et al., 2000).

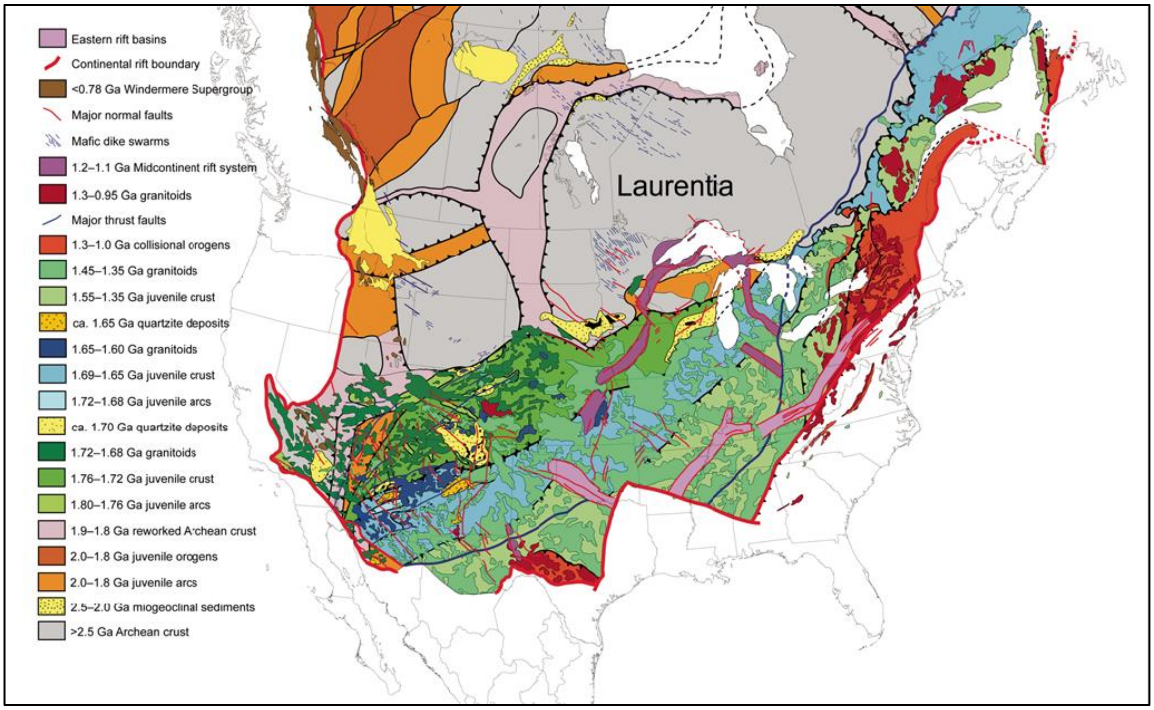


Figure 3.4. Map of Laurentia basement rocks and their configuration at the time of breakup of Rodinia (from Whitmeyer and Karlstrom, 2007).

Hoffman (1997) provided a general overview of the suspected orogens and his interpretation of the Rodinia plate configuration (Figure 3.5). The Grenville province rocks were accreted to the Laurentia craton by collision with the western margin of the Amazonia and Plata cratons (present-day South America). The Kalahari craton (present-day South Africa) possibly collided and sutured with the southern Laurentia margin. The Amazonia-Plata craton of South America is flanked by Grenville-age orogenic and plutonic rocks (Hoffman, 1997). Li et al. (2008) proposed a similar plate configuration for Rodinia, showing the Plata and Amazonia cratons had adjoined with the present-day southern and eastern margins of Laurentia, respectively.

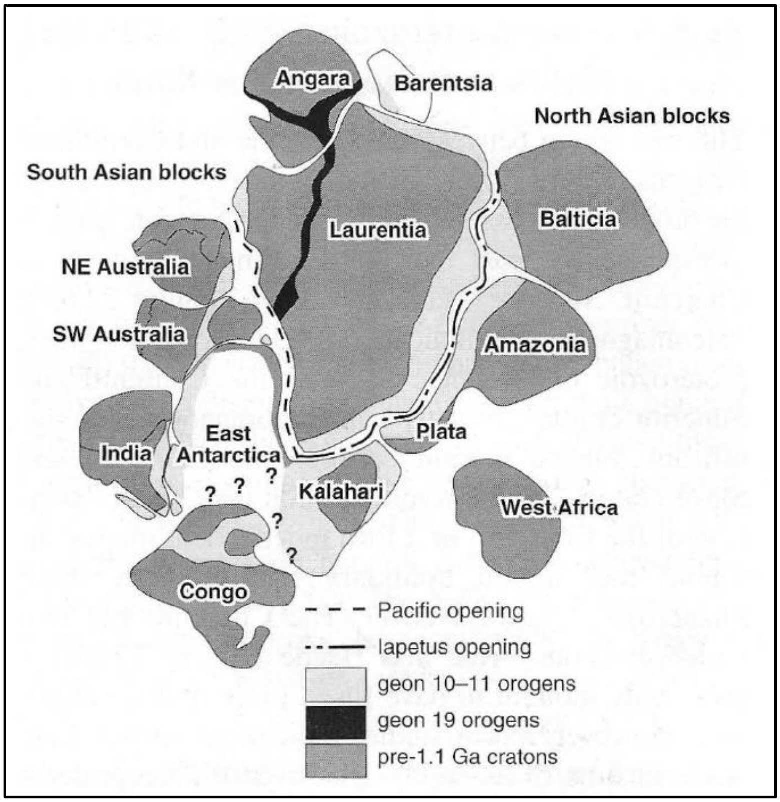


Figure 3.5. Hypothetical plate reconstruction of Rodinia proposed by Hoffman (1997).

As shown in Figure 3.3 and Figure 3.4, it is possible the formation of Rodinia and the associated Grenville orogeny formed structural trends that would later influence the breakup of Rodinia, which would in turn influence the geographic trends of the Ouachita orogen (Figure 3.2). However, Rodinia plate configurations are often a contentious and debated subject because exposures of Grenville-age rocks are rare as they are often deeply buried under the Phanerozoic sedimentary cover. In addition, numerous tectonic, metamorphic, and thermal events that followed in the Late Precambrian and throughout the Phanerozoic have overprinted the original Grenville-age structures.

Late Precambrian to Cambrian

Evidence for the breakup of Rodinia (Hoffman, 1997; Thomas, 2011) suggests Rodinia started to rift apart around 750 Ma. Rifting of the Laurentia craton, away from what would become the small supercontinent of Gondwana, progressed in a step-wise geometry along or near the Grenville suture zone. Age-dating of syn-rift and post-rift rocks indicates that rifting along the present-day Appalachians, and possibly the Marathon region of west Texas (Figure 3.2), began in Late Precambrian and a passive margin had developed in these areas by Early Cambrian (Thomas, 1991). Rifting shifted across the southern margin of Laurentia via large transform faults such as the Alabama-Oklahoma transform (Figure 3.1). Extension along the Ouachita rift zone and associated transform faulting along the Alabama-Oklahoma transform in the study area began later, starting in the Early Cambrian (~ 525 Ma), based on age-dating of igneous syn-rift rocks along the Southern Oklahoma Fault System (Thomas, 1991; Thomas, 2011).

A passive margin developed in the central part of the Ouachita rift by Late Cambrian after the Ouachita spreading ridge had moved far offshore into the opening Iapetus Ocean (Figure 3.6) (Thomas, 2011; Blakey, 2013). The right-stepping margin formed by the system of rifts and transform faults left a series of promontories (areas of continental crust that projected ocean-ward along the rifted margin) and embayments (ocean basins).

As a result, the southern margin of the Alabama promontory consisted of a continent-ocean, transform-style margin of thick continental crust juxtaposed younger, thinner oceanic crust that likely had important influence on the structural evolution of the

Ouachita orogeny in the Late Paleozoic (Thomas, 1991). The Ouachita embayment was the major depositional basin for the Ouachita facies rocks that would later be uplifted and transported northward during the Ouachita orogeny.

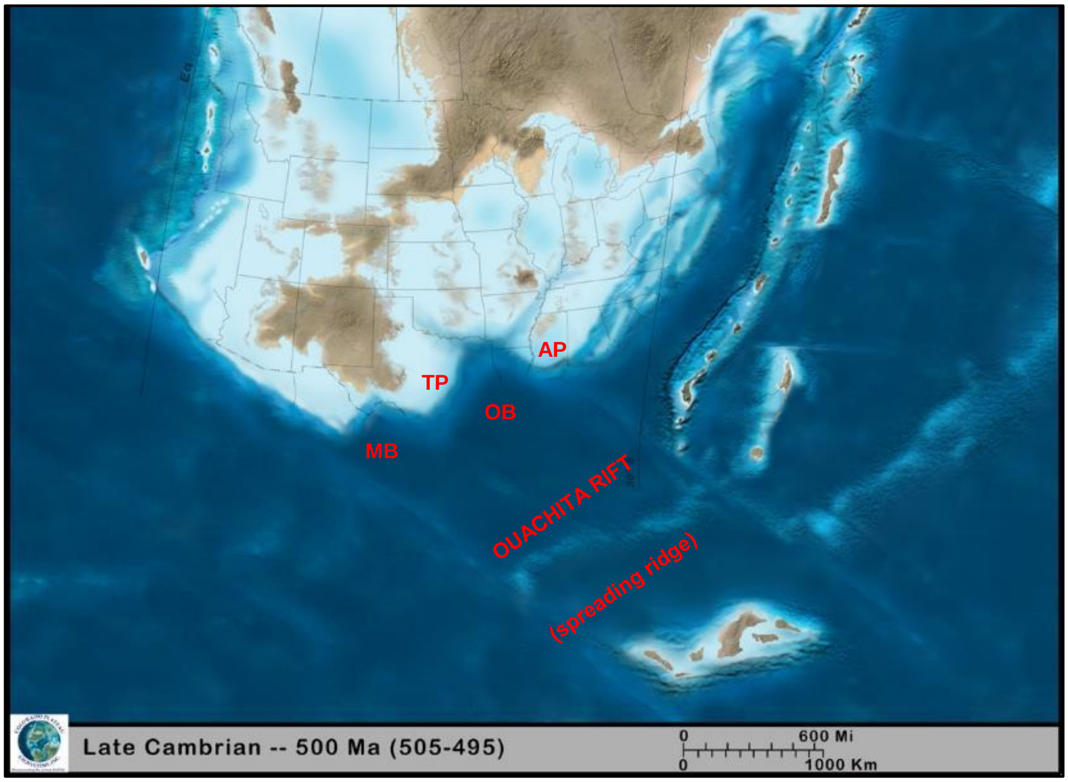


Figure 3.6. Late Cambrian paleogeography of southern Laurentia showing areas of continental shelf deposition (AP - Alabama Promontory; TP - Texas Promontory) and ocean basins (OB - Ouachia Basin; MB - Marathon Basin) (modified from Blakey, 2013).

Late Cambrian through Devonian

Following rifting, thermal subsidence coupled with marine transgressions led to continental shelf and slope environments on the Texas and Alabama promontories, dominated largely by carbonate facies, while the Ouachita and Marathon basins would provide accommodation space for marine sediments (Figure 3.6). Passive margin sedimentation and deposition continued through much of the Early Paleozoic. In the study area, the pre-orogenic continental shelf and slope strata are referred to as the "Arbuckle facies" and the marine strata of the Iapetus Ocean as the "Ouachita facies." A generalized correlation chart is shown in Figure 3.7.

The oldest recognized sedimentary unit of the Ouachita facies in the Ouachita Mountains is the Late Cambrian to Early Ordovician Collier Shale. Miser and Purdue (1929) were only able to recognize the top 200 feet of the Collier in surface exposures. Its base or any older, underlying sedimentary rocks have not been identified even in deep exploration wells such as the Weyerhaeuser 22-1 well which was drilled to 19,000 feet in the Broken Bow uplift (Allison et al, 2012).

Ordovician strata in the Ouachita Mountains are represented largely by the Mazarn, Blakely, Womble, and Bigfork Chert formations (Figure 2.2). The Mazarn and Womble Formations are dominated by shale with thin sandstone and limestone lenses; Buthman (1982) interpreted these as deep submarine fans with rapidly-deposited turbidites. The Blakely Sandstone has a large fraction of shale but with a higher occurrence of sandstone beds compared with the Mazarn and Womble Formations. Buthman (1982) also interpreted the Blakely as a submarine fan but with a greater influx of sandstone debris flows or watery slide deposits.

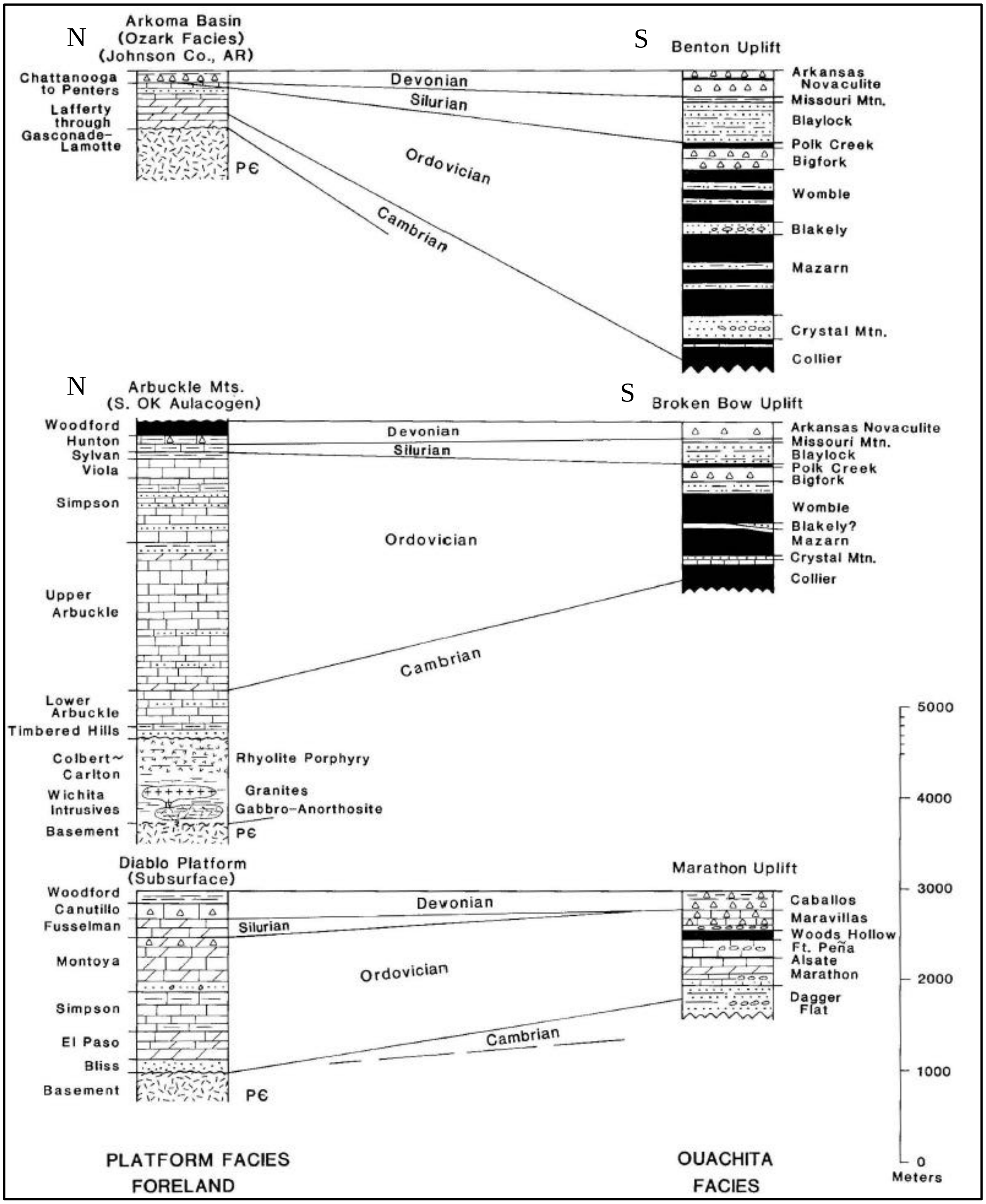


Figure 3.7. Generalized stratigraphic sections of Cambrian through Devonian strata in the Benton, Broken Bow, and Marathon uplifts compared to stratigraphic section from nearby areas on the North American shelf (modified from Viele and Thomas, 1989).

A general trend of Cambro-Orodovician deep water shales to more sand- and chert-dominated sedimentation from the Late Orodovician through the Late Devonian is observed in the Ouachita facies (Figure 3.7). In the Benton Uplift, the Late Ordovician Bigfork Chert, Silurian Blaylock Sandstone, and Devonian-Mississippian Arkansas Novaculite mark this shift in marine sedimentation (Viele and Thomas, 1989). Some researchers (Stone and Haley, 1984; Arbenz, 1989) have suggested periods of minor or modest tectonic activity in the Ouachita embayment region, possibly in the Silurian or Devonian. Studies of metamorphism in the Ouachita Mountains also suggest a mild thermal event in the Devonian (Keller et al., 1985).

Laurentia and Gondwana continued to converge in the Middle Paleozoic as the Iapetus Ocean closed, and the Ouachita Basin was dominated by silica sedimentation in the Late Devonian to Early Mississippian that would form the Arkansas Novaculite. Lowe (1975) proposed that as the Iapetus Ocean closed, the Ouachita ocean basin was essentially starved of clastic detritus from the stable North American craton (Figure 3.8).

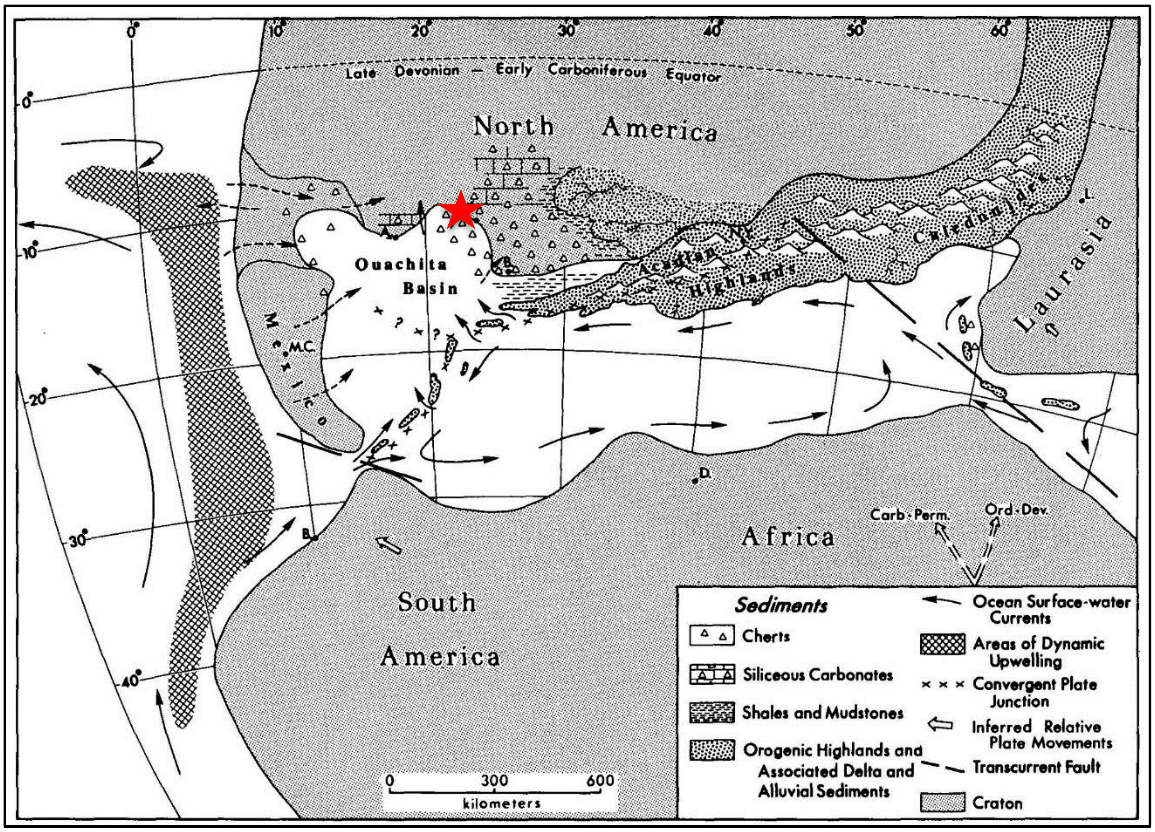


Figure 3.8. Late Devonian – Early Mississippian paleogeography, paleotectonics, and local sedimentary facies of western Iapetus Ocean (from Lowe, 1975). Key to geographic locations – MC, Mexico City; A, Austin, Texas; B, Birmingham, Ala.; NY, New York City. Laurasia: L, London. Approximately location of the study area shown by red star.

Volcanism along an island arc to the south and a region of significant upwelling along the west coast of North America may have supplied silica to the closing ocean basin. This silica was deposited by radiolaria and sponges across the basin and adjacent shelf margins, forming the chert and novaculite formations observed in the Late Devonian-Early Mississippian section of the Ouachita and Marathon Mountains (Lowe, 1975). The starved basin conditions likely led to anoxic bottom water conditions, preserving rich organic matter in the interbedded shales (Sholes, 1977; Godo et al., 2011).

Mississippian

In Middle Mississippian time, an island arc or microcontinent to the south (Figure 3.9; Figure 3.10) converged on the southern margin of Laurentia. North- and south-dipping subduction models have been proposed for the closure of the Iapetus Ocean, but most favor a south-dipping subduction zone under the approaching landmass (Briggs and Roeder, 1975, Lillie et al., 1983).

As Iapetus Ocean crust was subducted, tectonic loading of the crust formed a relatively narrow, trench-like basin ahead of the approaching terrains where a thick accumulation of submarine sediments and turbidities were deposited. In the Ouachita Mountains these strata are known as the Stanley Group, consisting of a thick flysch sequence of shales, siltstones, and sandstones (Arbenz, 1989). Much of the flysch sediment was probably sourced from the converging landmasses and tectonic highlands (Arbenz, 1989).

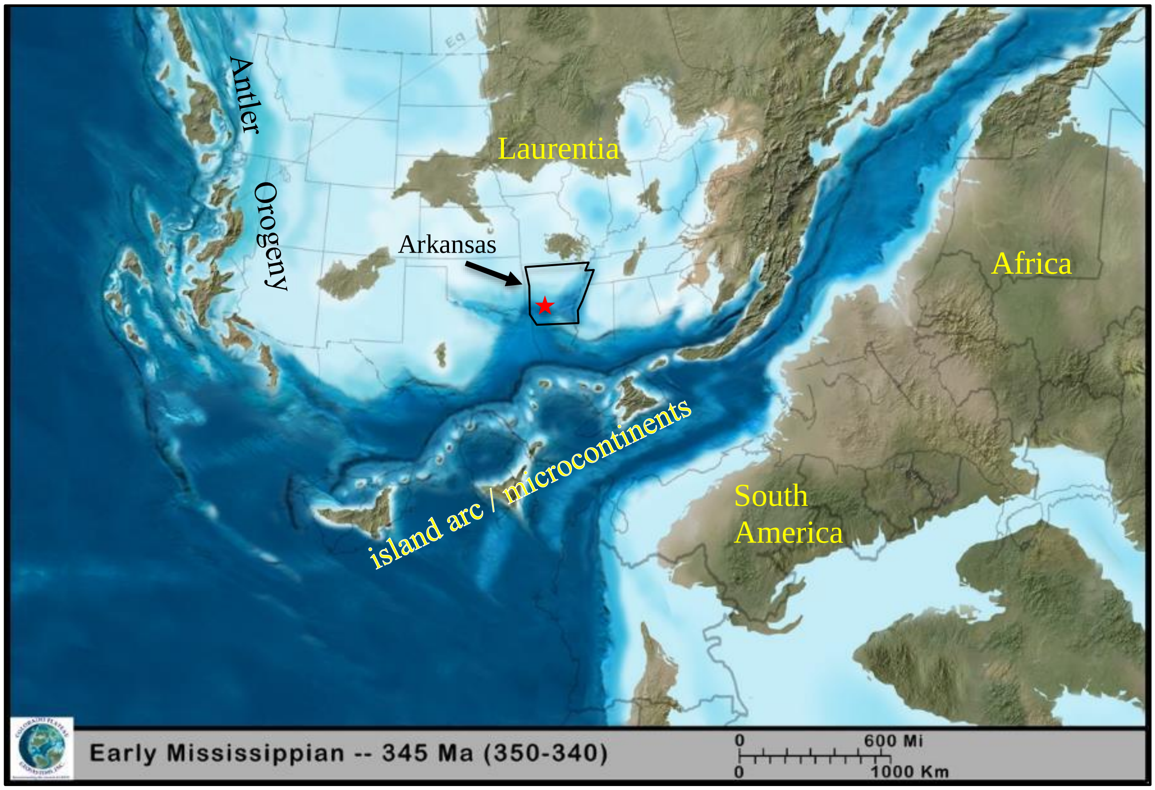


Figure 3.9. Early Mississippian paleogeography of southern Laurentia, island arc landmasses, and northern South America (modified from Blakey, 2013). Approximate location of the study area shown by red star.

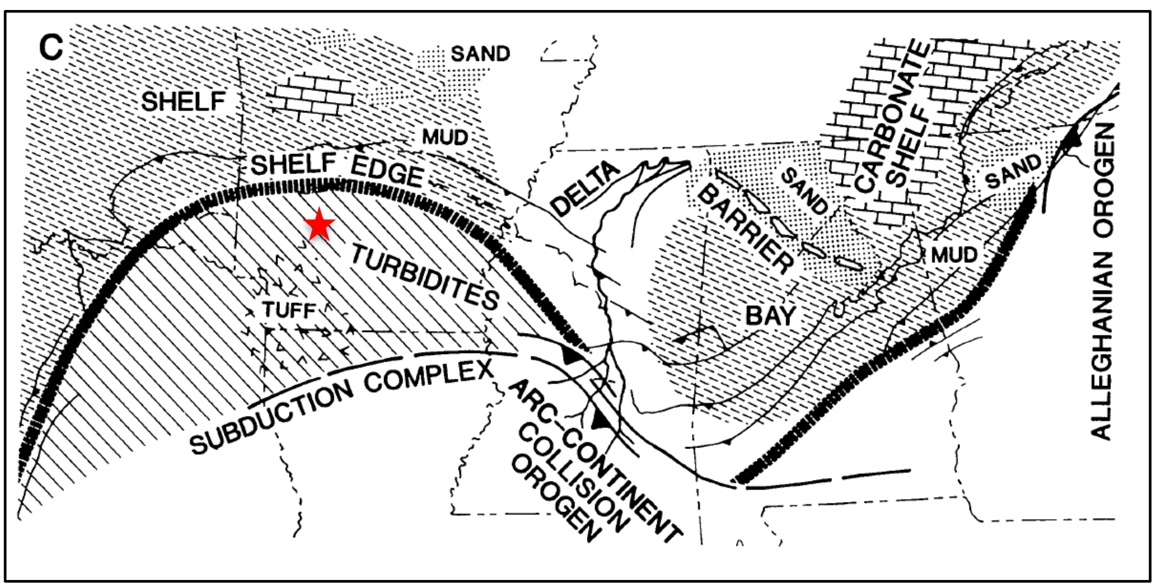


Figure 3.10. Late Mississippian paleogeographic construction of southern Laurentia showing onset of arc-continent collision at the eastern end of the Ouachita orogenic belt (from Thomas, 1985). Approximate location of the study area shown by red star.

Arc-continent collision likely began along the southern extent of the Alabama promontory first, near the juncture with the Appalachian Mountains, while subduction continued in the region of the Ouachita Basin (Figure 3.10). Thomas (1985) reported that a collisional margin had formed as early as Late Meramecian time (~ 335 Ma) based on progradation of clastic-wedge sediments onto the Laurentian shelf; the provenance of these sediments suggests an arc-continent collision. Meanwhile, turbidite and deep water deposition continued in the trough now occupying the Ouachita Basin, as the landmasses had not yet collided with the arcuate margin of the embayment (Figure 3.10).

Pennsylvanian to Permian

Arc-continent collision progressed westward along the Alabama-Ouachita transform margin during the Early Pennsylvanian as a southern landmass continued to converge northward on the Ouachita Basin, eventually subducting the Iapetus oceanic crust and thrusting the offshore Ouachita facies rocks over and onto the passive margin Arbuckle facies. In response to this crustal shortening, foreland basins subsided to the north of the orogen (Figure 3.1). These consist of the Arkoma Basin in Arkansas and Oklahoma north of the Ouachita Mountains, and the northeast-trending Dallas-Fort Worth Basin along the buried foreland of the Ouachita thrust front in eastern Texas. By the Middle Pennsylvanian, the intervening island-arc between Laurentia and Gondwana was accreted onto the southern margin of Laurentia (Figure 3.11). Collision with South America followed in the Late Pennsylvanian to Early Permian, culminating in the assembly of Pangea (Arbenz, 1989).

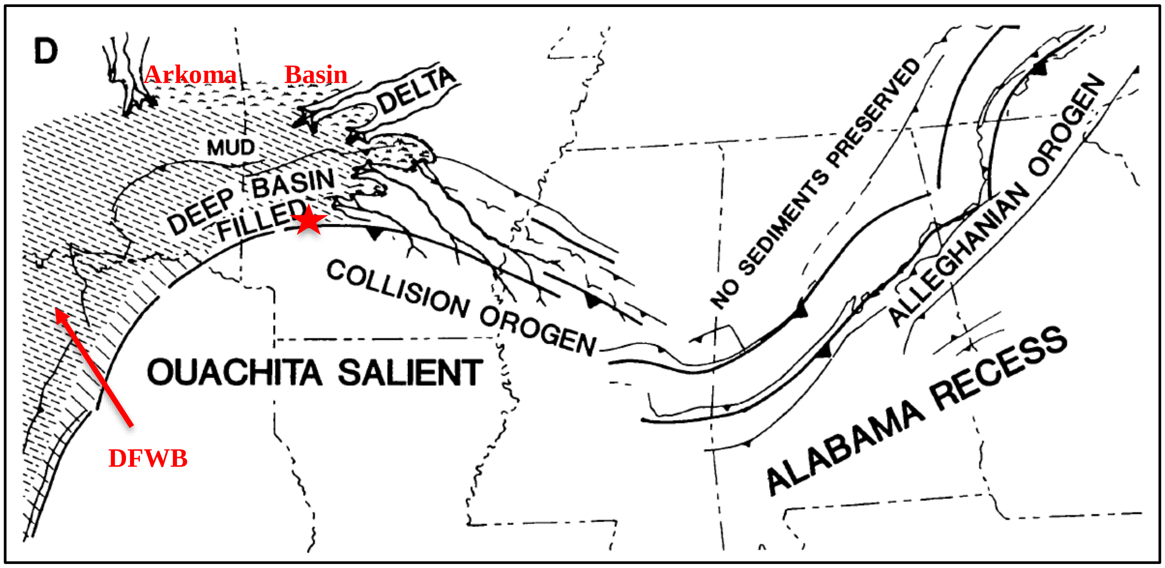


Figure 3.11. Generalized Middle Pennsylvanian (Late Atokan) paleogeography of southern Laurentia (modified from Thomas, 1985). Approximate location of the study area shown by red star. DFWB = Dallas-Fort Worth Basin.

Some studies in the Ouachita Mountains indicate there were at least two phases of deformation related to changing stress orientations in the crust during the Ouachita orogeny; other investigations suggest that up to three or four phases may have occurred (Evansin, 1976; Buthman, 1982; Arbenz, 1989; Whitaker and Engelder, 2006; Cox, 2009). The first phase was a NNE-directed compressional stress field generated by the accretion of offshore landmasses onto the Laurentian margin in the Middle Pennsylvanian (Atokan time); these landmasses may be the buried Sabine and Monroe basement uplifts in eastern Texas and northern Louisiana (Figure 3.12) (Whitaker and Engelder, 2006; Ewing, 2009).

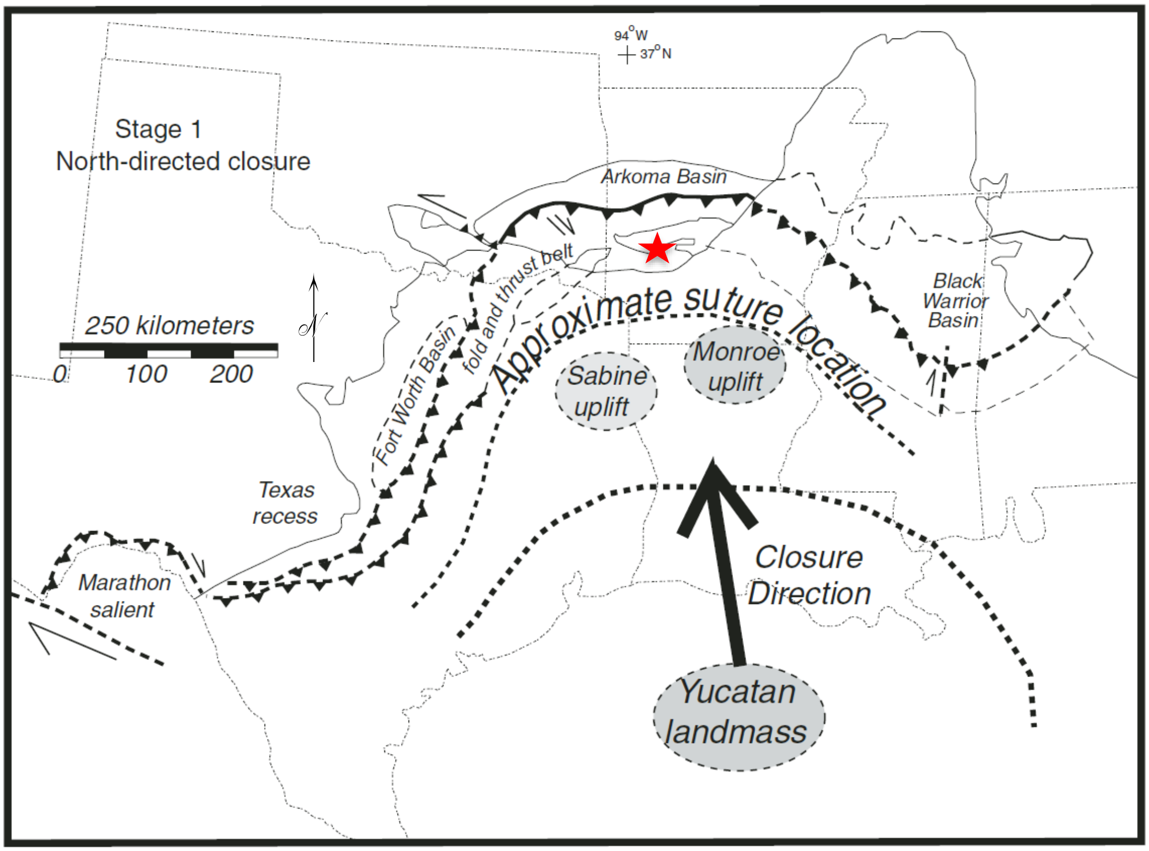


Figure 3.12. First stage of the Ouachita orogeny characterized by north-directed compression during accretion of the Sabine and Monroe terranes to Laurentia (modified from Whitaker and Engelder, 2006). Approximate location of the study area shown by red star.

A second phase of compression has been interpreted from a NNW-striking joint set in the central Ouachita Mountains that indicates a rotation or shift in the crustal stress field caused by the closure of the Ouachita trough by the Middle Pennsylvanian (Arbenz, 1989; Whitaker and Engelder, 2006). This culminated with the collision of the Yucatan landmass with southern Laurentia and with collision of Laurentia with Gondwana in the final assembly of the Pangea supercontinent (Figure 3.13).

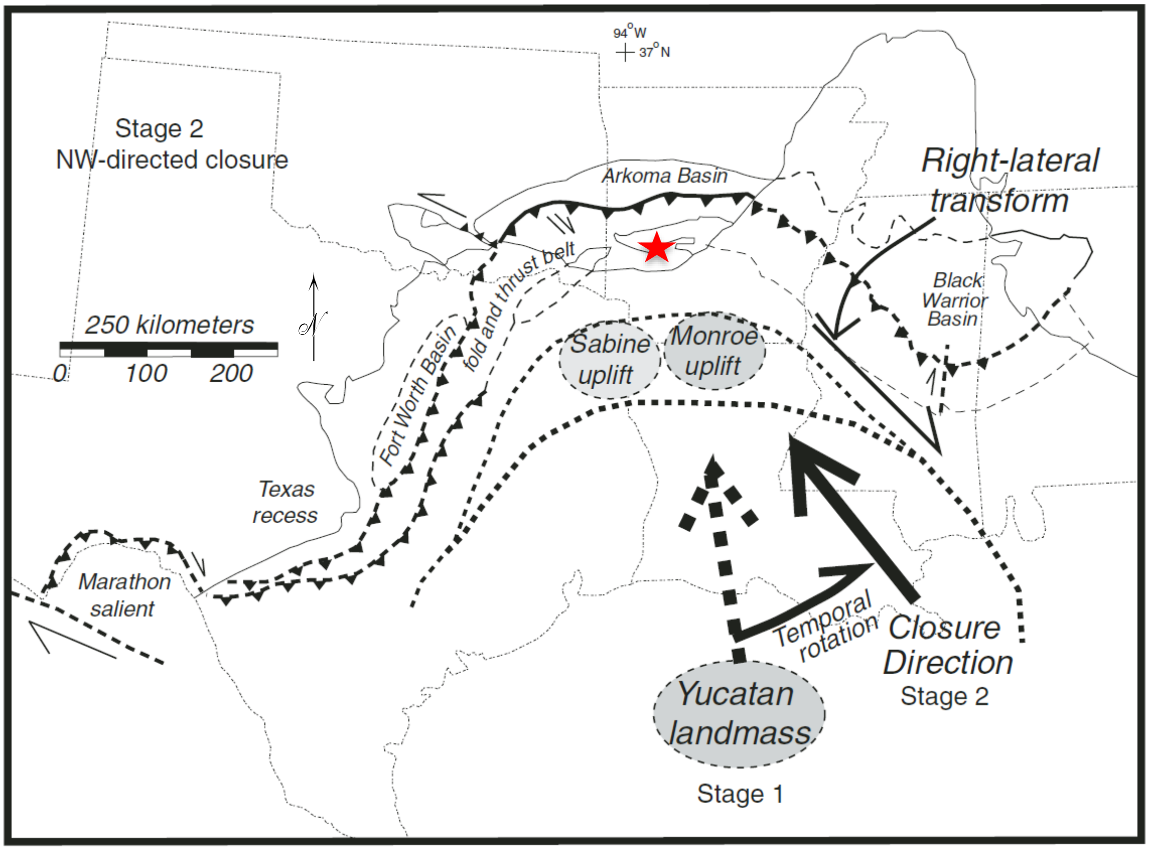


Figure 3.13. Second stage of the Ouachita orogeny characterized by northwest-directed compression during collision of Laurentia with Yucatan landmass (from Whitaker and Engelder, 2006). Approximate location of the study area indicated by ***red*** *star.*

Buthman (1982) reported that low-angle thrust faults in the Benton uplift have been folded, also supporting the argument for multiple phases of compression in the Ouachitas. Buthman mapped a dextral tear fault that may have offset older folds and faults, which suggests more than one phase of deformation. Buthman also observed rotated folds, which supports the interpretation of Whitaker and Engelder (2006) that there was a change in the direction of the maximum principal stress during the Ouachita orogeny.

The structural style of thrust faulting and folding was dependent on the mechanical properties of the stratigraphic units involved (mainly weak ductile shale versus rigid chert), and their relative proportion to each other. Detachments in the ductile shale units played a very important role in the thrust faulting and folding of the Ouachita facies (Arbenz, 1989; Godo et al., 2011). Folds were largely controlled by the deformational style of the faulting through the two types of strata. Pre-existing basement faults may also have controlled fold geometry where thrust faults ramped up and over the older faults, resulting in fault-propagation folding (Arbenz, 1989).

Structural fabrics in the Ouachita Mountains are largely north-directed, except for south-directed elements in the Benton and Broken Bow uplifts. Arbenz (1989) suggested a duplex thrust ramp system in continental basement rocks under the Benton and Broken Bow uplifts that would have allowed overturning of the north-vergent structures and folding of older thrust faults.

The polarity of Ouachita subduction has been often debated, but modern geologic and geophysical models strongly suggest south- or southeast-dipping subduction of the Iapetus oceanic crust under the approaching landmasses (Figure 3.14) (Keller et al., 1989; Viele and Thomas, 1989; Harry and Londono, 2004). This is supported by the lack of Pennsylvanian or Permian plutonism or volcanism in the Ouachita foreland, while igneous rocks of Late Permian age have been encountered in a few deep wells in the Sabine and Monroe uplifts (Figure 3.13) (Nicholas and Waddell, 1989; Ewing, 2009).

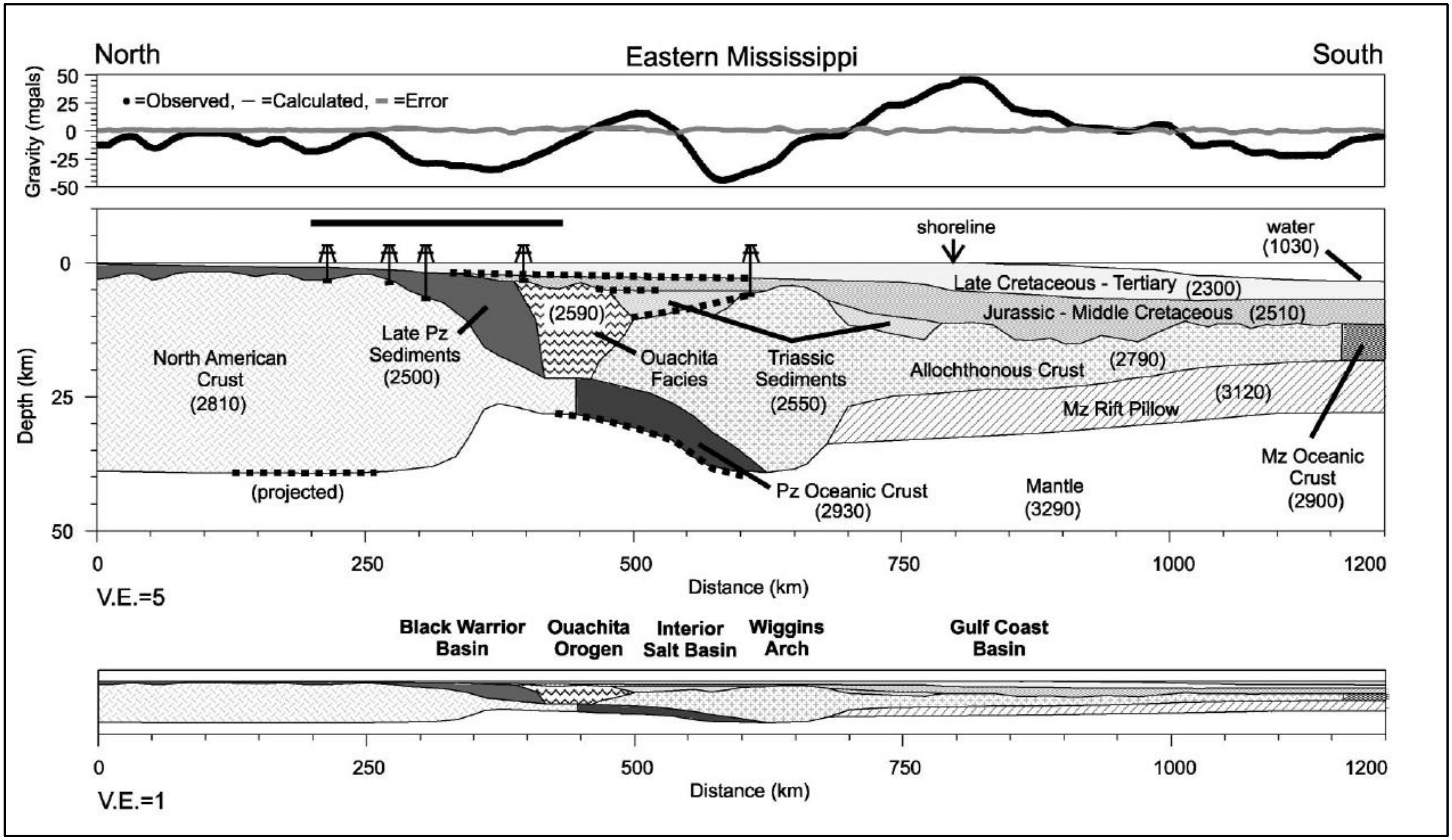


Figure 3.14. Subsurface model of the Ouachita orogenic margin showing relict Paleozoic oceanic crust with apparent southward-dipping subduction under accreted allocthonous landmass (from Harry and Londono, 2004). Note the thick block of allocthonous Triassic rocks buried under Gulf Coastal Plain sediments that may be an exotic microcontinent or island arc block that was thrust over the Paleozoic ocean crust.

A significant hydrothermal event during the final stages of the Ouachita orogeny is thought to be responsible for the low-grade metamorphism observed in the Ouachita Mountains (Keller et al., 1985; Arbenz, 1989).

Mesozoic to Cenozoic

Rifting of Pangea began in the Triassic and accelerated in the Jurassic and Cretaceous periods. The Gulf of Mexico initially opened in the Middle Jurassic (Harry and Londono, 2004; Hudec et al., 2013), rifting the Yucatan microplate from the Ouachita region of the Laurentian margin. Continued extension and onset of sea-floor spreading in the Late Jurassic further stretched and rifted the Ouachita hinterland (Figure 3.14).

A period of igneous activity in Arkansas occurring in the Late Cretaceous emplaced a northeast-trending series of extrusive and intrusive rocks from near Murfreesboro towards Little Rock (Haley et. al., 1993; Ewing, 2009). This trend cuts across the Ouachita orogeny and may be related to zones of weakness along the margin of the Reelfoot Rift (Figure 3.15), as a trend of buried plutons continues northeast under the Mississippi Embayment from near Newport, Arkansas into the Bootheel of Missouri (Hildenbrand and Hendricks, 1995, Ewing, 2009).

Thermal subsidence coupled with a major eustatic sea level rise in the Cretaceous flooded the eroded Ouachita hinterland, forming the basin margin around the opening Gulf of Mexico. Cretaceous to Tertiary basin infilling and progradation of continental and marginal marine sediments have buried the entire Ouachita hinterland and most of the Ouachita fold and thrust belt under the present-day Gulf Coastal Plain (Figure 3.2; Figure 3.14).

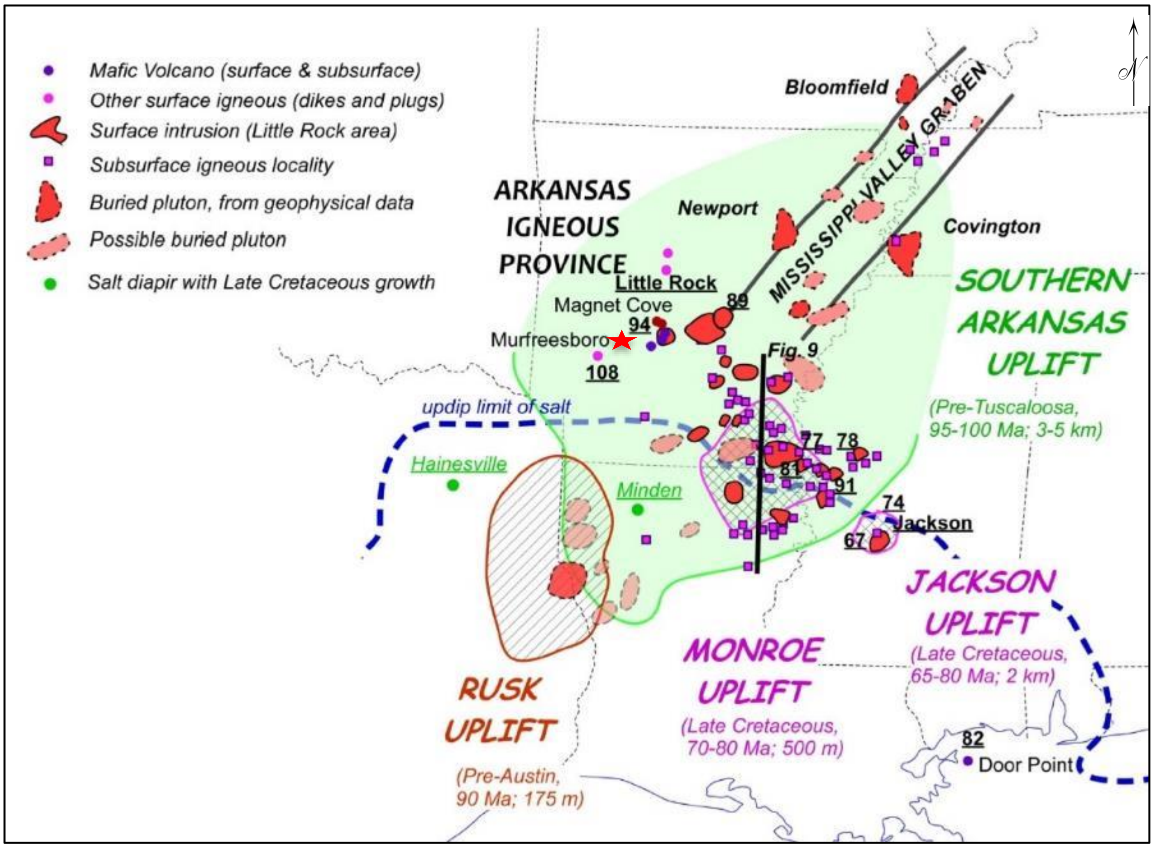


Figure 3.15. Map of Cretaceous uplifts and igneous rocks in the northern Gulf of Mexico and the Gulf Coastal Plain region (modified from Ewing, 2009). Note the northeast trend of igneous rocks through central Arkansas, paralleling igneous bodies along the margins of the Mississippi Valley (Reelfoot) Graben. Approximate location of the study area is shown by ***red*** *star.*

CHAPTER 4

Field Observations

Introduction

Detailed geologic field mapping conducted over numerous visits to the study area led to the discovery of previously unmapped structures in the Caddo Mountains. Initial mapping efforts focused on identifying the various rock units in the heavily-forested and colluvium-mantled terrain, recognizing formational contacts (where possible), and recording data about geologic structures that included faults, folds and bedding attitudes.

Because of the generally poor exposure in the study area, an emphasis was placed on collecting a high concentration of bedding and fault measurements during detailed field work, and to use GIS mapping to improve structural interpretation of this portion of the Caddo Mountains. These methods made it possible to map out the three informal members of the Arkansas Novaculite. Numerous fault surfaces were identified in the study area including normal, thrust, strike-slip and oblique. However, only a relatively small number of folds were identified in the field due to poor exposure; most were small-scale folds in the Middle Chert and Shale Member of the Arkansas Novaculite.

The most prominent structure in the study area is the Nelson Mountain Anticline (Figure 1.4**;** Figure 1.5) as mapped by Evansin (1976), Haley and Stone (1991) and Haley et al. (2009). This map-scale fold trends approximately east-west with a gently east-plunging nose as inferred by its topographic expression on maps (Figure 1.5).

Haley and Stone (1991) interpreted Strawn Mountain and much of the corresponding ridge to the east as a backthrust within the Arkansas Novaculite (Figure 1.13). To refine the previous geologic maps and to test this backthrust model, part of this study focused on mapping the individual members of the Arkansas Novaculite and collecting a dense array of bedding and fault measurements to better constrain the structural geometry of these rocks forming this mountain.

Large areas on both the south and north flanks of Strawn Mountain consist of novaculite and chert talus slopes; numerous cobbles and boulders with slickenlines were observed, suggesting significant faulting and deformation in this area. Field mapping on Strawn Mountain found a prominent, but previously unmapped, fault plane cutting through the Lower Member of the Arkansas Novaculite that could be traced at the outcrop for at least 800 feet. The fault had indicators of both normal and thrust sense of slip. A zone of faulted and brecciated Lower Novaculite could also be traced for at least one-half mile on the southwest flank of Strawn Mountain. In addition, a few surfaces in the Lower Novaculite were found with two sets of slickenlines that trend at different angles, suggesting reactivation of faults in this area.

Another significant finding in this study is a previously unmapped network of northeast-tending strike-slip faults on the south-facing slope below South Caddo Mountain within the Lower Member of the Arkansas Novaculite. Evidence for this style of faulting in this area include prominent fault planes with horizontal to near-horizontal slickenlines, chatter marks, tension fractures, and large outcrops of intensely fractured to massively brecciated Lower Novaculite. Because of the poor exposure and lack of definitive marker beds, the amount of displacement is unknown. However, one fault does juxtapose the Middle Chert and Shale Member against massive beds of the Lower Novaculite Member, indicating relatively significant displacement along these faults.

The following section presents field observations from each of the units in the study area in order from oldest to youngest. These units are discussed in Chapter 2 based on information from the geologic literature; see Figure 2.2 for a detailed stratigraphic column of the units.

Womble Shale (Middle Ordovician)

As discussed in Chapter 2, there are very few exposures of the Womble Shale in the study area, which makes structural analysis of these Middle Ordovician rocks difficult. Limited exposures were found in the northern and southern channel of Bean Creek and in the western part of Jones Valley along Gap Creek; however, all of these exposures are on private lands. The northern Bean Creek exposures range from undeformed, planar, parallel bedding (Figure 2.3), to folded bedding (Figure 4.1) to chaotically-deformed outcrops.

The exposures along Gap Creek in Jones Valley generally consist of planar, fractured bedding with zones of chaotic deformation interpreted as shear zones. The mean bedding orientation ($n = 9$) in this area is N85°W (275°) with moderate to steep (58° to 84°) dips to the south (except one bed dipping 85° N). Given the small sample size from this unit, structural analysis of the Womble is limited to incorporation of bedding measurements and inferred formational contacts into the geologic map.


Figure 4.1. Folded Womble Shale beds in northern channel of Bean Creek (Stop 253). Hammer in center of photo for scale.

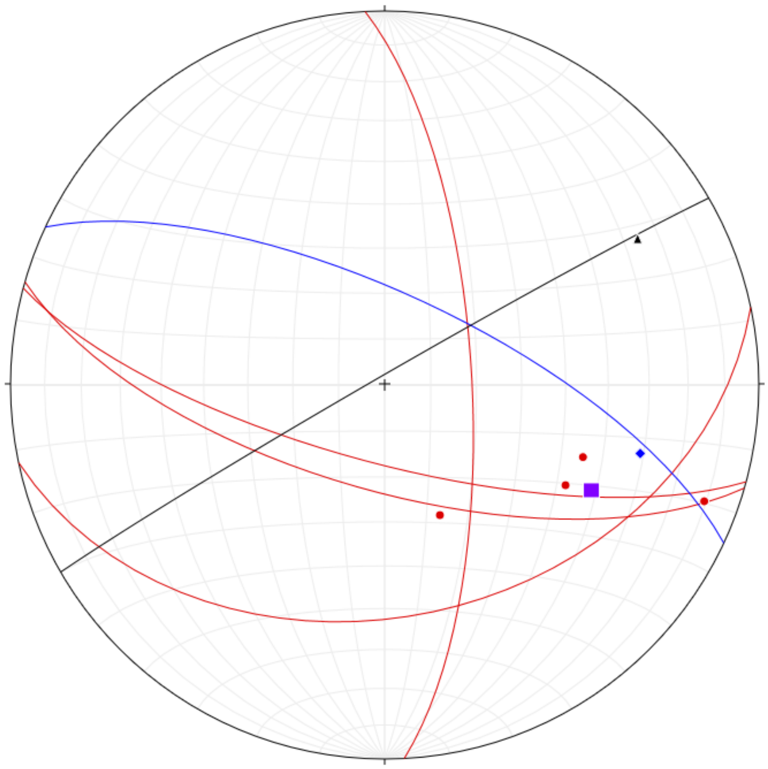
Bigfork Chert (Middle to Upper Ordovician)

The Bigfork Chert is moderately to poorly exposed in the study area and commonly forms hummocky hills and knobs. Numerous creek bed and stream gully exposures were observed in the core of the Nelson Mountain Anticline (Jones Valley). While folds are very common in the Bigfork Chert in many places in Arkansas, only a handful of small-scale folds in the Bigfork were observed due to the relatively poor exposure. All of these were observed in Jones Valley where the Bigfork (along with the Womble Shale) forms the core of the Nelson Mountain Anticline (Figure 2.4; Figure 4.2, Figure 4.3). Bedding measurements and float observations constituted the bulk of the data collected from the Bigfork.

Figure 4.2. Tight fold in the Bigfork Chert at Stop 770. Hammer and field notebook for scale. The measured fold axial plane is N65°W, 70°NE and fold axis is 30°, S75°E.

Figure 4.3 shows the Bigfork folds observed in the core of the NMA overall plunge gently to moderately towards the southeast. The average fold axis from the five folds measurements in the western and central parts of the NMA is 38°, S64°E. The sixth fold observed in the eastern core of the NMA is a small stream outcrop with poor lateral observable extent and is interpreted as small-scale local fold as the fold geometry differs considerably from the other folds observed in the Bigfork within the NMA.

Stereonet of Folds in Bigfork Chert,
Nelson Mountain Anticline



Average Fold Axis (purple square):
38°, 116° (38°, S64°E)
(excludes Stop 778 – black triangle)

Figure 4.3. Stereonet diagram of folds observed in the Bigfork Chert; all were located in the core of the Nelson Mountain Anticline. Colors: ***blue*** **-** *western core of Nelson Mountain Anticline (Stop 770),* ***red*** *– central core of Nelson Mountain Anticline (Stop 773; Figure 2.4),* ***black*** *– eastern core of Nelson Mountain Anticline (Stop 778). Note the concentration of fold axes in the southeast quadrant (Stereonet 9 Program, Allmendinger, 2016).*

Polk Creek Shale (Upper Ordovician)

The Polk Creek Shale was rarely observed in-place and was very difficult to differentiate from other shale units. Competent exposures were usually small, very limited in lateral extent, and highly weathered. The best exposures thought to be Polk Creek were observed along the middle portion of Bean Creek where a set of crenulation folds and small surfaces with slickenlines (probably flexural slip on bedding planes) were observed. Float observations from overturned tree stumps constituted the bulk of data retrieved from the Polk Creek.

Missouri Mountain Shale (Upper Silurian)

The Missouri Mountain Shale was also rarely exposed but could be recognized with more confidence by float of tan to green to maroon, platy, weathered shale fragments in overturned tree stumps, deep washouts, and steep hillsides or cutbanks. At the abandoned prospect pits discussed in Chapter 2, this shale was tan to red-maroon in color, weathered, and intensely fractured. Exposures in a wash gully under and parallel to the utility power lines just east of the Caddo Gap road cut exhibited chaotic folding and deformation; bedding was completely obliterated. Float observations and only a handful of bedding measurements were gathered from the Missouri Mountain Shale.

Arkansas Novaculite (Late Devonian-Early Mississippian)

Because of its resistance to weathering, the Arkansas Novaculite provided the best exposures for geologic mapping and gathering structural data in the study area. The massive Lower Novaculite Member is the primary ridge former, whereas the more shale-rich Middle Chert and Shale Member often form talus slopes or saddles between the Lower and Upper Novaculite Members. The Upper Novaculite often forms subtle flatirons or knobs on the flanks of the Caddo Mountains, as it is more competent than the underlying Middle Chert and Shale.

The resistant Novaculite forms four main structural features within the study area: 1) the Nelson Mountain Anticline, 2) the Strawn Mountain Ridge Backthrust, 3) the "South Ridge" which includes the previously unmapped northeast-trending strike-slip faults, and 4) two large, moderately plunging synclinal folds that form South Caddo Mountain and Arrowhead Mountain where Novaculite bedding has been folded around about 120 to 140 degrees, forming structures that in map view resemble "fishhooks," as they will be referred to in this study (Figure 4.4).

The Lower Member of the Arkansas Novaculite does not appear to be folded at outcrop scale (as observed at the Caddo Gap road cut – see Figure 2.9) due to its thickness and rigidity, but together with the other members it is folded into large map-scale anticlines (Nelson Mountain Anticline) and synclines (South Caddo Mountain and Arrowhead Mountain fishhook folds). Most field data were collected from the Lower Novaculite given its resistance and good exposure. Measurements included bedding, faults, slickenlines and tension joints. All fault types were observed including normal, thrust, strike-slip and oblique faults. An area with numerous northeast-trending strike-slip faults through the Lower Novaculite was found on the south-facing slope of the South Ridge, just below South Caddo Mountain.

Examination of the Caddo Gap road cut shows the Middle Member can be intensely folded, sheared and deformed (Figure 1.12, Figure 2.11) at outcrop to map scales given its larger percentage of shale and thinner bedding. Of the few outcrop-scale folds observed in the field, most were in gully and cutbank exposures of the Middle Member (Stops 4, 94, 547, 559, 882 and 947). A stereonet plot of these folds (Figure 4.5) shows a wide range of axial plane and axis orientations. Additional fold measurements across the field area would be needed to better constrain fold trends in the Middle Chert and Shale Member but the thick colluvium apron significantly hinders data collection on folds.

The Upper Novaculite, while more resistant than the underlying Middle Chert and Shale Member and the overlying Stanley Shale, is generally poorly exposed in the study area. It often forms subtle flatirons and knobs in the topography capped with boulders and float. This geomorphology can be best observed on the limbs and nose of the Nelson Mountain Anticline. In-place beds were best observed in mountain-flank streams that have incised through the Upper Novaculite. Measurements from this member included bedding, faults and slickenlines. No folds were observed in the field, which is not surprising given that none are present at the road cut. Numerous prospect pits, probably for manganese mineralization, were observed in this unit across the field area.

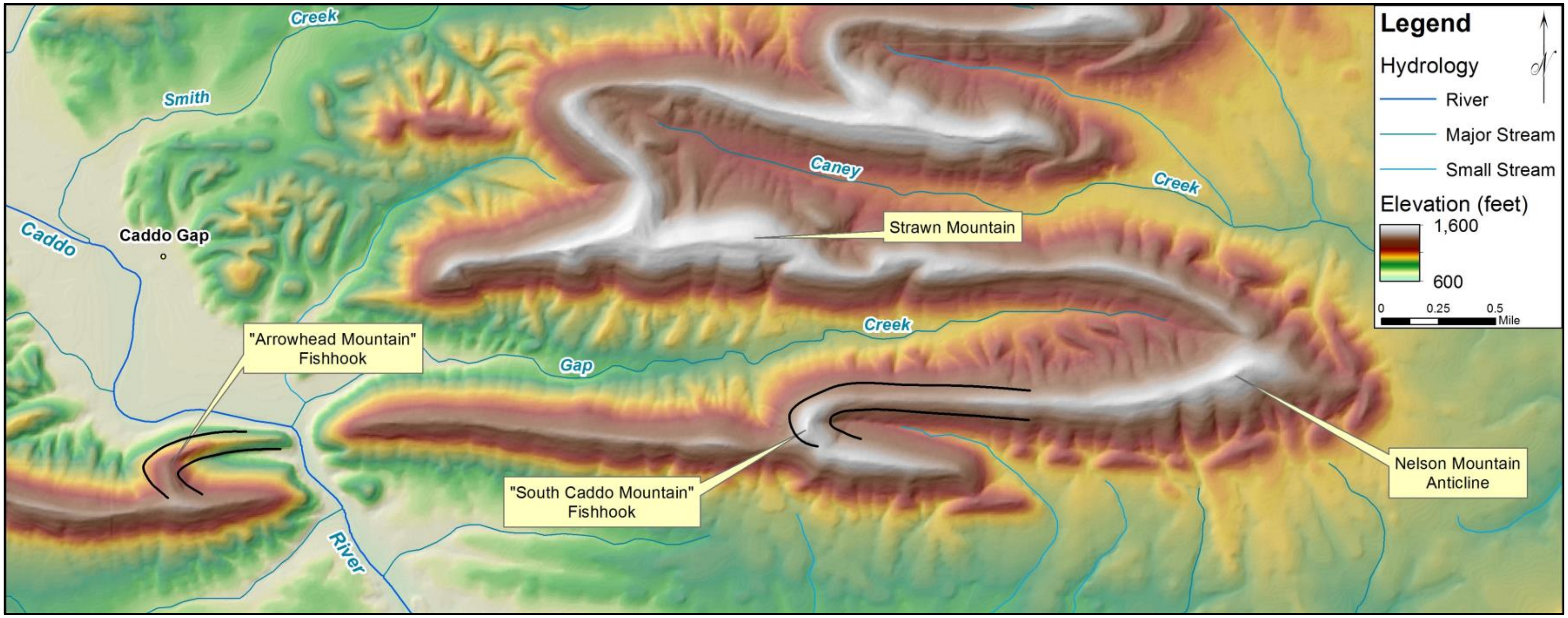


Figure 4.4. Digital elevation map of the Caddo Mountains highlighting the "fishhook" folds (black lines) within the study area (USGS, 2000).

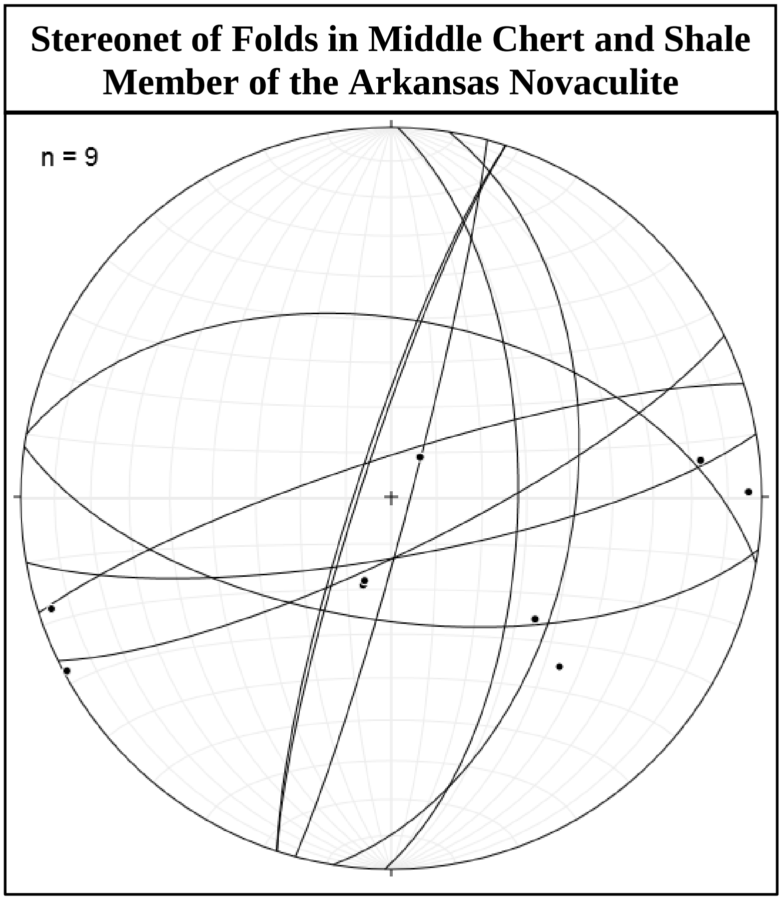


Figure 4.5. Stereogram of outcrop-scale folds in the Middle Chert and Shale Member of the Arkansas Novaculite. Note the wide range of orientations and trends.

<u>Stanley Shale (Mississippian)</u>

The Stanley Shale is non-resistant and easily eroded and, thus, is poorly exposed in the study area; it is usually only observed on steep cut banks, road cuts, major creek channels and along the Caddo River. It forms the valleys on the south, east and northeast parts of the study area. Where exposed in the study area it is typically a gray to black platy shale with minor siltstone and sandstone interbeds, but colors can range from red to green to purple to black. In some areas the Stanley has undergone low grade metamorphism into slate (Stop 1) but is largely shale across the study area.

For this study, the most significant aspect of the Stanley is that it contains an angular, poorly sorted, coarse sand to coarse pebble, black chert conglomerate bed (or float thereof) observed near the base of the unit across the field area. A traceable bed up to 6 feet thick was found on the north limb of the Nelson Mountain Anticline (Figure 2.13). Where this key marker bed was found in place or as float, the contact between the Arkansas Novaculite and Stanley was assumed to be near or some distance uphill.

Only a marginal number of bedding measurements were gathered from the Stanley Shale due to its poor exposure. An excellent road cut through a small section of Stanley is present on the east side of Highway 8, about one quarter mile south of the study area. Other roadside exposures can be found along county roads crossing the eastern end of the field area.

A large quarry in the Stanley Shale is located along the south edge of the study area in the SW ¼ of Section 22, T. 4 S., R. 24 W. Based on Google Earth imagery, the quarry is about 40 acres in size and about 150 feet deep from the surrounding land surface. The quarry would be an excellent vantage point to collect detailed measurements in the Stanley; however, requests to enter the mine site were denied by the operator due to MSHA safety regulations and liability concerns.

Evansin (1976) was able to gain access to the quarry during his field study and found a number of thrust and reverse faults in the quarry. The thrust sheets reportedly ranged in thickness from about 5 to 20 feet. Fault surfaces had a general east-west strike and dipped between 55° and 70° to the south; slickenlines indicated north-directed thrust faulting (Zimmerman et al., 1984).

Jackfork Sandstone (Lower Pennsylvanian)

The Pennsylvanian age Jackfork Sandstone is only present within the southeastern corner of the study area where it forms the northeast-southwest trending Pigeon Roost Ridge (Figure 1.4; Figure 1.5). Haley et al. (2009) mapped this geographic feature as southeast-dipping thrust sheets overlying a major northeast trending thrust fault traced through the stream valley between Nelson Mountain and Pigeon Roost Ridge (Figure 1.13; Figure 4.6). This fault is referred to as the Hopper Thrust (after the town of Hopper to the west of the field area) and it is considered to be a structure of regional significance (Zimmerman et al., 1984 – see Figure 4.6).

Jackfork beds observed at Stops 939 and 940 strike approximately N40°E and dip moderately southeast. Because only a small portion of this formation lies within the study area and the larger portion of the Pigeon Roost structure lies outside the field area, the Jackfork was only mapped at reconnaissance scale in this study using existing geologic maps of the structure (Zimmerman et al., 1984; Haley and Stone, 1994; Haley et al., 2009).

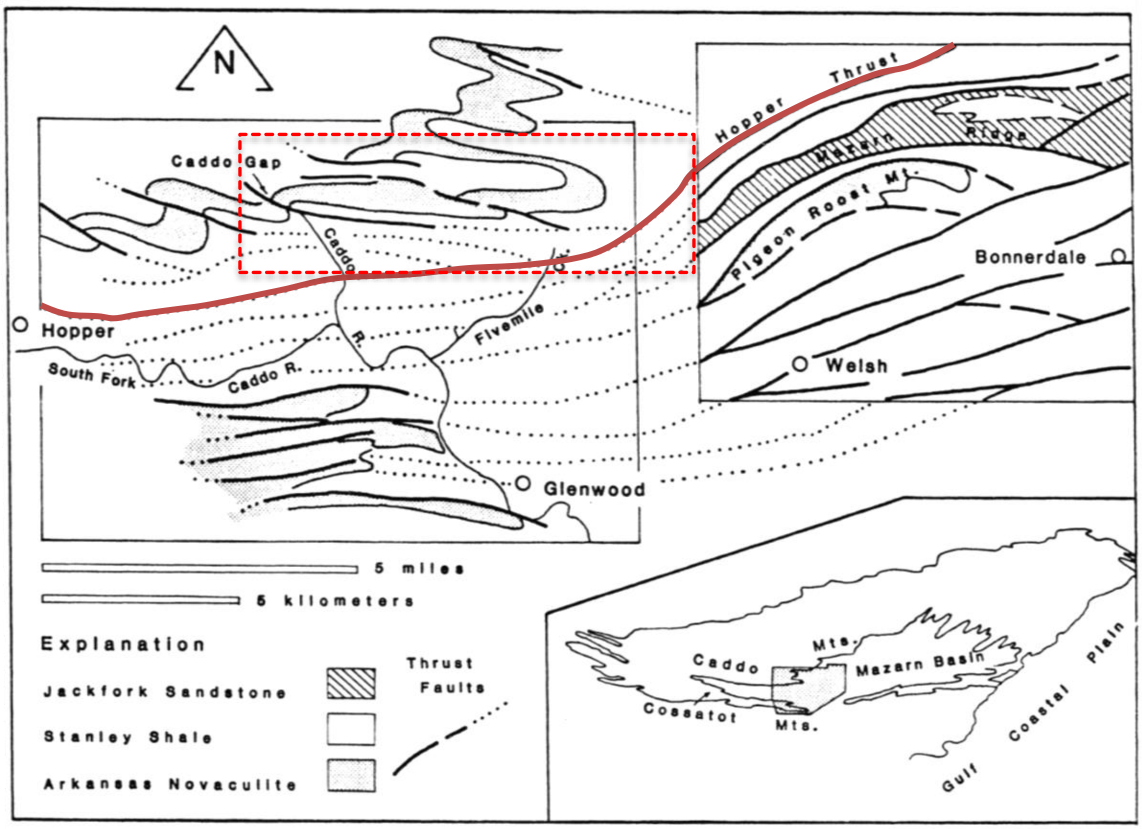


*Figure 4.6. Generalized geologic map of the Caddo Gap-Hopper-Glenwood-Bonnerdale area showing areas mapped by D.P. Evansin (left) and V.S. Ragan (right); linear dot pattern shows thrust faults from Haley and others (1976) with the Hopper Thrust Fault highlighted in **dark red**. Study area shown by **red** dashed outline. Map modified from Zimmerman et al. (1984).*

The Pigeon Roost structure extends southwest into the Glenwood Quadrangle (Haley and Stone, 1994) and northeast into the Bonnerdale quadrangle. Zimmerman et al. (1984) and Haley et al. (2009) show multiple thrust sheets forming Pigeon Roost Mountain with the Devonian-Mississippian Arkansas Novaculite thrusted northwest over younger Mississippian Stanley Shale and Early Pennsylvanian Jackfork Sandstone. The general east-west trend of geologic structures observed in the Caddo Gap-Hopper-Glenwood area appear to change to a northeast strike moving east towards Bonnerdale (Figure 4.6).

If the northwest-directed compression that formed the Pigeon Roost structures was from a later phase of deformation, as is suggested by the fact that the Hopper Thrust has deformed younger Pennsylvanian-age rocks, then this northwest-directed compression may have also affected the structures forming the Caddo Mountains. This may explain why the Caddo Mountain range takes an approximate 35-45 degree turn towards the northeast from Strawn Mountain (Figure 1.3; Figure 1.5; Figure 4.6).

Structures

Introduction

The major map-scale structural features in the study area include the Nelson Mountain Anticline, the Strawn Mountain Ridge Backthrust, the South Ridge Strike-Slip Faults, and the two fishhook folds forming South Caddo Mountain and Arrowhead Mountain. These are described in the following sections and will be analyzed in the next chapter.

Nelson Mountain Anticline

The Nelson Mountain Anticline (NMA) is a broad, map-scale fold, the nose of which occupies the eastern part of the study area (Figure 4.7). Evansin (1976) derived bedding plane attitudes (n = 25) from topographic interpretation of each limb, which indicated a vertical, east-west striking axial plane. He interpreted the NMA as a horizontal upright fold according to the Rickard (1971) classification (Evansin, 1976). However, no detailed field data delineating the structural geometry and character of this fold could be found in the literature.

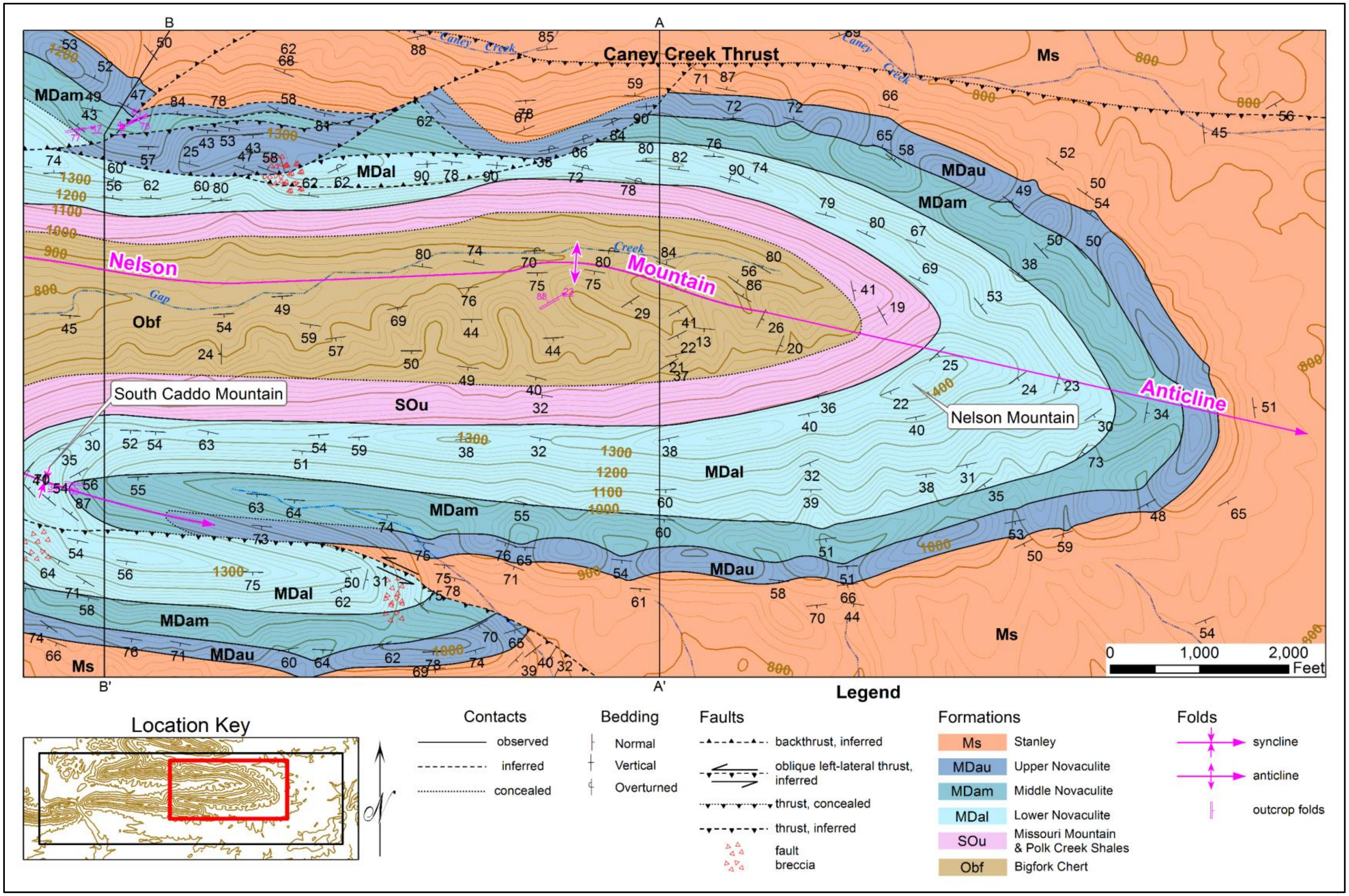


Figure 4.7. Map of the plunging nose of the Nelson Mountain Anticline.

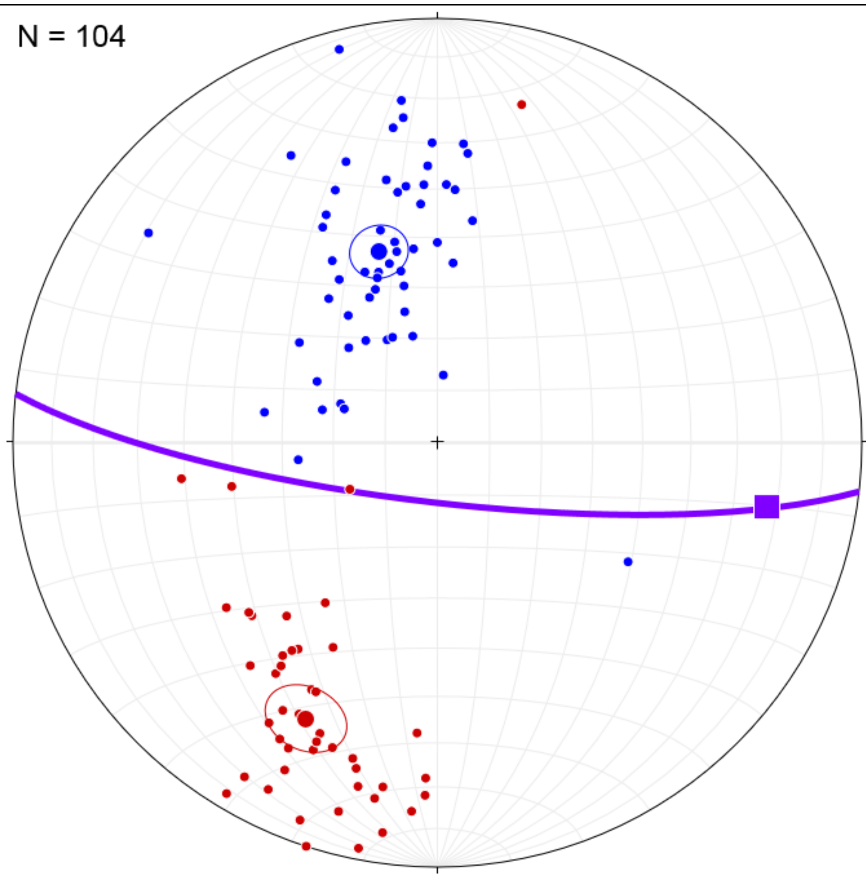
Field mapping and bedding measurements from this study show the NMA is an asymmetric, north-vergent, steeply inclined, gently plunging fold (Fleuty, 1964) that plunges to the east-southeast. The NMA is cored by Bigfork Chert and the limbs are well-defined by the Arkansas Novaculite. The youngest unit involved in the fold is the Stanley Shale. The core of the NMA has been breached and eroded down into the Bigfork Chert, forming Jones Valley (Figure 4.4; Figure 4.7). The topography of the limbs is very steep with thick undergrowth that is difficult to traverse. The nose of the anticline, plunging gently towards the east-southeast, is characterized by more gentle slopes; however, few in-place outcrops were observed within the fold hinge zone, probably the result of intense fracturing from extensional stresses along the crest of the structure during folding.

Most of the north limb of the NMA has been cut by a series of backthrusts along Strawn Mountain Ridge (Figure 1.4) so structural analysis of this limb is limited to data collected east of the line of cross section A-A' (Figure 4.7). Going northwest from the nose of the fold, the north limb trends about N65°W before turning more due west where it has been cut and deformed by backthrusts off the Strawn Mountain - Caney Creek Thrust. The dip of the beds is relatively gentle near the nose of the fold and becomes steep or even vertical moving westward along strike away from the nose (Figure 4.7). Novaculite beds on the north limb of the NMA approach vertical and, moving further west, some dip steeply south, suggesting that the beds have been overturned. However, very few geopetal (top’s-up) indicators were found which could have confirm overturning; thus, overturned beds are inferred from inverted stratigraphic relationships.

The south limb of the NMA tends about N85°W between South Caddo and Nelson Mountains (Figure 4.7) and dips moderately to steeply south, though the dips are lower and the outcrops wider, on the south limb compared with the north limb. Beds on the south part of the nose of the fold dip gently east to southeast. Stereonet analysis (Figure 4.8) shows that the fold axis plunges gently about 22° towards S79°E. The orientation of the fold axial plane of the NMA, calculated from 104 bedding measurements, is N84°W, 78°SW.

The subsurface interpretation of the NMA is shown in cross section A-A' (Figure 4.9). In this interpretation, the asymmetry and north-vergence of the fold is clearly evident. The Caney Creek Thrust has cut through the Womble-Stanley stratigraphic section and fault drag has tilted the north limb to near-vertical and possibly overturned bedding at depth. Beds of the south limb extend into the subsurface where they may have been folded into a syncline due to fault drag from an inferred major thrust fault traced along the southern edge of the study area (Haley et al., 2009). The left-lateral strike-slip movement inferred on this fault in this study (Figure 4.9) will be discussed in the next chapter.

Stereonet of Nelson Mountain Anticline



Mean Vectors (Poles to Planes):

North Limb: 29°, 205° (29°, S25°W)

South Limb: 51°, 343° (51°, N17°W)

Calculated Fold Axial Plane (purple great circle):

096°, 78° (N84°W, 78°SW)

Calculated Fold Axis (purple square):

22°, 101° (22°, S79°E)

Figure 4.8. Stereonet diagram of poles to bedding (N = 104) on the Nelson Mountain Anticline as poles to planes with mean vectors (south limb=blue; north limb=red). The larger transparent circle within the poles represents the average pole with a 95% certainty (Allmendinger, 2013). Calculated fold axial plane:purple great circle, calculated fold axis: purple square.

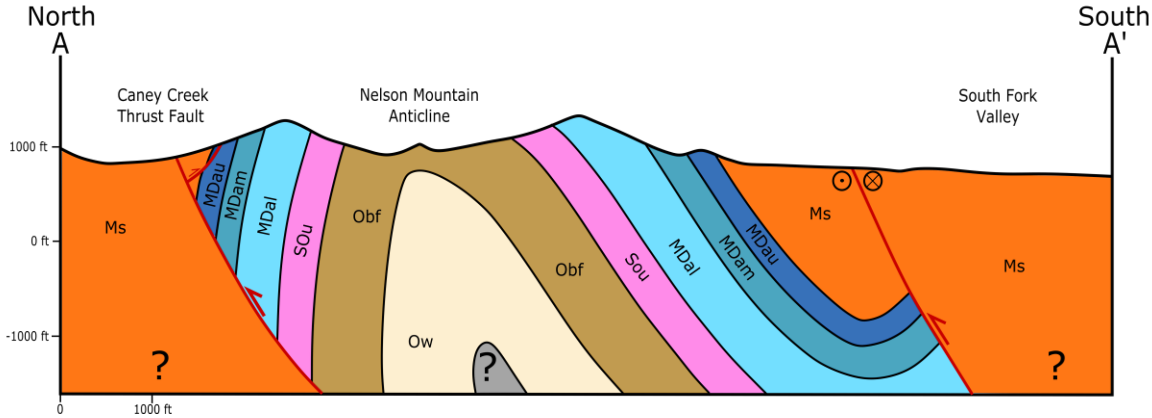


Figure 4.9. Cross section A-A' through the Nelson Mountain Anticline. No vertical exaggeration.

This interpretation has similarities to that of the Rattler natural gas prospect in northern Pike County (7.5 miles south of this study) that was explored by Shell in the 1980's (Godo et al., 2011). Their model (Figure 4.10) was based on the surface geology of that area, coupled with data from the Arivett 1-26 well (with a total depth of 10,570 feet in the Missouri Mountain Shale) and industry seismic reflection data that better constrained the subsurface interpretation. Their model shows a low-angle detachment fault in the Womble Shale that extends northwards under the Cossatot Mountains. If this detachment extends north to the study area on a footwall flat, it may explain the geometry of the map-scale folds such as NMA at Caddo Gap via break-forward thrusting.

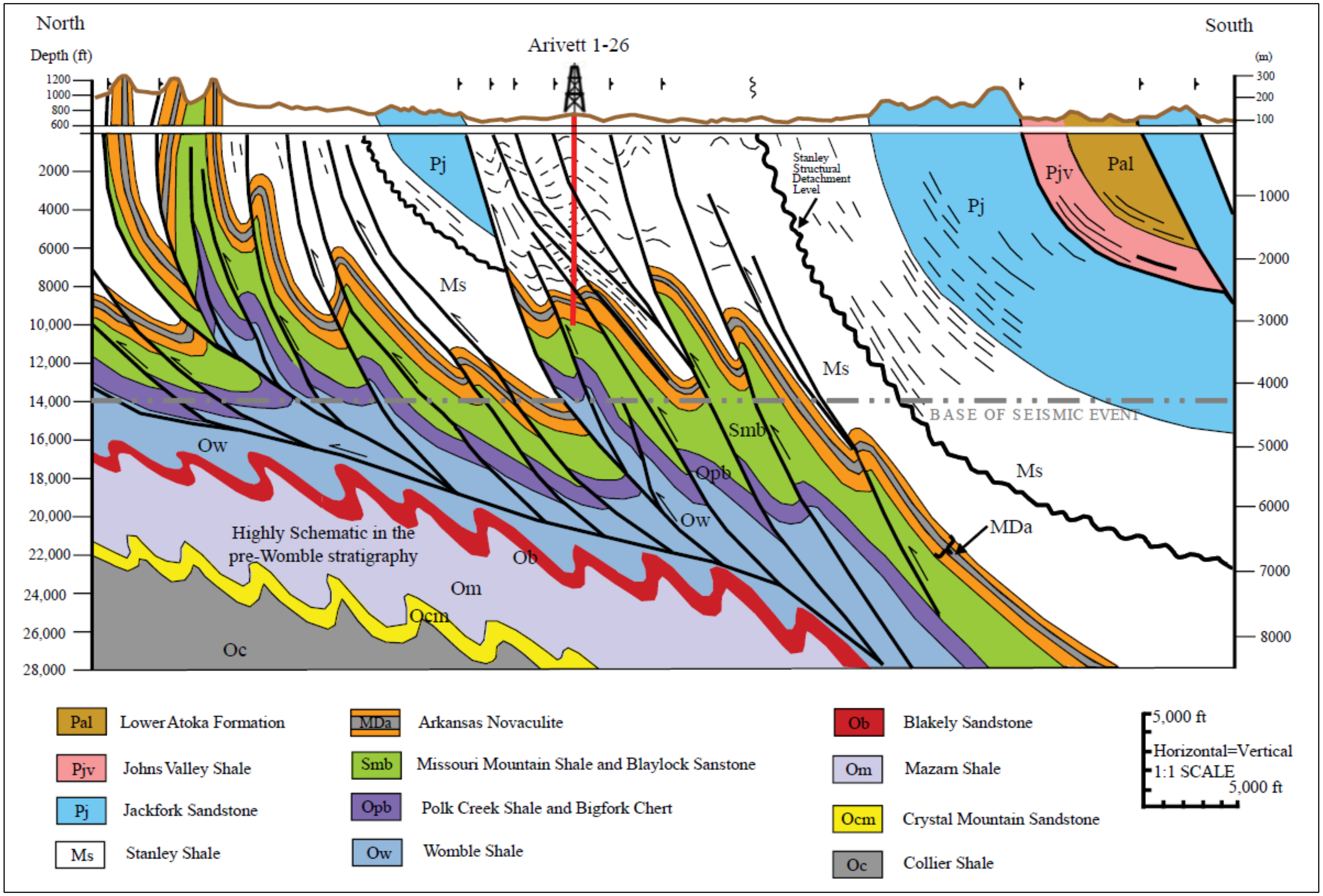


Figure 4.10. Structural cross section across the Rattler natural gas prospect, northern Pike County, Arkansas (Godo et al., 2011). This well is approximately 7.5 miles south of the study area. Note the similarities of the fold geometries in this interpretation to that of the Nelson Mountain Anticline shown in cross section A-A' in Figure 4.9. No vertical exaggeration.

Strawn Mountain Ridge Backthrust Faulting

Introduction

Strawn Mountain (Figure 4.4) is the westward extension of the north limb of the Nelson Mountain Anticline (Figure 4.7). Haley et al. (2009) mapped Strawn Mountain and the ridge to the east (referred to as Strawn Mountain Ridge in this study) as a simplified backthrust structure off the unnamed thrust fault traced along Caney Creek (Figure 4.11). This study confirmed the earlier interpretation to be valid and detailed mapping revealed that the structural geology of Strawn Mountain Ridge (SMR) is very complex because the Arkansas Novaculite has been duplicated, offset and intensely deformed by a complex of several backthrusts (Figure 4.12; Figure 4.13) where the transport direction (south to southeast) is opposite to the regional northward transport of the majority of thrusts in the Ouachita Mountains (Figure 1.11; Figure 4.10; Figure 4.14).

The terrain of this area is very difficult to traverse and both flanks of SMR are often covered by loose Novaculite boulders, float and talus fields. The south flank is particularly steep and some areas could not be mapped safely due to treacherous talus-covered cliffs. Strawn Mountain is also the most remote area in the study area with the closest vehicle parking being located at the end of Forest Service Road C46 over a mile to the east. Long abandoned, overgrown roads in Jones Valley provided some hiking access from the southwest.

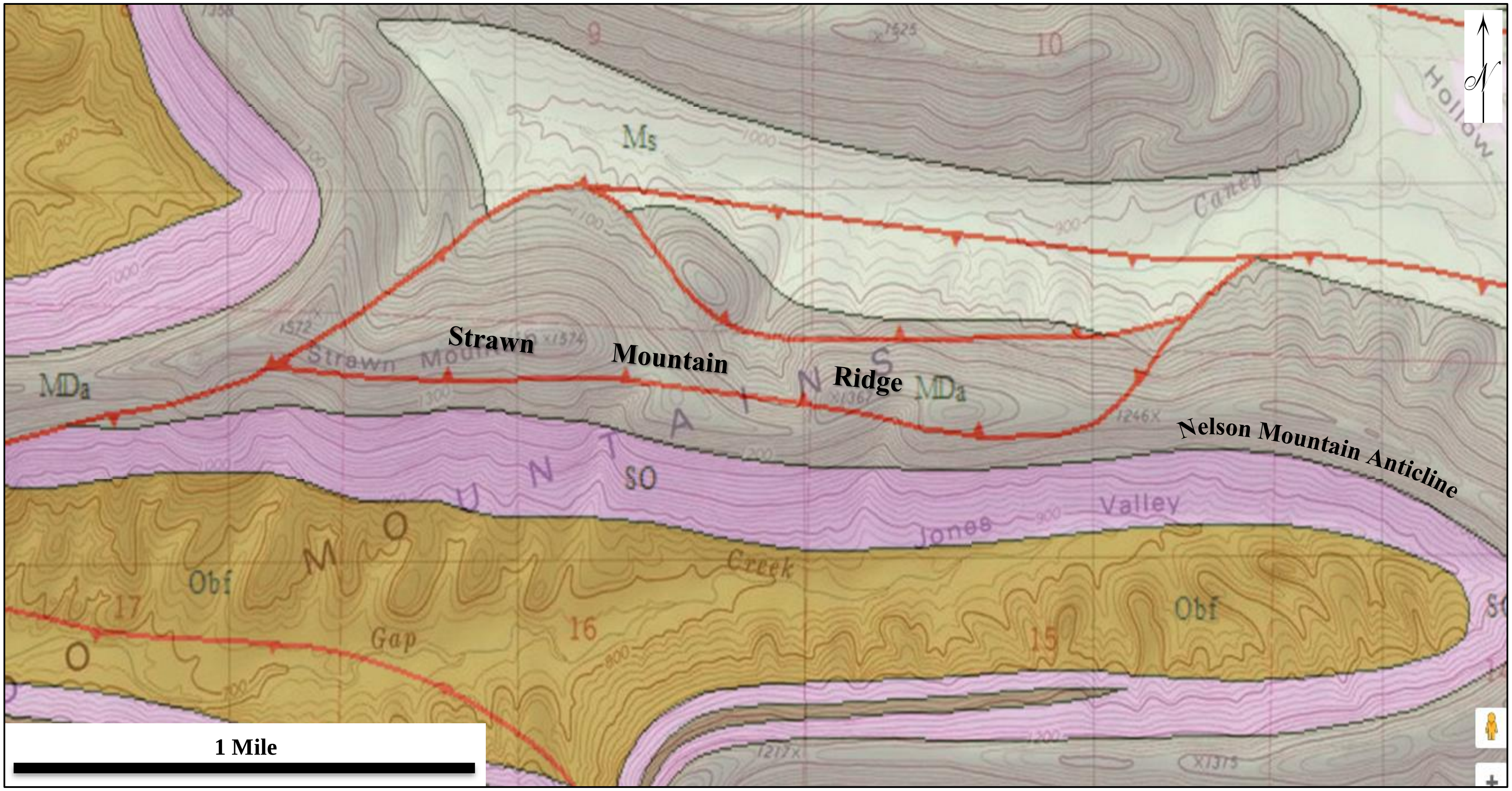


Figure 4.11. Simplified backthrust interpretation of Strawn Mountain from Haley et al. (2009). Units: Obf, Bigfork Chert; SO, Polk Creek and Missouri Mountain Shales; MDa, Arkansas Novaculite; Ms, Stanley Shale. Red lines interpreted as thrust faults with teeth on hanging wall block. See Figure 1.13 for legend.

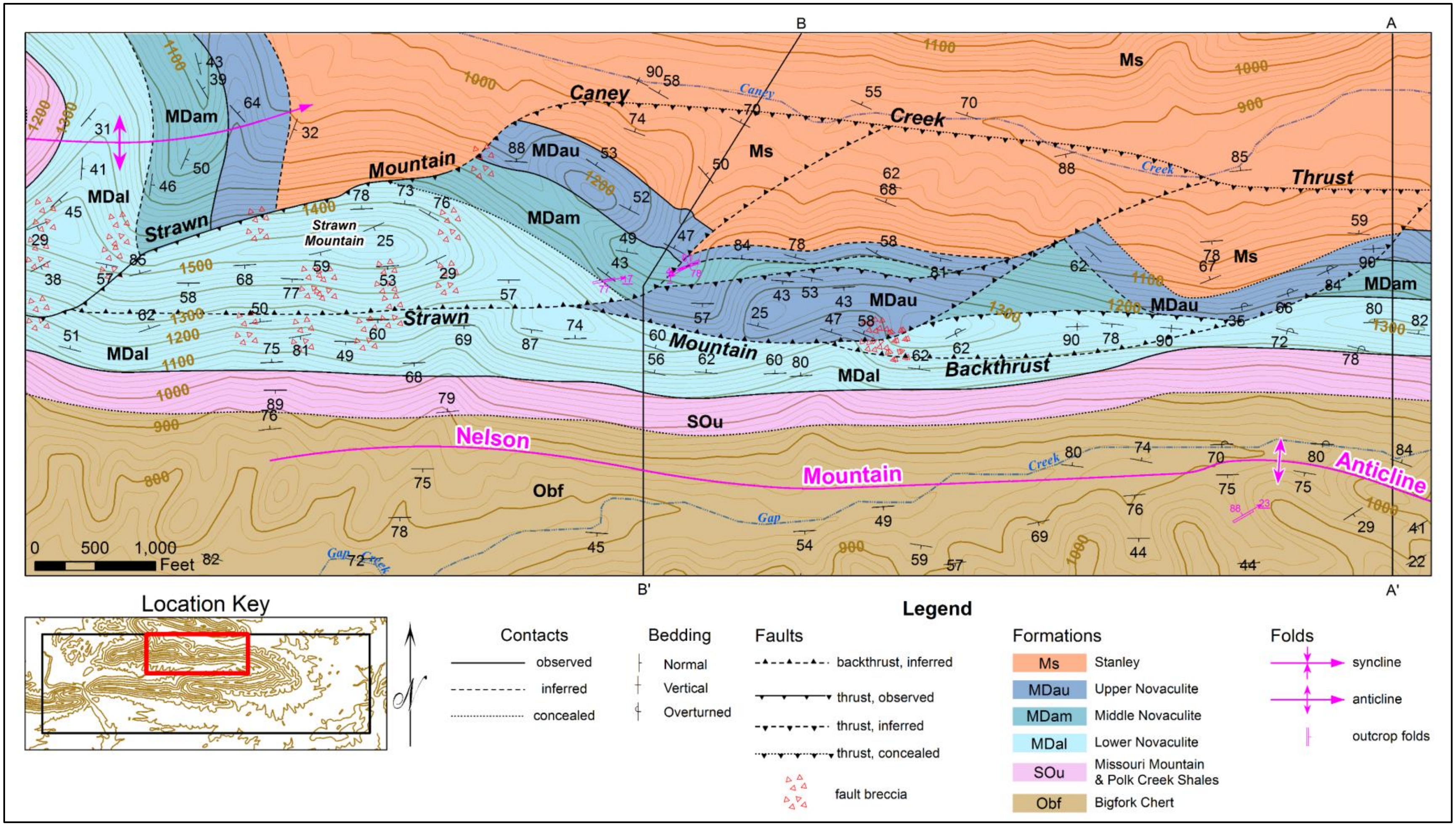


Figure 4.12. Overview map of the Strawn Mountain Ridge Backthrust. SM: Strawn Mountain. This interpretation is based on data collected in this study and shows approximately the same area as Figure 4.11.

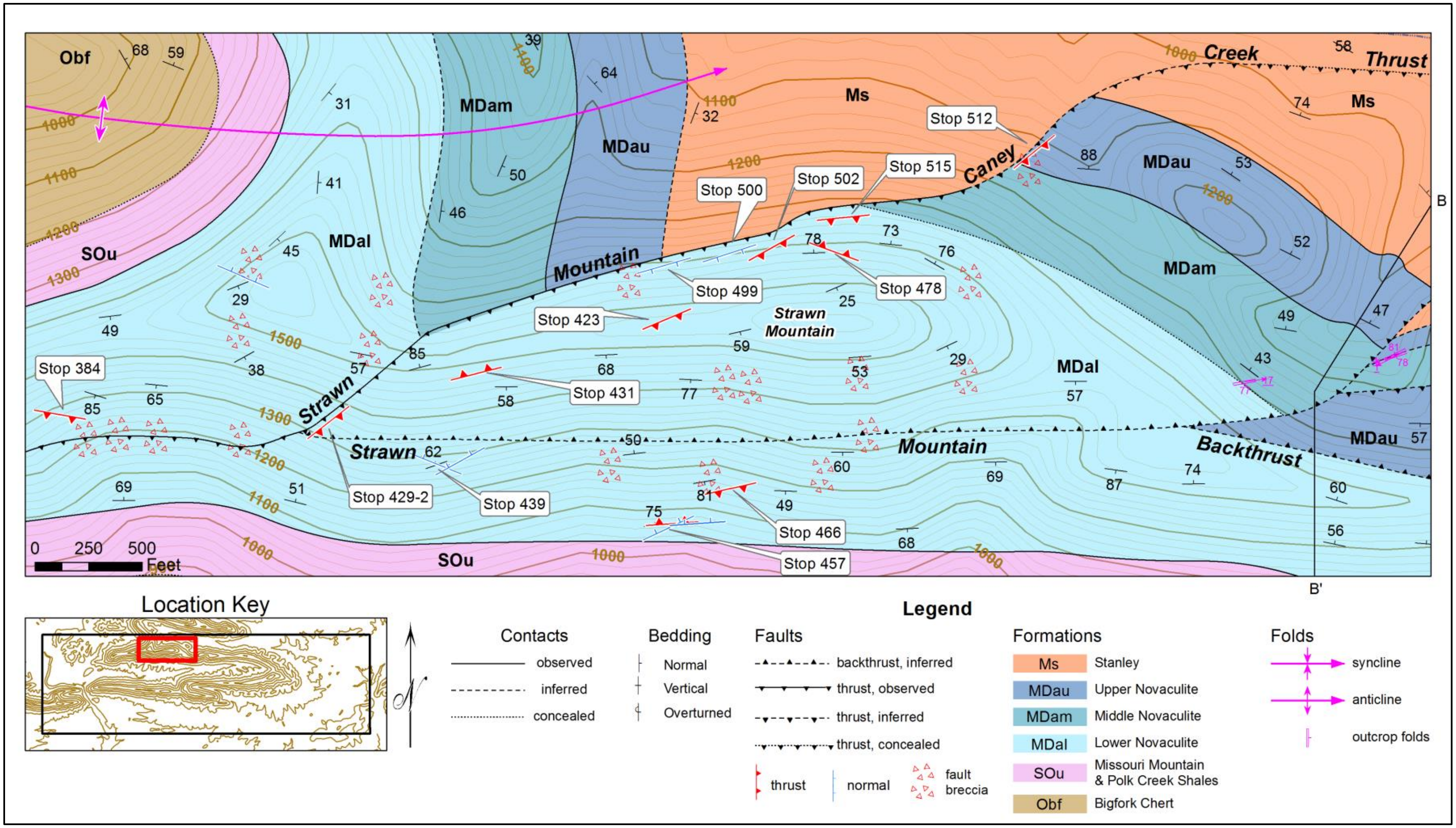


Figure 4.13. Map showing the locations of fault plane exposures and fault breccia outcrops discovered on Strawn Mountain.

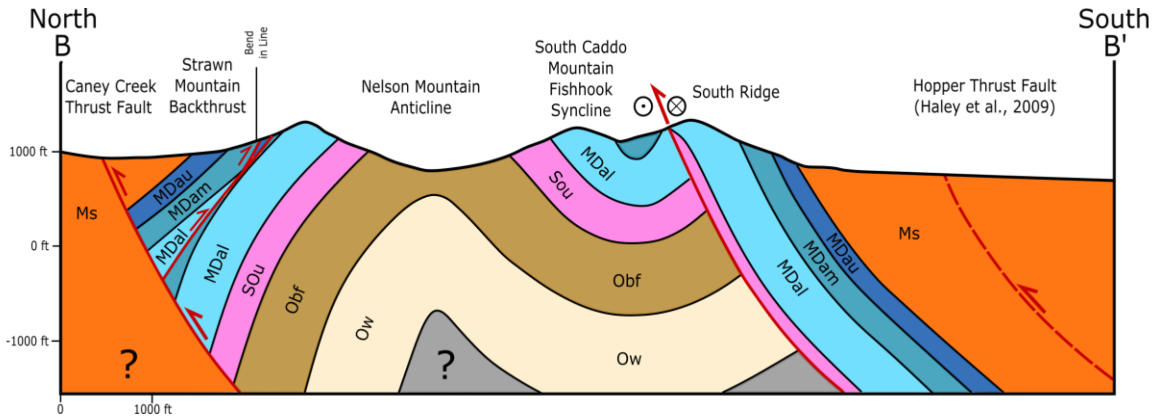


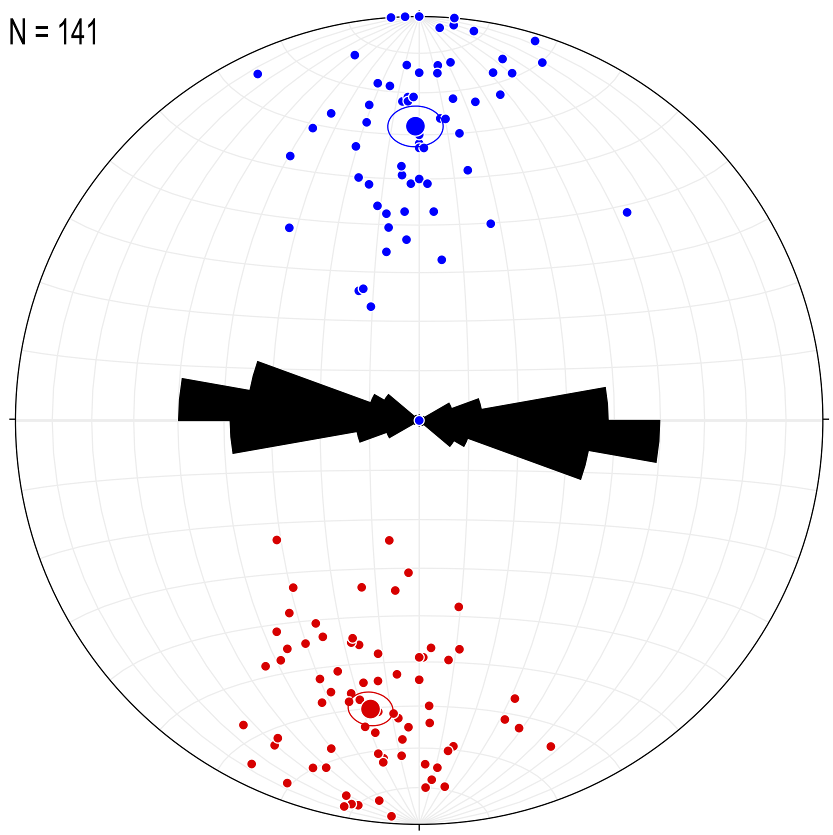
Figure 4.14. Cross section B-B' through the Strawn Mountain Backthrust, Nelson Mountain Anticline, and South Ridge. No vertical exaggeration. Note the inferred Hopper Thrust Fault (see Figure 4.6).

Bedding

Despite the amount of deformation that has occurred on SMR, bedding surfaces are common across the structure and can be traced for considerable distances. Over 140 bedding measurements were collected in the Arkansas Novaculite on SMR and these exhibit a consistent near east-west trend of N86°W (Figure 4.15). However, changes in dip direction along strike were encountered in some places, such as along the base of the Lower Novaculite on the south flank of Strawn Mountain.

Stereonet analysis confirms there are two distinct clusters of poles to bedding: the average strike and dip of north-dipping beds is N80°W, 62°NE and the average strike and dip of south-dipping beds is N89°E, 62°SE (Figure 4.15). Backthrusting likely resulted in local folding of the Arkansas Novaculite. Data in the block of Lower Novaculite forming the peak of Strawn Mountain suggest bedding may be folded into an antiform (Figure 4.13). No horizontal or subhorizontal bedding was found, as would be expected in the hinge zone of a fold, but it may not be preserved due to extensional fracturing in the hinge during folding. A block of Upper Novaculite about one-half mile to the east, interpreted to be bounded by backthrusts, appears to be folded into a synform based on bedding data (Figure 4.12). Only two outcrop-scale folds were found on SMR (in the Middle Novaculite) and only one of these folds had an axial plane orientation that agreed with the surrounding structural data (Figure 4.13).

Stereonet of Novaculite Bedding on Strawn Mountain Ridge



Mean Strike of Bedding: 274° (N86°W)

Average Strike and Dip of Beds:

North Dipping Beds: 280°, 62° (N80°W, 62°NE)

South Dipping Beds: 089°, 62° (N89°E, 62°SE)

Mean Vectors (Poles to Planes):

North Dipping Beds: 28°, 190° (28°, S10°W)

South Dipping Beds: 28°, 359°(28°, N01°W)

Figure 4.15. Stereonet of bedding (N=141) recorded on Strawn Mountain Ridge as poles to bedding with rose diagram. The average strike of bedding is 274° (N86°W).

Faults

Numerous fault surfaces were found in the Lower Novaculite and a few were also found in the Upper Novaculite on SMR. Most were apparently small and limited in lateral extent and were traceable in outcrop for an average of 10 or 20 feet before being lost in the outcrop or buried by cover. One prominent south-dipping thrust fault near the base of the Lower Novaculite was discovered on the north side of Strawn Mountain at Stops 499, 500, 502 and 515 (Figure 4.13). The fault could be traced at the outcrop for several hundred feet (Figure 4.16, Figure 4.17, Figure 4.18). Another thrust fault (Stop 512) was found along strike further downhill to the northeast in the Upper Novaculite (Figure 4.13) and may be related.

The average strike and dip of the continuous thrust fault surface from Stops 499, 500, 502, 512, and 515 is 069°, 54° (N69°E, 54°SE), which agrees with the inferred northeast-striking thrust fault mapped by Haley et al. (2009) that cuts through the ridge to the west of Strawn Mountain (Figure 4.11). Faint, suspected fault grooves at Stops 499 and 500 were 34°, 105° and 25°, 105°, respectively, and tension joints at Stop 499 indicate normal faulting. However, a few chatter marks at Stop 500 did not support this interpretation. At Stop 502, slickenlines on a well-polished surface trend 49°, 201° (S21°W) and chatter marks indicate thrust faulting. While no slickenlines were present at Stops 512 and 515, tension fractures at these locations also suggest thrust faulting.

Stereonet analysis of the fault data collected on SMR shows there is a prominent east-northeast trend of about N71°E (Figure 4.19). There appears to be two general groups of faults: one set dipping south and another dipping north.

Figure 4.16. Prominent fault cutting through the Lower Novaculite on the northwest slope of Strawn Mountain (Stop 499). Faint grooves (?) on the fault and possible tension joints in the footwall suggest oblique left-lateral normal faulting. View is looking west, hammer for scale.

Figure 4.17. Same fault surface at Stop 500, about 300 feet away. Footwall rocks were densely fractured to brecciated. Faint fault grooves (?) and conflicting chatter marks indicated both oblique left-lateral normal and oblique right-lateral reverse sense of slip. View is looking west, hammer for scale.

Figure 4.18. Subvertical, polished slickensided fault in Lower Novaculite at Stop 502 on the north side of Strawn Mountain. Chatter marks and tension joints indicate thrust faulting. Hammer for scale.

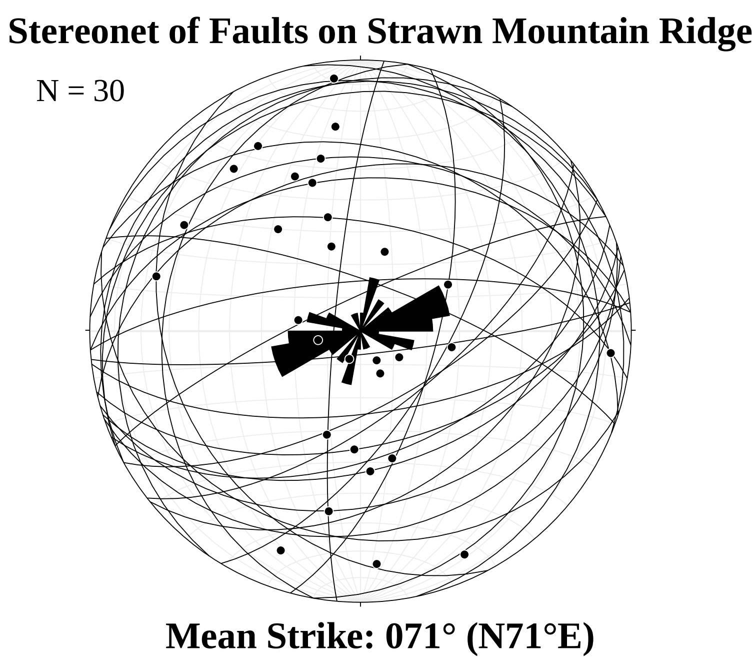


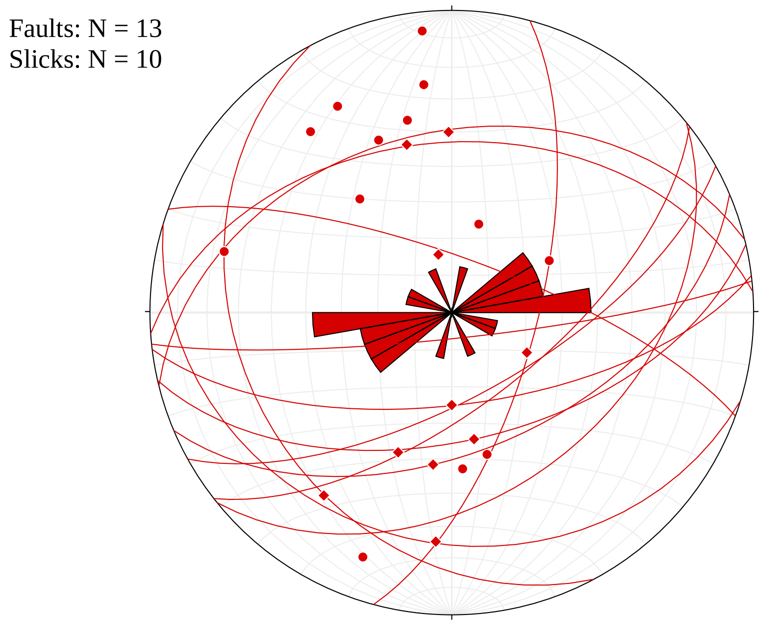
Figure 4.19. Stereonet of all fault planes measured on Strawn Mountain Ridge with rose diagram showing prominent northeast trend (N71°E). Poles to fault planes align along a trend of 162°, 85° (N18°W, 85° SW).

Stereonet analysis of the faults by sense of slip (Figure 4.20) shows very similar trends for apparent thrust faults (N76°E) and apparent normal faults (N75°E), suggesting they are related in some way. The apparent normal faults (such as Stop 499) may have originally been thrust faults that were reactivated with normal displacement during Mesozoic extension of Pangea and rifting of the Ouachita hinterland to the south. Field evidence for this reactivation will be discussed at the end of this section.

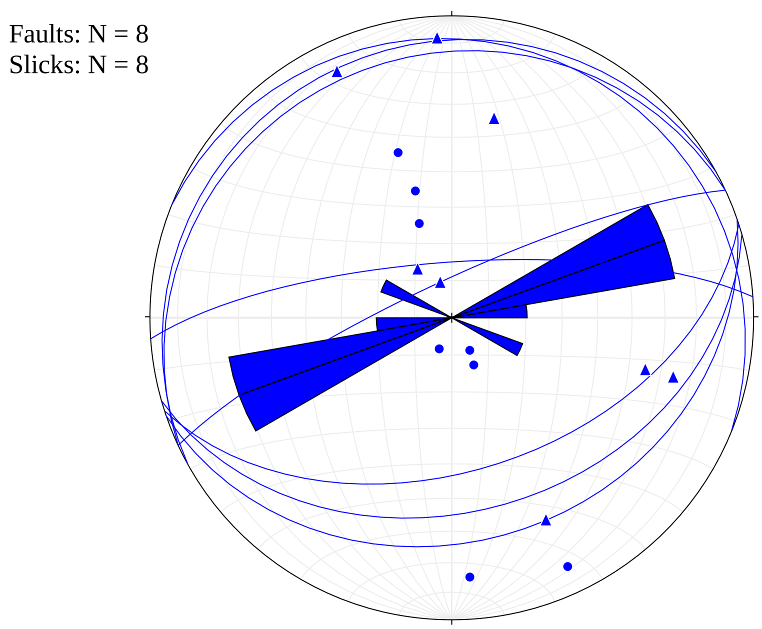
One possible explanation for why the normal and thrust faults in this area have essentially the same strike is that they are actually either one or the other. Chatter marks that might indicate normal or thrust movement are unfortunately faint on most surfaces, but the way the hanging wall juts up out of the ground suggests that most or all of the faults in this area are thrust faults. Another less likely possibility is that these area scissor faults with both senses of movement.

Bingham analysis shows the line of best fit to the slickenline data from apparent thrust faults is 181°, 86° (N01°E, 86°NW), consistent with north-directed compression associated with the Ouachita orogeny.

Stereonets of Thrust and Normal Faults on Strawn Mountain Ridge



Mean Strike of Thrust Faults: 076° (N76°E)



Mean Strike of Normal Faults: 075° (N75°E)

Figure 4.20. Stereonets of thrust and normal faults measured on Strawn Mountain Ridge. Top: thrust faults as planes and poles to planes (circles), slickenlines (where present) as ***red*** *diamonds. Bottom: normal faults as planes and poles to planes (circles), slickenlines (where present) as* ***blue*** *triangles.*

Two north-dipping fault surfaces in the Lower Novaculite located on the south flank of SMR (Figure 4.13) display two sets of slickenlines (Stops 439-2 and 457-1). At Stop 439-2, the orientation of the fault surface is N68°W, 9°NW; orientation of bedding just downhill of the fault is N71°E, 62°NW. This fault can be traced along strike for about 100 feet, but other exposures (Stops 439-3 and 439-4) do not display double slickenlines. The two sets of slickenlines plunge 8°, N10°W and 6°, N40°W (Figure 4.21). Chatter marks on both sets indicate normal faulting. Slickenlines at Stops 439-3 and 439-4 both plunge 08°, N03°W. Pronounced chatter marks at 439-4 also indicate normal faulting.


Figure 4.21. Double slickenlines at Stop 439-2. Scale card is 6 inches long and shows true north. Pencils aligned with slickenlines. These two sets of slickenlines have very similar trends and chatter marks suggest normal faulting.

Figure 4.22. Double slickenlines at Stop 457-1. Pencils aligned with slickenlines. Fault is oriented N72°W, 33°NE. Plunge and bearing of the slickenlines: 33°, N12°E (black pencil, L_{S1}) and 30°, N15°W (red pencil; L_{S2}). Chatter marks near L_{S2} indicate normal faulting while chatter marks near L_{S1} indicate thrust faulting.

Stereonet of Fault Data, Stop 439, Strawn Mountain Ridge

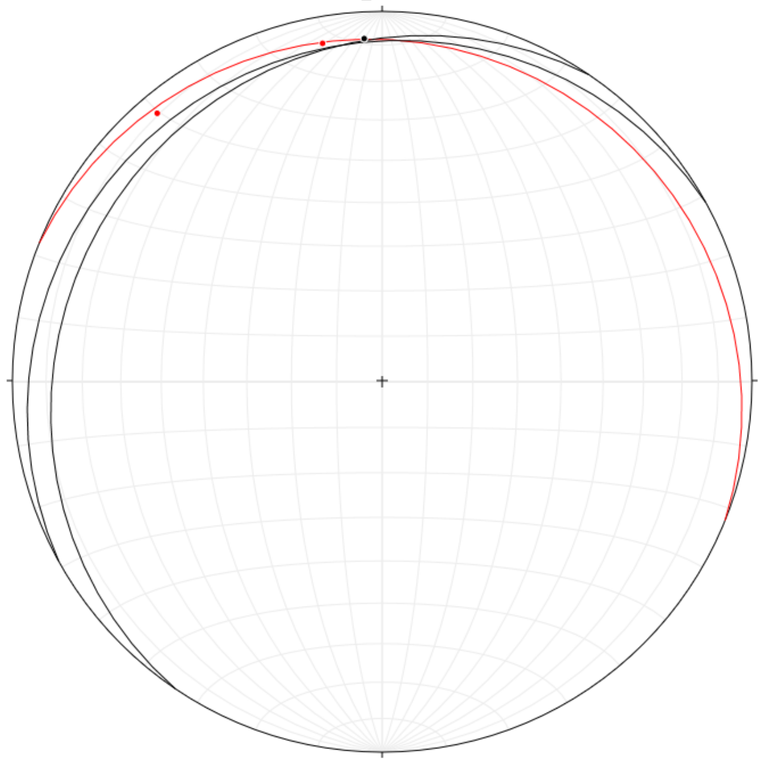


Figure 4.23. Stereonet of fault and slickenline data collected at Stop 439. Red data are Stop 439-2 (double slickenlines). Black data are from 439-3 and 439-4, slickenlines on both faults had the same plunge and bearing (8°, N03°W).

At Stop 457-1 (Figure 4.13; Figure 4.22), a fault oriented N72°W, 33°NE has two sets of slickenlines plunging 33°, N12°E (L_{S1}) and 30°, N15°W (L_{S2}). Chatter marks near L_{S2} indicate normal faulting, but chatter marks near L_{S1} indicate thrust faulting. This suggests possible reactivation of this fault surface. Fault surfaces several feet to the west of this location have only one set of slickenlines but also have conflicting chatter marks (both normal and thrust sense of slip).

Fishhook Folds – South Caddo Mountain and Arrowhead Mountain

Within the south part of the study area there are two macroscopic folds where bedding has been folded around sharply, resembling the curve of a fishhook in map view (Figure 4.4). These fishhook folds, one located at the western terminus of the south limb of the Nelson Mountain Anticline (South Caddo Mountain; Figure 4.24) and another at the western terminus of the South Ridge (Arrowhead Mountain; Figure 4.25), form east-plunging synclines of resistant Novaculite. While these folds appear to involve the entire stratigraphic section from the Bigfork Chert upwards into the Stanley Shale, most data on these folds were in the Lower Novaculite Member as the other units are very poorly, if at all, exposed on these folds.

Stereonet analysis shows these folds are remarkably similar in geometry and attitude (Figure 4.26, Figure 4.27): the average axial planes are N70°W, 71°SW and N71°W, 81°SW for the South Caddo Mountain and Arrowhead Mountain folds, respectively. Likewise, the plunge and trend of the fold axes are 37°, S55°E and 40°, S63°E for South Caddo Mountain and Arrowhead Mountain, respectively.

The similar geometry and juxtaposition of these folds against east-west ridges of Arkansas Novaculite suggests they may have formed by the same mechanism. Previous geologic maps (Evansin, 1976; Zimmerman et al., 1984; Haley et al., 1993; Haley et al., 2009) show major thrust faults passing between each fishhook fold and the east-west ridges (Figure 1.13); however, field work for this study did not find convincing evidence for thrust faulting in these areas. It is possible that the thrust faults are not exposed in these areas due to intense brittle deformation and subsequent weathering out of the weakened rocks expected in such fault zones. However, the number of prominent strike-slip faults with near-horizontal slickenlines that are present on the South Ridge immediately adjacent to South Caddo Mountain suggests that these folds formed by a different mechanism. While field work did not find a similar network of prominent strike-slip faults on the east-west ridge south of and adjacent to Arrowhead Mountain (Figure 4.25), some evidence for strike-slip faulting was found in this area on a small fault surface.

An alternative hypothesis explaining the formation of these folds via strike-slip faulting will be discussed in the next chapter.

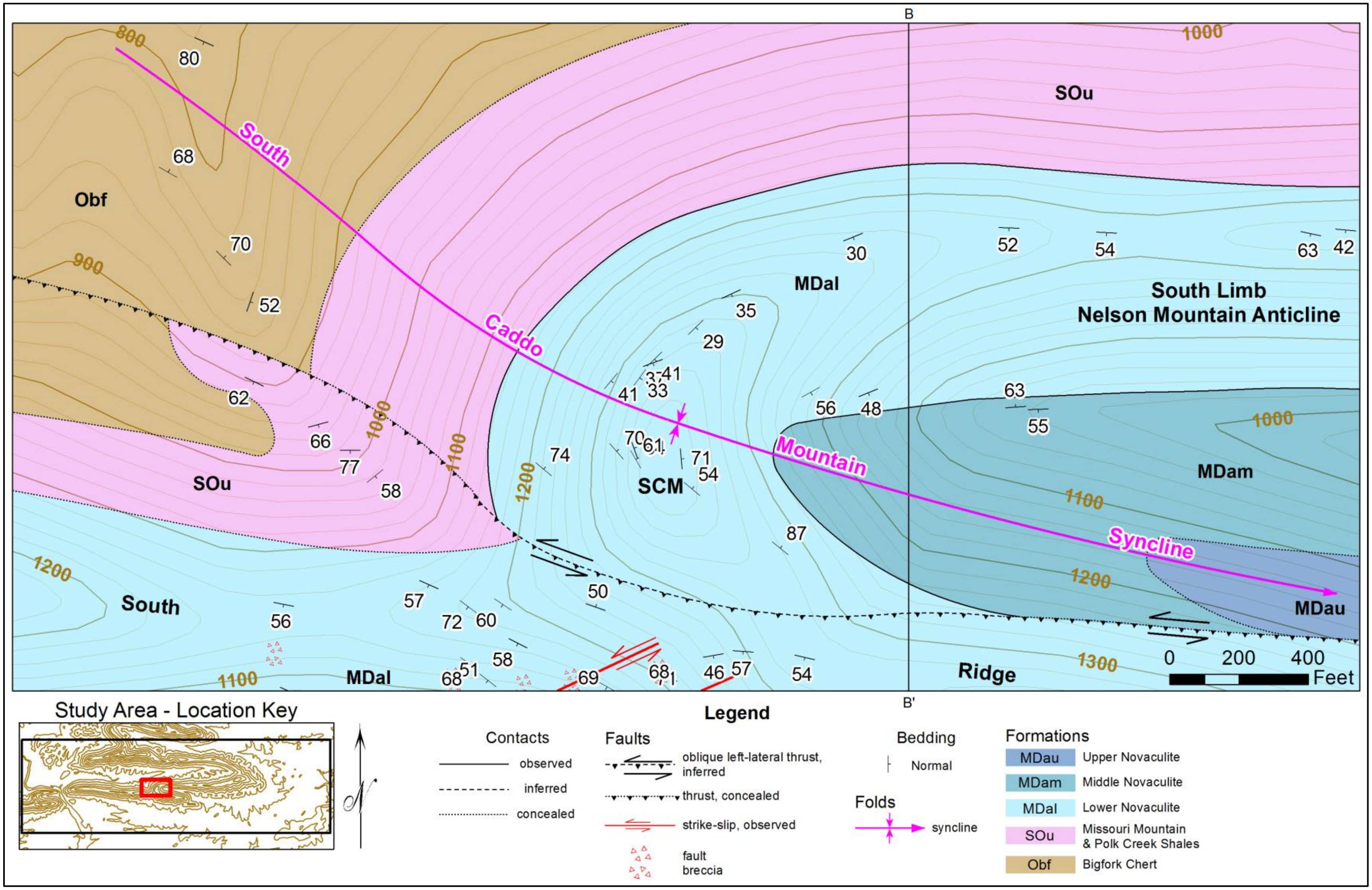


Figure 4.24. South Caddo Mountain Fishhook Fold. SCM: South Caddo Mountain. Note the South Ridge strike-slip faults at bottom of map.

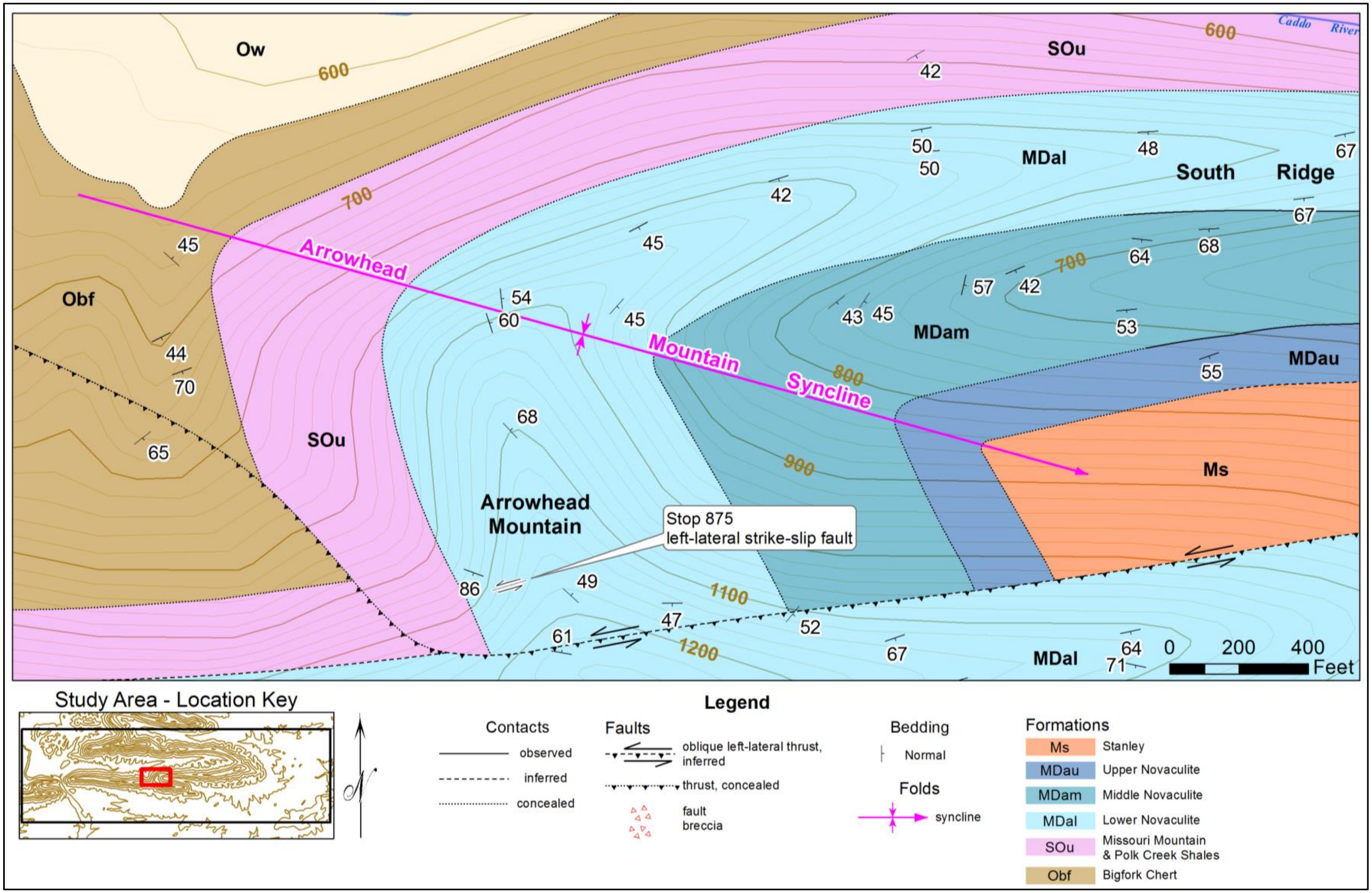
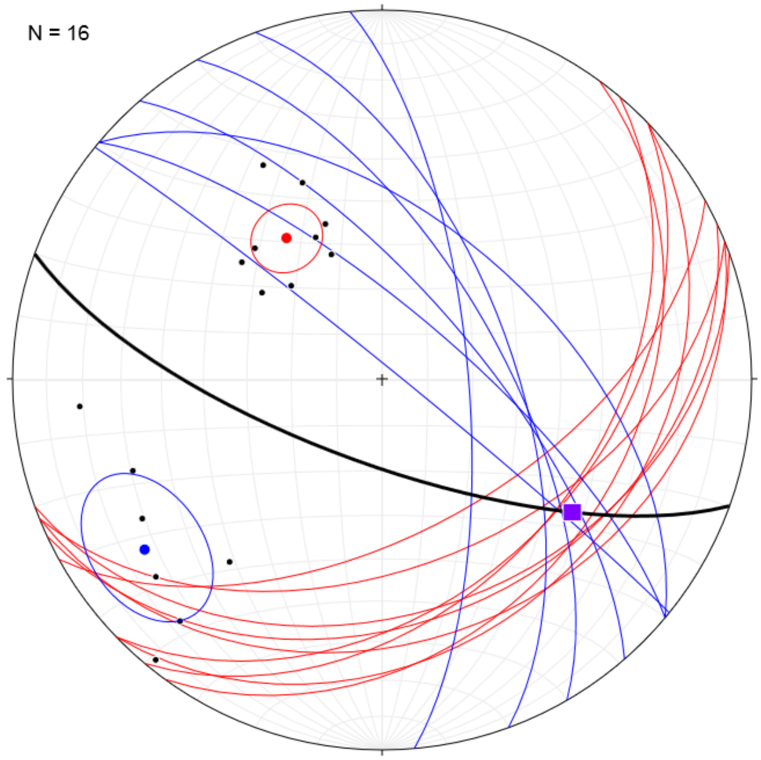


Figure 4.25. Arrowhead Mountain Fishhook Fold.

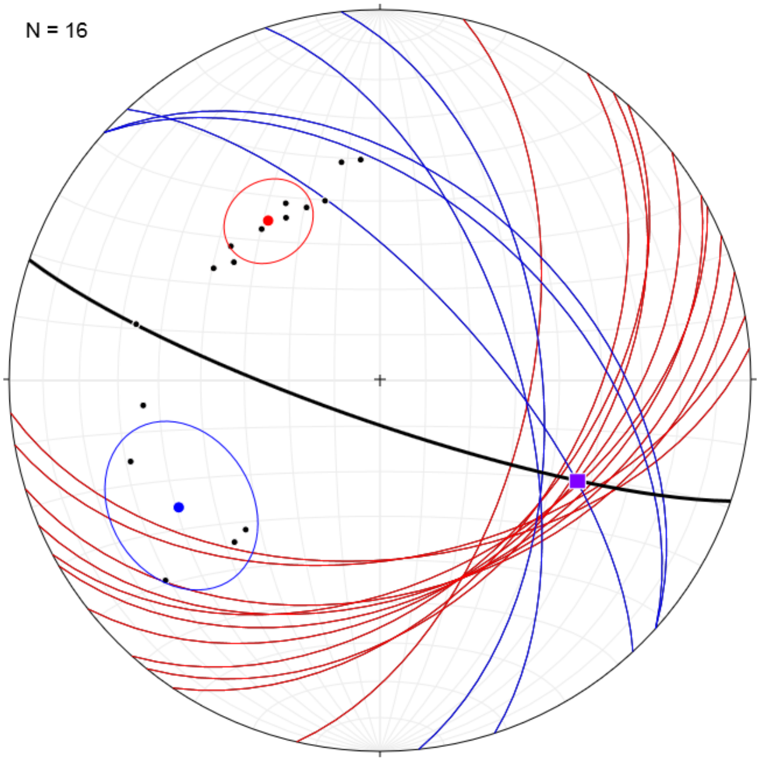
Stereonet of Bedding on South Caddo Mountain Fishhook Fold



Average Strike and Dip of Beds:
North Limb: 056°, 38° (N56°E, 38°SE)
South Limb: 325°, 68° (N35°W, 68°NE)
Mean Vectors (Poles to Planes):
North Limb: 52°, 326° (52°, N34°W)
South Limb: 22°, 235°(22°, S55°W)
Average Fold Axial Plane (black line):
110°, 71° (N70°W, 71°SW)
Fold Axis (purple square):
37°, 125° (37°, S55°E)

*Figure 4.26. Stereonet diagram of Lower Novaculite beds (n = 16) on the syncline of the South Caddo Mountain Fishhook Fold as planes and poles with mean vectors (south limb=**blue**; north limb=**red**). The larger transparent circle within the poles represents the average pole with a 95% certainty (Allmendinger, 2013). Average axial plane:**black great circle**, fold axis: **purple square**).*

Stereonet of Bedding on Arrowhead Mountain Fishhook Fold



Average Strike and Dip of Beds:

North Limb: 055°, 44° (N55°E, 44°SE)

South Limb: 328°, 54° (N32°W, 54°NE)

Mean Vectors (Poles to Planes):

North Limb: 46°, 325° (46°, N35°W)

South Limb: 36°, 238° (36°, S58°W)

Average Fold Axial Plane (black great circle):

109°, 81° (N71°W, 81°SW)

Fold Axis (purple square):

40°, 117° (40°, S63°E)

*Figure 4.27. Stereonet diagram of all bedding (n = 16) on the syncline of the Arrowhead Mountain Fishhook Fold as planes and poles to planes with mean vectors (south limb=**blue**; north limb=**red**). The larger transparent circle within the poles represents the average pole with a 95% certainty (Allmendinger, 2013). Average axial plane:**black great circle**, fold axis: **purple square**).*

South Ridge

Introduction

The South Ridge extends west-east across the southern part of the study area and is dissected by the Caddo River at Caddo Gap (Figure 1.4; Figure 1.5; Figure 4.28). Field work for this study found previously unmapped, steep to vertical strike-slip faults within the Arkansas Novaculite on the South Ridge immediately adjacent to South Caddo Mountain. Because of the intense deformation and faulting observed in this area, it was mapped at detailed (1:2,000) scale (Figure 4.31) to better understand the mechanics of this faulting.

Bedding

At map scale, the South Ridge is a relatively linear ridge of resistant Arkansas Novaculite with beds dipping moderately to steeply south (Figure 4.14), but in some places beds are subvertical, such as the base of the Lower Novaculite on the Caddo River. At outcrop scale, many small local structures can be observed. Stereonet analysis of 141 bedding measurements (Figure 4.29) on the ridge show an average orientation of 099°, 59° (N81°W, 59°SW).

Strike-Slip Faulting

Large planar fault surfaces were observed at Stops 50, 111, 121, 914, 917, 918, and 919 (Figure 4.31). Slickenlines, chatter marks and tension fractures indicate left-lateral slip on these faults (Figure 4.32, Figure 4.33), except for right-lateral faulting at Stops 111 (Figure 4.34), 917 and 918. While tension fractures at Stops 917 and 918 indicate right lateral slip, a prominent fault surface at Stop 919, just 25-30 feet downhill has juxtaposed Middle Chert and Shale beds on the east side of the fault with Lower Novaculite beds on the west side of the fault (Figure 4.31). Since the bedding dips south, this offset would require left-lateral faulting.

Interpretation of high-resolution Google Earth imagery (Figure 4.30) shows two prominent, northeast linear trends in the fault breccia that is widespread in this area (Figure 4.35).

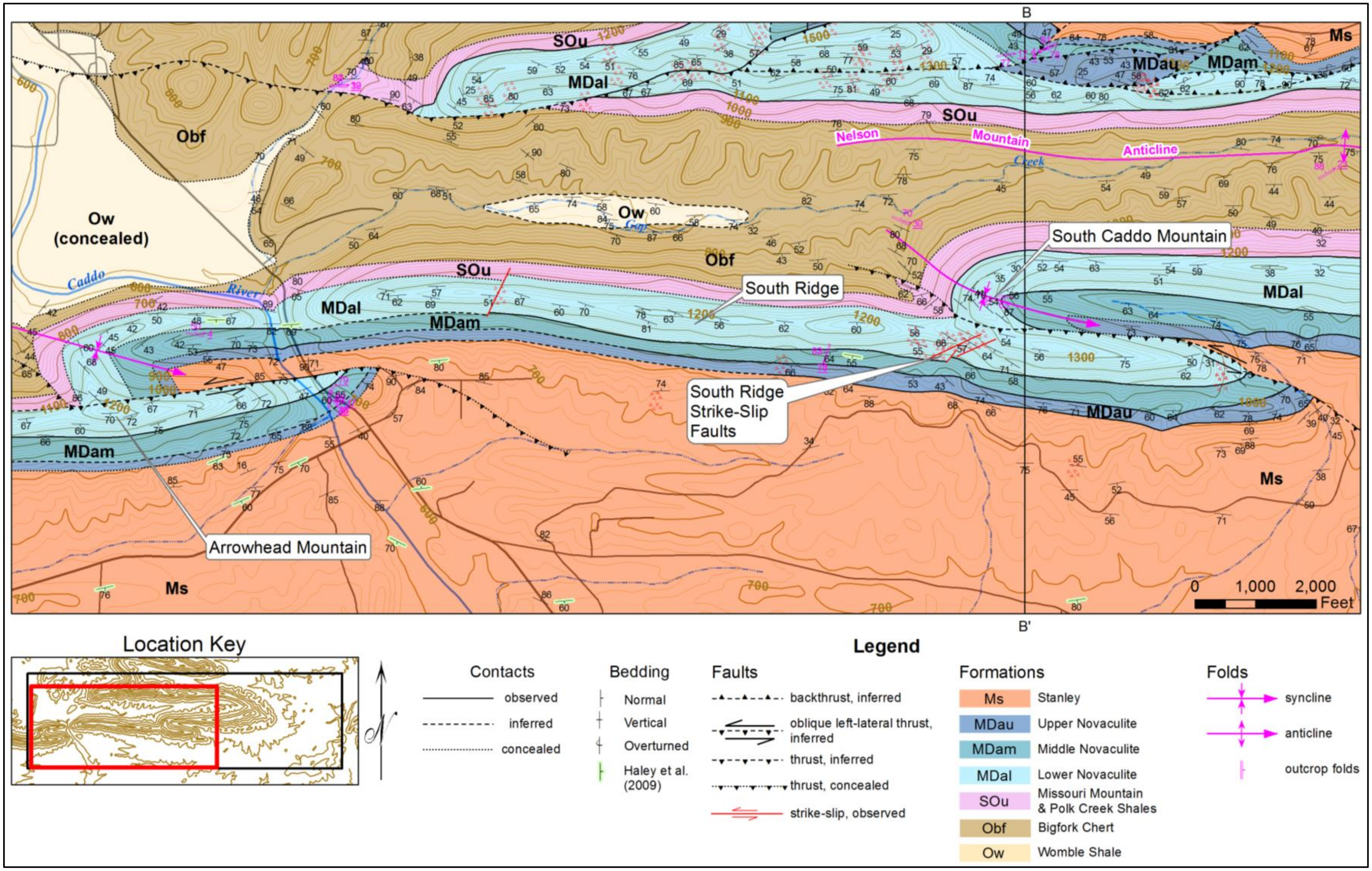
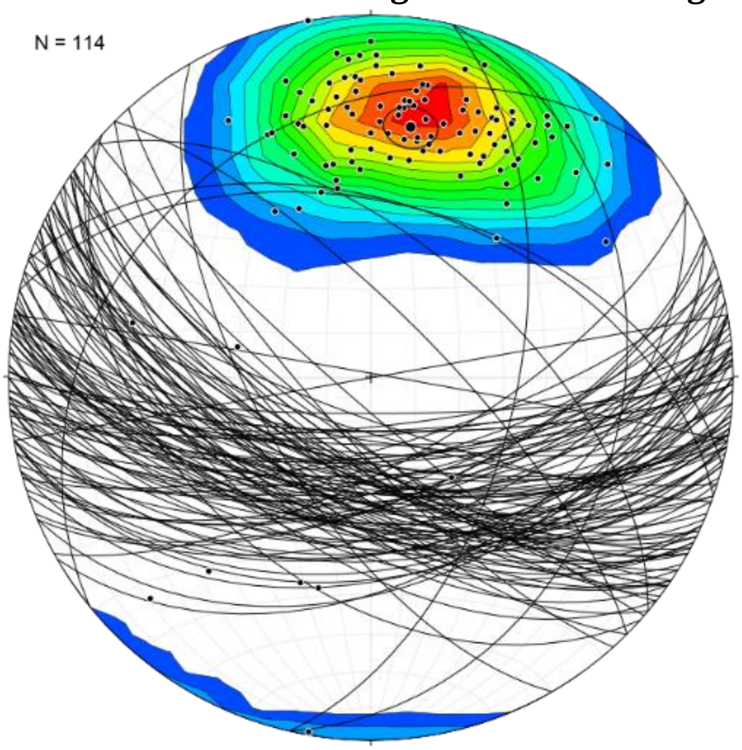


Figure 4.28. Geologic map of the South Ridge and adjacent structures.

Stereonet of Bedding on the South Ridge



Average Bedding: 099°, 59° (N81°W, 59°SW)
Mean Vector (poles to planes): 31°, 009° (31°, N09°E)

Figure 4.29. Stereonet of bedding in Arkansas Novaculite along the South Ridge.

Several other small fault surfaces were observed in the area. Large outcrops of massive Lower Novaculite breccia occur throughout the area, probably the result of brittle deformation related to the strike-slip faulting. In all, 15 reliable strike-slip faults were measurements were recorded in the area. Unfortunately, due to the thick soil and vegetative cover, lack of conspicuous marker beds and intense deformation in the Lower Novaculite in this area, the amount of displacement on these faults cannot be quantified. However, the large outcrops of breccia that occur here suggest significant displacement. At Stop 919, the contact between the Lower and Middle Novaculite members is offset by approximately 100 feet (Figure 4.31).

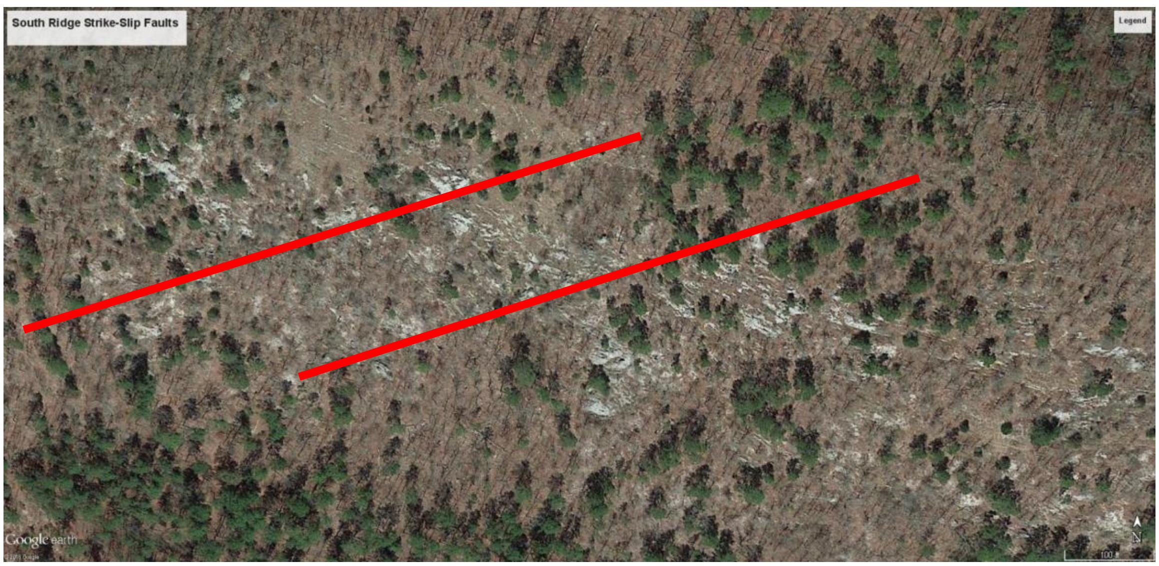


Figure 4.30. Top: Google Earth (2017) view of South Ridge immediately south of South Caddo Mountain. Note how the west-northwest trend of bedding appears to be cut or interrupted along northeast linear trends. Bottom: Interpretation of faults from aerial imagery and field data (Figure 4.31). Scale bar in lower right of figures is 100 feet across.

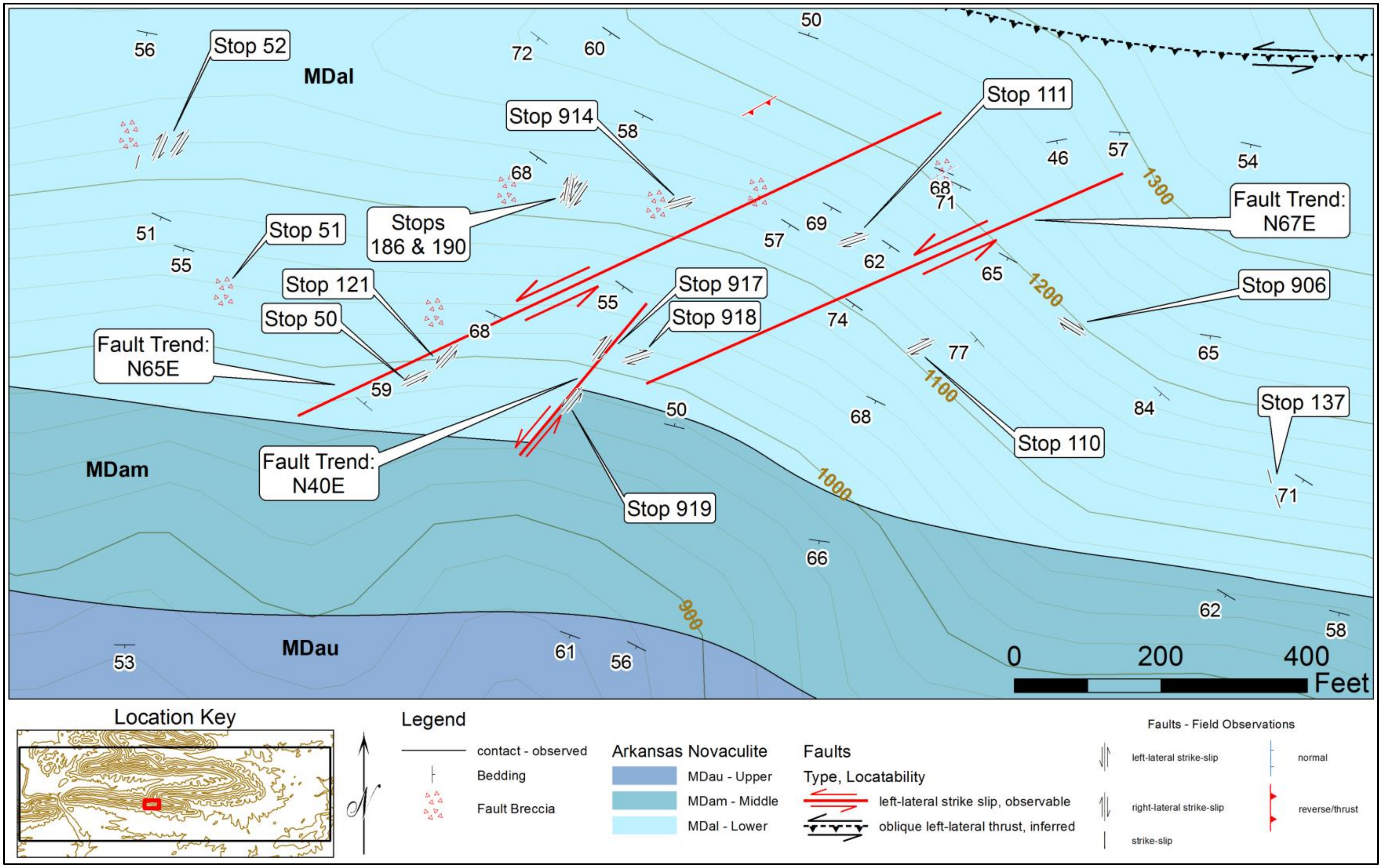


Figure 4.31. Strike-slip faults in the Arkansas Novaculite on the South Ridge. The main strike slip faults (shown in ***red****) are interpreted from field data as well as prominent linear trends in fault breccia observed in high resolution aerial photography from Google Earth (2017).*

Figure 4.32. Large planar strike-slip fault surface (approximately 8 ft. high by 15 ft. across) in Lower Novaculite (Stop 50; see Figure 4.31 for location). Horizontal slickenlines and chatter marks indicate left-lateral slip; ***red*** *arrow points in the shear direction of missing block.*

Figure 4.33. Horizontal slickenlines on left-lateral strike-slip fault (Stop 50;Figure 4.32). Pencil points in the shear direction of missing block.

Figure 4.34. Right-lateral strike-slip fault with slickenlines at Stop 111 (see Figure 4.31 for location). Brunton for scale.

Figure 4.35. Large outcrop of massive Lower Novaculite breccia on the South Ridge (Stop 51, about 285 feet northwest from Stop 50; see Figure 4.31 for location). Bedding is completely obliterated. Such outcrops are common in the area of strike-slip faulting on the South Ridge. Notebook and hiking pole for scale.

Stereonet analysis of the fault data shows a prominent northeast (N39°E) trend with a possible secondary trend of about N75°E (Figure 4.36). The N39°E trend matches the strike of the fault offsetting the Lower and Middle Arkansas Novaculite at Stop 919, while the N75°E trend agrees with the two inferred faults from aerial imagery (Figure 4.30) and detailed field mapping (Figure 4.31).

These strike-slip faults are located directly adjacent to the South Caddo Mountain fishhook fold and therefore they may be local features related to the formation of that structure. Mapping on the South Ridge, both to the west and east, found no other prominent strike-slip faults similar to the faults in this area. A strike-slip fault was inferred at Stops 59-62 (located about 1.5 miles west) where a subvertical left-lateral strike-slip fault trending about N26°E was found in the Lower Novaculite (Figure 4.28). Inspection of aerial photography also confirms field mapping observations that the massive beds near the base of the Lower Novaculite are offset with left-lateral sense by about 115 feet. This fault appears to be located on a flexure in the South Ridge where the strike of bedding changes from east-west to more west-northwest. Therefore, this fault is probably a local structure and unrelated to the strike-slip faults on the South Ridge adjacent to South Caddo Mountain.

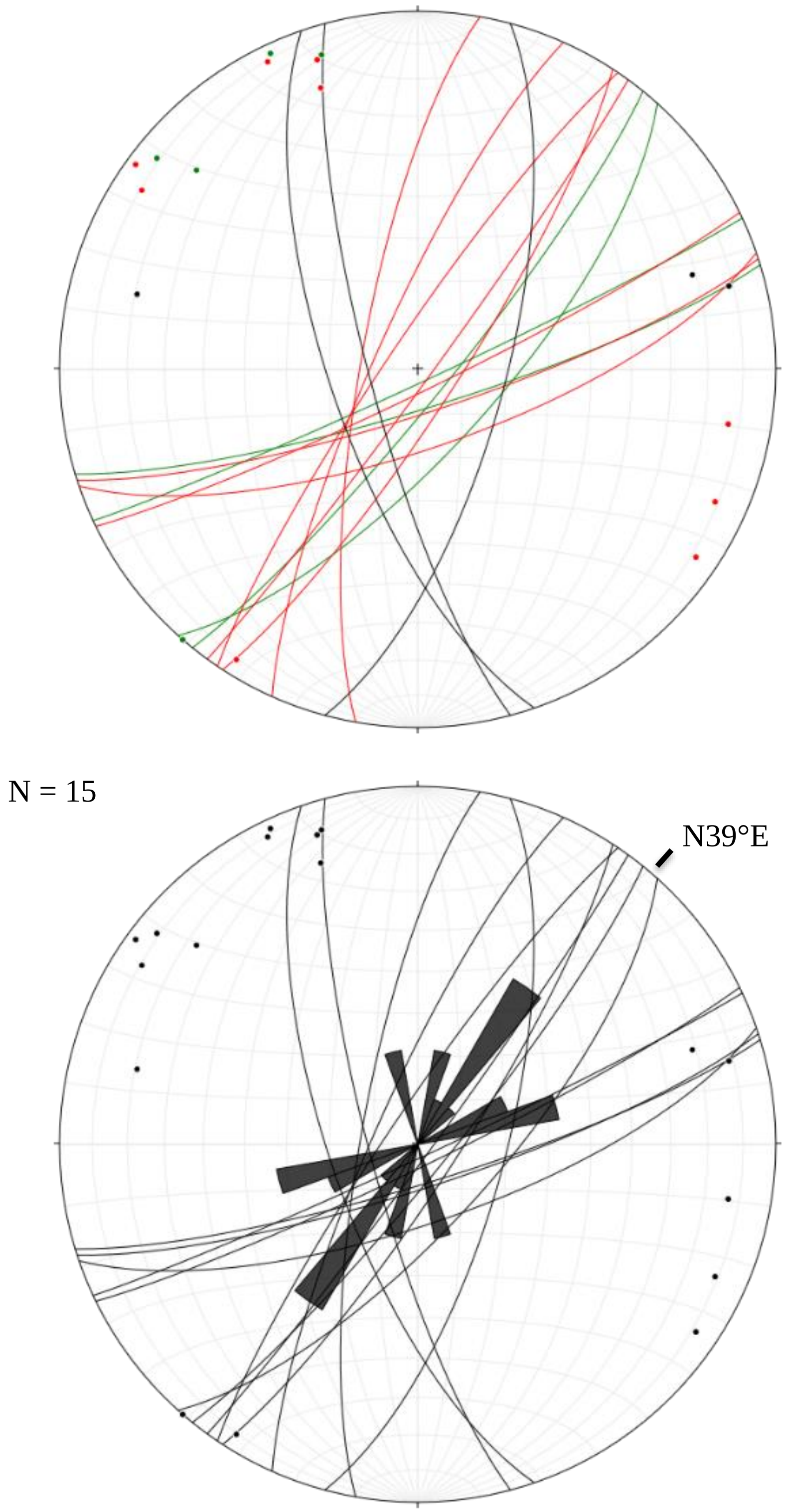


*Figure 4.36. Stereonets of the strike-slip faults discovered on the South Ridge. Top: planes and poles to planes (**green**: left-lateral, **red**: right-lateral, **black**: strike-slip sense unknown). Bottom: rose diagram of strike-slip faults with mean vector of N39°E.*

CHAPTER 5

Discussion

Introduction

The main goals of this study were to determine the geology and structures of the southern portion of the Caddo Gap quadrangle and to better understand the structural evolution of this part of the Ouachita thrust belt. Detailed field mapping resulted in a new geologic map with careful delineation of the structures and geologic units of the area and included mapping out the three informal members of the Arkansas Novaculite (Figure 5.1).

An area of prominent strike-slip faulting was found on the South Ridge that has not been reported in the literature nor shown on other geologic maps of the area. In addition, the geometry of the fishhook folds forming South Caddo and Arrowhead Mountains may suggest a different style of faulting than previous interpretations for this part of the Caddo Mountains.

The structure previously interpreted as a backthrust forming Strawn Mountain and the adjacent ridge (Haley et al., 2009) on the north side of the study area was confirmed but was found to be more complex than previously thought. A high concentration of bedding and fault measurements, coupled with numerous float observations in the Arkansas Novaculite, provided a better, though still partially inferred, delineation of this structurally complex area. The structures found in the study area are discussed in more detail in this chapter.

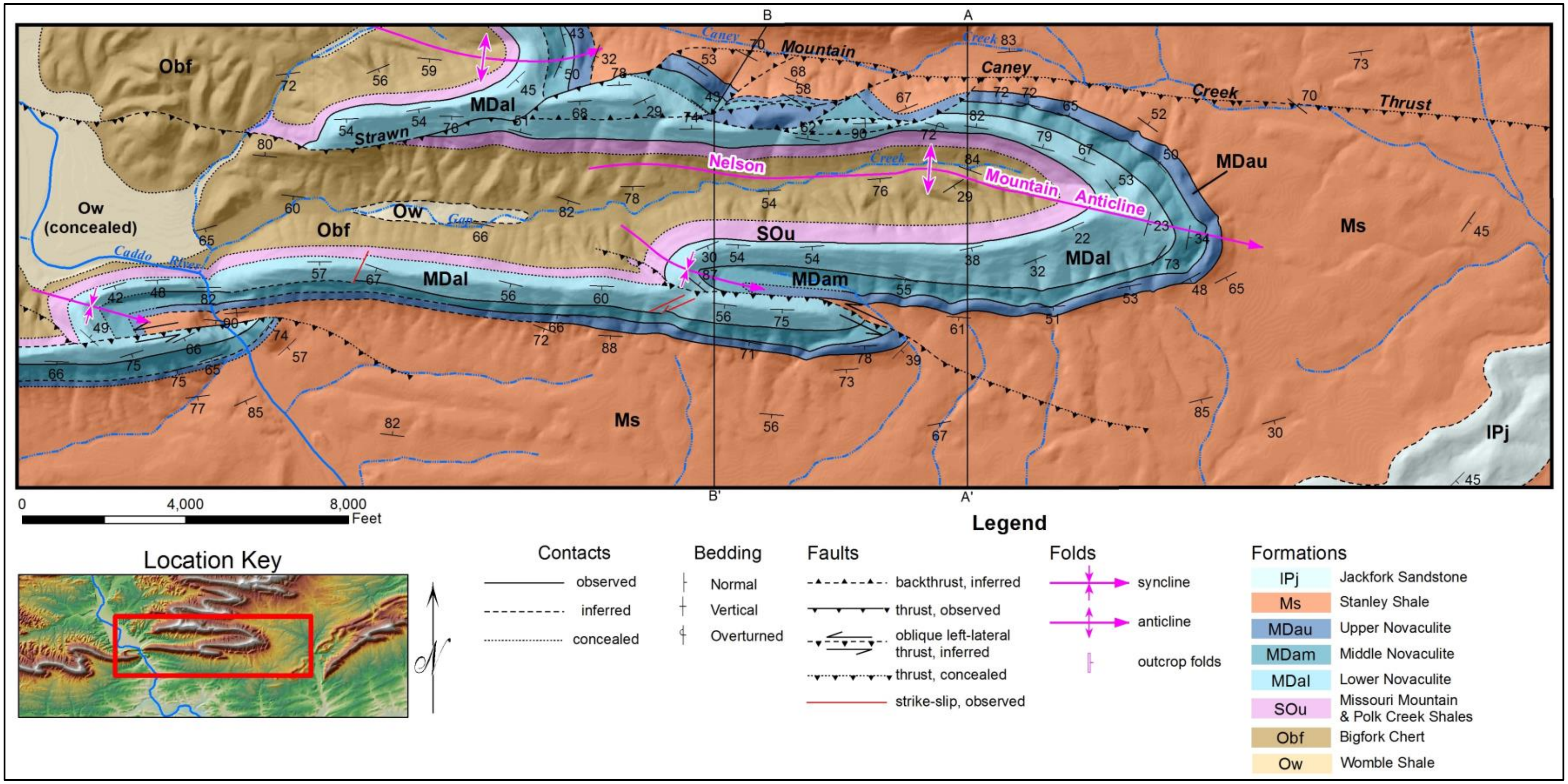


Figure 5.1. Geologic map of the southern portion of the Caddo Gap quadrangle.

Folding

Introduction

One objective of this study was to determine the mechanics and style of folding in the area. The effects of folding are readily apparent in the long, straight, narrow ridges and valleys of this part of the Ouachita fold belt (Figure 1.5). However, good outcrops of actual rocks are scarce and sporadic because the area is heavily forested. The best exposures for examining and analyzing the mesoscopic-scale folding of the study area are at the Caddo Gap road cut along Arkansas Highway 8 and the abandoned rail grade just below the highway (Evansin, 1976; Zimmerman, 1984). The geologic map and cross sections produced in this study provide additional insight into the evolution of map-scale folding in the area.

The Caddo Gap road cut is an excellent exposure of the Arkansas Novaculite and both the stratigraphy and structure at this location have been studied in great detail by previous researchers (Evansin, 1976; Zimmerman, 1984). Frequent visits and examination of the road cut in this study more or less confirmed those observations (Figure 1.12) made by Zimmerman (1984); however, even at 1:12,000 scale, the high level of geologic detail that is observed from the road cut cannot be mapped beyond the area directly adjacent to Caddo Gap because of the relatively poor field outcrops and thick forest cover (Figure 5.2).

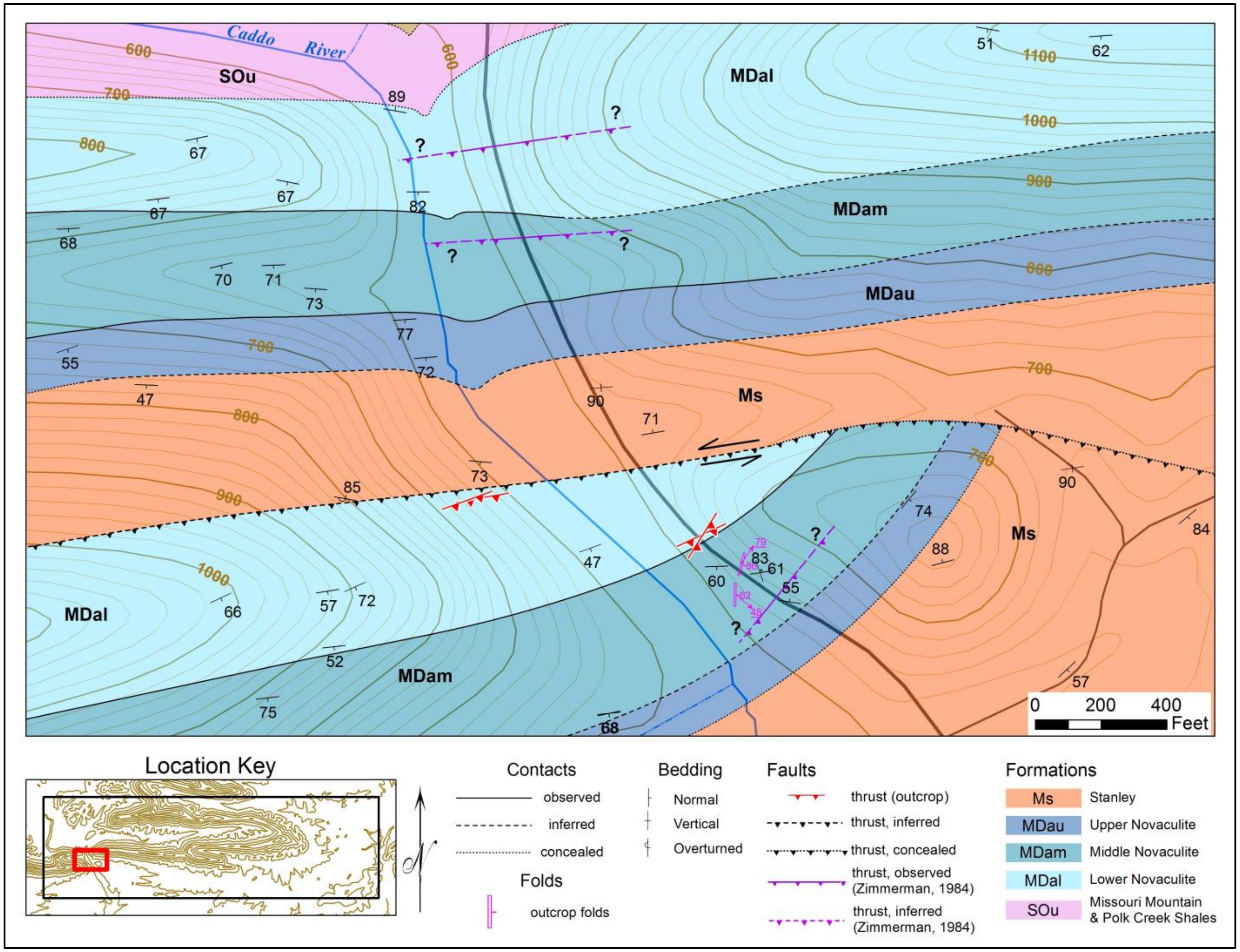


Figure 5.2. Inset (detailed) map of the Caddo Gap section with major road cut structures of Zimmerman (1984) shown in ***purple****. See Figure 1.12 for the detailed road cut section and associated structures.*

Syndepositional Slumping

Previous researchers (Evansin, 1976; Roths, 1988) have suggested some of the mesoscopic folds seen in the Caddo Mountains may be syndepositional slump features, based on their sense of rotation relative to other folds. Evansin (1976) used structural analysis and outcrop observations from the Caddo Gap road cut to interpret that a large fold in the Lower Novaculite (his "Fold 18"), about 60 feet south of the contact with the underlying Missouri Mountain Shale (Figure 5.3), is a syndepositional slump fold.

Because of the limited number and isolated nature of folds observed in this study away from the highway road cut, and the small lateral extent of fold exposures along the heavily forested ridges, this study was unable to find any additional syndepositional slump folds. The main ridge-forming folds, however, are clearly tectonic in origin.

Figure 5.3. Fold in Lower Novaculite beds at the north end of the Caddo Gap road cut. Evansin (1976) interpreted this fold as a syndepositional slump feature and not tectonic.

Compressional Tectonics

Folding in the Ouachita Mountains was caused primarily by compressional stresses resulting from the Late Paleozoic collision of the Sabine, Monroe and Yucatan microcontinents with southern Laurentia (Figure 3.13; Whitaker and Engelder, 2006), followed by suturing of Laurentia with Gondwana in the final assemblage of the supercontinent Pangea in the Early Permian (Figure 5.4). As the Iapetus Ocean closed ahead of the approaching landmasses, the deep water pre-orogenic Ouachita facies rocks deposited off the Laurentian craton were transported northwards to their present position in the Benton and Broken Bow Uplifts (Figure 2.1; Blythe, 1988; Viele and Thomas, 1989). The Broken Bow and Benton uplifts record multiple phases of compressional and oblique tectonics (Evansin, 1976; Buthman, 1982; Viele and Thomas, 1989).

Evansin (1976) discussed a possible sequence of at least two, possibly three phases of tectonic folding at Caddo Gap. The first phase was north-directed compression forming east-west oriented mesoscopic folds. The second phase was characterized by northeast-directed compression forming the NW-trending macroscopic folds of the Caddo Mountains (inferred folds north of Strawn Mountain), refolding the earlier east-west mesoscopic folds. Evansin suggests the macroscopic Nelson Mountain Anticline formed either contemporaneously or, more likely, during a subsequent third phase of north-directed compression.

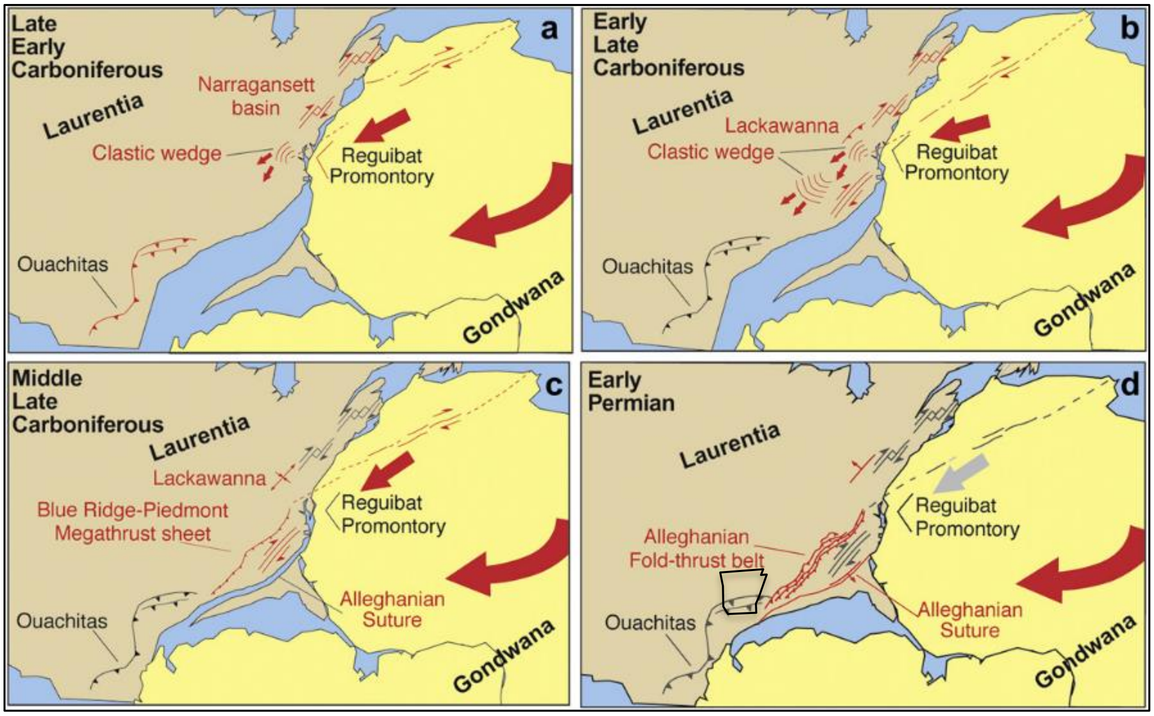


Figure 5.4. Oblique rotational collision between Laurentia and Gondwana after Hatcher (2002). Symbols in red identify features active during the time interval represented. a: Initial contact between Laurentia and Gondwana during the Late Mississippian; b: southward motion and clockwise rotation of Gondwana during the Early Pennsylvanian; c: continued rotation and southward movement of Gondwana in the Late Pennsylvanian; and d: head-on Laurentia Gondwana collision in the Early Permian (modified from Nance et al., 2012). Note the NW-directed compression from the Alleghanian fold and thrust belt in the Early Permian that is oblique to the east-west Ouachita fold and thrust belt in present-day Arkansas (black outline).

Buthman (1982) proposed a similar sequence of compressional tectonics from his field work in the northern part of the Caddo Gap quadrangle. The first phase was characterized by strong north-directed compression with east-west oriented mesoscopic and macroscopic folds transported northwards along low-angle thrust faults. The second phase involved refolding of the earlier structures by northeast-directed compression, resulting in northwest-trending folds. A third phase, not discussed by Evansin, resulted from a change to more northwestly-directed compression, forming southwest-northeast trending thrusts and northwest-oriented tear faults with apparent dextral shear. Buthman interpreted 1.5 miles of right-lateral offset of the Middle Ordovician-age Blakely Formation (Figure 2.2) along the trend of the Caddo River, and mapped another tear fault north of Black Springs with right-lateral relative movement (Figure 1.8).

Buthman suggested the ridges of Lower Ordovician-age Crystal Mountain Sandstone to the north of his study area, which are only present east of the Caddo River and not west of it, may have acted as a barrier to the northwest transport of Blakely and Mazarn structures east of the Caddo River. The northwest transport of Blakely and Mazarn structures on the west side of Caddo River was relatively unimpeded, creating a possible mechanism for right-lateral, northwest-oriented tear faulting in this area. The fourth phase interpreted by Buthman was regional uplift of the Ouachita Mountains.

Folding Style

The high ductility contrast of the alternating shale-chert-shale-novaculite-shale sequence (Figure 2.2; Figure 5.6) in the study area likely had considerable influence on the style of folding. Referencing work by Wiltschko and Chappie (1977) in the Appalachian Mountains, Godo et al. (2011) described the Ouachita Mountains, on a regional scale, as an upper rigid zone of folded rocks (referring to the uppermost, sandstone-rich Stanley Shale and overlying Pennsylvanian sandstones) that overlie a lower deformed zone of thick, weak, essentially ductile beds (the shale-dominated Ouachita facies). This combination resulted in complicated faulting and ductile flow of shale that originated at depth and transported rocks a considerable distance (Figure 5.7).

Aspects of this regional-scale model can be applied at the local scale to the Ouachita facies present at Caddo Gap, where ductile deformation has dominated in the weaker shale units (Womble, Polk Creek, Missouri Mountain and Stanley Shales) while the more competent units (Bigfork Chert and Arkansas Novaculite) underwent more brittle-style deformation (e.g., fracturing).

In several outcrops the Womble and Missouri Mountain Shales appeared to be chaotically-deformed with a "flowing" appearance (Figure 5.5), whereas the Lower and Upper Novaculite members often displayed brittle styles of deformation such as planar faults, layer-parallel slickenlines, chatter marks, joints and massive angular fault breccia (Figure 4.35). This is also evident at the Caddo Gap road cut where the thick bedded to massive, rigid Lower and Upper Novaculite beds appear relatively undeformed (aside from their steep dip to the south) compared with the intensely folded Middle Chert and Shale member (Figure 2.11).

Layer-parallel slickenlines were observed at several localities throughout the study area (Figure 5.8) and may suggest flexural slip along bedding planes (Figure 5.9) occurred during folding of the alternating sequences of ductile-rigid strata in the study area. Buthman (1982) also interpreted flexural slip as a mechanism for bedding-parallel slickenlines he observed in folded strata in the north half of the Caddo Gap quadrangle.

Figure 5.5. Chaotically-deformed Polk Creek Shale (?) at Stop 274 with ductile-flow appearance; bedding is indiscernible. Pencil for scale.

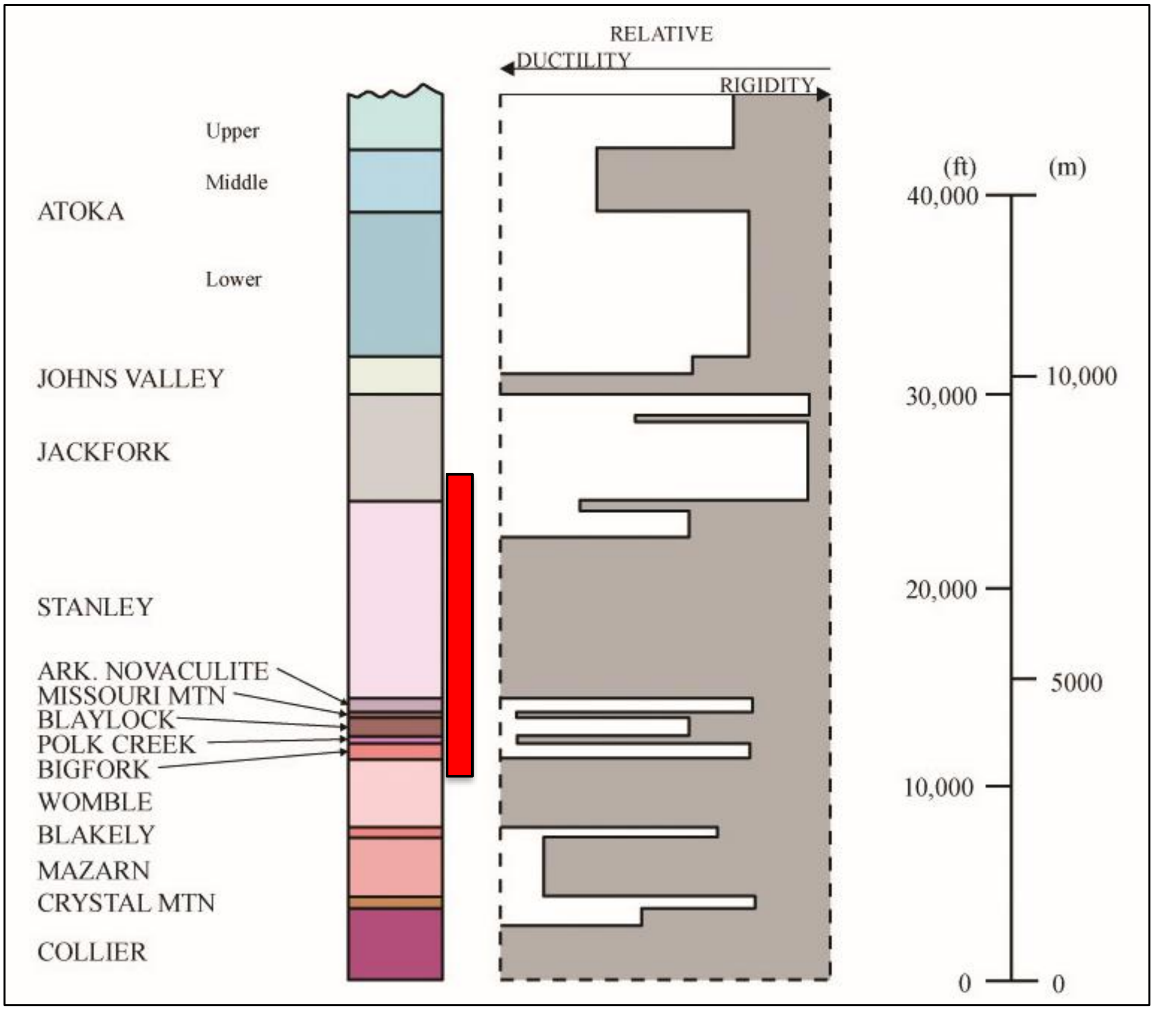


Figure 5.6. Mechanical stratigraphic section of Paleozoic rocks in the Ouachita Mountains indicating the distribution of relatively ductile and rigid formations (modified from Godo et al., 2014). ***Red bar*** *indicates the stratigraphic section of the the study area. Note the alternating sequence of ducilte-rigid rocks (the Blaylock Sandstone is considered absent from the study area).*

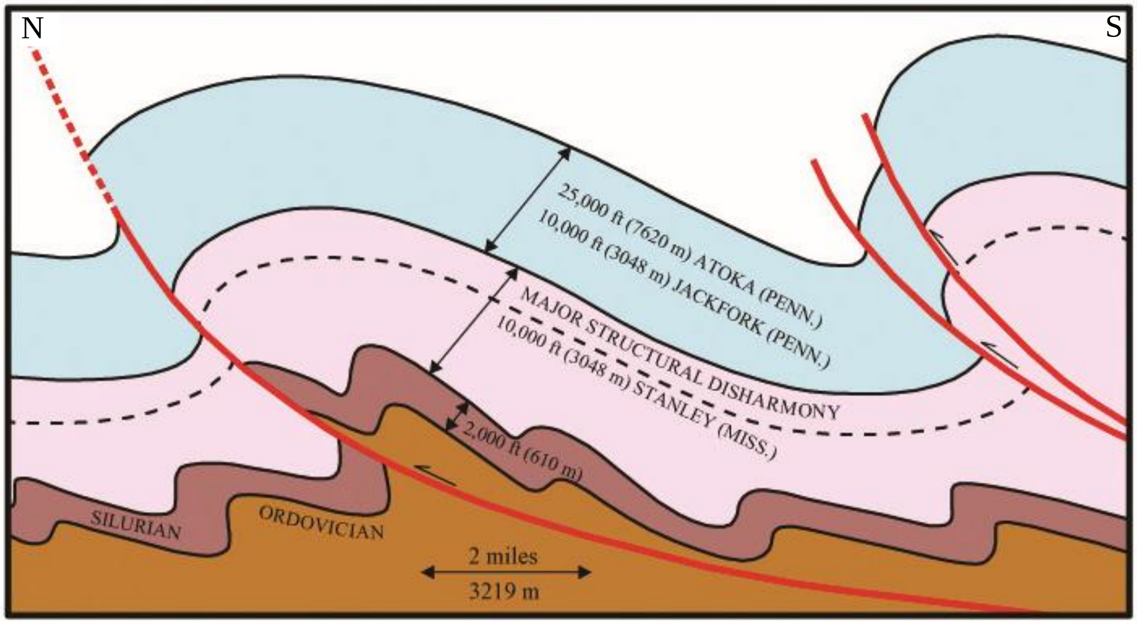


Figure 5.7. Generalized diagrammatic section of structural disharmony between Late Paleozoic sandstones (uppermost pink and blue) and Early-Middle Paleozoic interbedded chert, sandstone, and shale (modified from Godo et al., 2011). Note the characteristic fault propagation folding in the Late Paleozoic competent zone versus the more complex folding in the Early-Middle Paleozoic rocks (brown, maroon, lower pink).

Figure 5.8. Bedding-parallel slickenlines in Stanley Shale at Stop 8 along the Caddo Gap road cut. Pencil for scale.

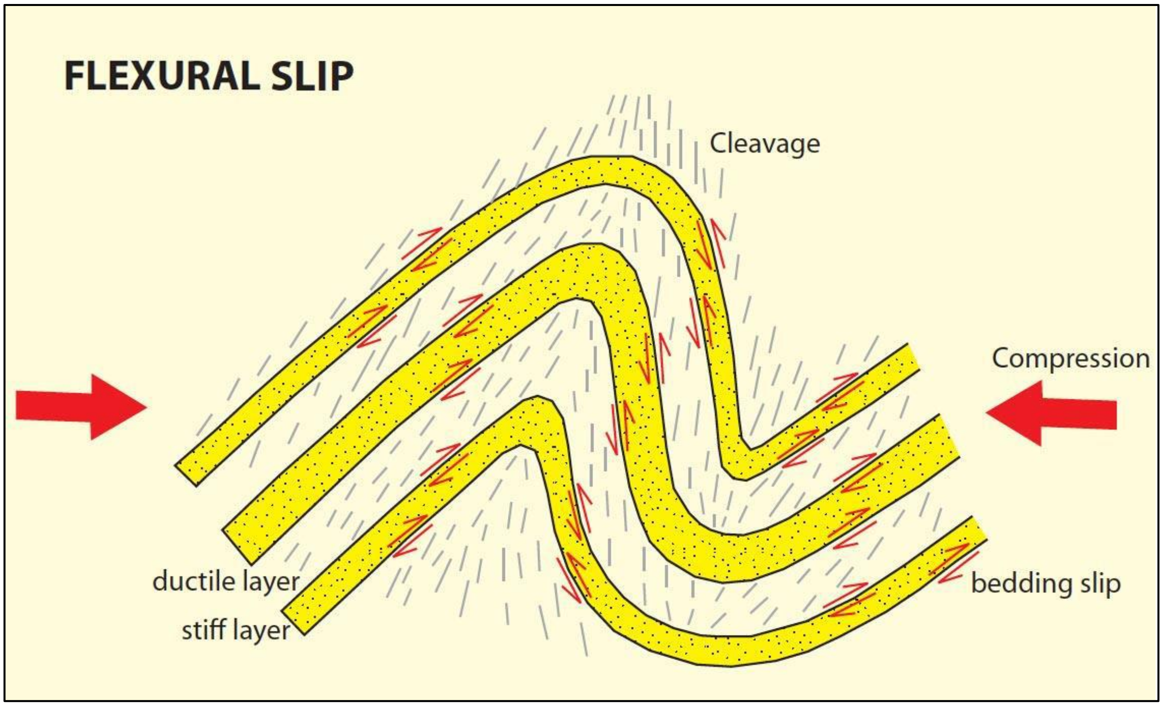


Figure 5.9. Flexural slip illustration showing the slip between layers in a system with a high ductility contracts (Hatcher, 1995).

Faulting

Introduction

The style of faulting observed in the Ouachita Mountains is predominately north-directed thrust faulting that resulted from the Late Paleozoic Ouachita Orogeny when the pre-orogenic marine Ouachita facies were transported northward onto the Laurentian craton (Thomas and Viele, 1989). However, some north-dipping faults on the southern margin of the Benton Uplift have an apparent normal sense of movement when viewed in outcrop (Evansin, 1976; Zimmerman, 1984; Roths, 1988). Several hypotheses have been postulated to explain these faults and associated folds, such as folding and clockwise rotation (overturning) of older faults during later phases of compression during the Ouachita Orogeny (Evansin, 1976; Buthman, 1982; Zimmerman, 1984; Thomas and

Viele, 1989). Roths (1988) suggested the north-dipping normal faults in her study area near Mosquito Gap were thrust faults later reactivated as normal faults during the final uplift of the Benton Anticlinorium, although a mechanism for this late-stage normal faulting, such as orogenic collapse or lateral flow (van der Pluijm and Marshak, 2004), was not presented.

Previous regional-scale mapping and structural interpretations of the study area (Haley et al., 2009) show the Caddo Mountains as a series of folded ridges of Arkansas Novaculite cut by a regional network of east-west trending thrust faults (Figure 1.13). Unnamed thrust faults were mapped to explain the juxtaposition of the South Caddo Mountain and Arrowhead Mountain fishhook folds against linear east-west ridges of Arkansas Novaculite on the south side of these folds (Figure 1.13; Figure 4.4). Field mapping in this study did find evidence for thrust faulting at Stops 499, 500, 502, 512 and 515 on the north side of Strawn Mountain (Figure 4.13; Figure 4.16; Figure 4.17; Figure 4.18), supporting the backthrust interpretation of Haley et al. (2009) for Strawn Mountain.

However, thrust faulting was not found on the southern flanks of South Caddo and Arrowhead Mountains (Figure 1.4). Detailed mapping at 1:2,000 scale during this study revealed no evidence for thrust faulting in area between South Caddo Mountain and the South Ridge. In contrast, several northeast-trending strike-slip faults, many with subhorizontal to horizontal slickenlines, were found on the South Ridge immediately adjacent to South Caddo Mountain. The geometry and orientation of the South Caddo and Arrowhead Mountain fishhook structures strongly resemble fault drag folds in map view

(Figure 4.4), suggesting these structures were formed by strike-slip faulting, or possibly by left-lateral oblique strike-slip thrust faulting.

Thrust Faulting – "Strawn Mountain-Caney Creek Thrust"

Evidence for an east-northeast trending thrust fault across the northern part of the study area was found between North Caddo Mountain and Strawn Mountain (Figure 1.4; Figure 4.9; Figure 4.14; Figure 5.10). This unnamed thrust fault is shown on the Arkadelphia 1:100,000 scale geologic map (Figure 1.13; Haley et al., 2009) and is termed "Strawn Mountain – Caney Creek Thrust" in this study for the major geographic features the fault crosses and likely forms.

The western-most evidence of this fault in the study area was found at Stop 285 on the southwestern flank of North Caddo Mountain (Figure 5.10). Historical mineral prospecting at this location has left boulders of mineralized Lower Novaculite with slickenlines, suggesting faulting (and associated mineralization) in this area. However, no outcrops of Lower Novaculite were found at this location to inspect for fault surfaces. The fault is inferred to continue generally due west based on topographic expressions in the Bigfork Chert as previously mapped by Haley et al. (2009). Between North Caddo and Strawn Mountains, a series of mineralized Novaculite fault breccia outcrops, often associated with slickensided fault surfaces or boulders (Stops 370, 403, 404, 406, 408 and 409; Figure 5.10), were found along an easterly trend moving towards Strawn Mountain.

At Stop 371, a large fault surface with an apparent normal sense of slip has a strike and dip of N80°W, 74°NE; a smaller fault surface on the same outcrop is similarly oriented at N79°W, 78°NE and also has an apparent normal sense of slip. About 300 feet to the east at Stop 372, a slickensided fault surface trends N82°E, 85°SE (no sense of slip indicators). These data suggest the fault is subvertical and possibly an overturned thrust fault (Figure 5.10). At Stop 384, a fault with apparent thrust movement is oriented N80°W, 77°SW with slickenlines plunging 68°, S34°E.

The orientation of fault plane surfaces at Stop 429 (N52°E, 65°SE) and a change in dip direction of bedding moving along strike suggests that this fault turns northeast and cuts across the crest of the ridge where the Lower Novaculite is intensely brecciated and fractured; boulders with prominent slickenlines were also found here (Stops 408 and 409). The fault is best exposed in the Lower Novaculite on the north side of Strawn Mountain as discussed in Chapter 4. From Strawn Mountain, the fault is inferred to trend due east along the channel of Caney Creek where it is lost in steeply dipping to vertical Stanley Shale beds (Figure 4.12).

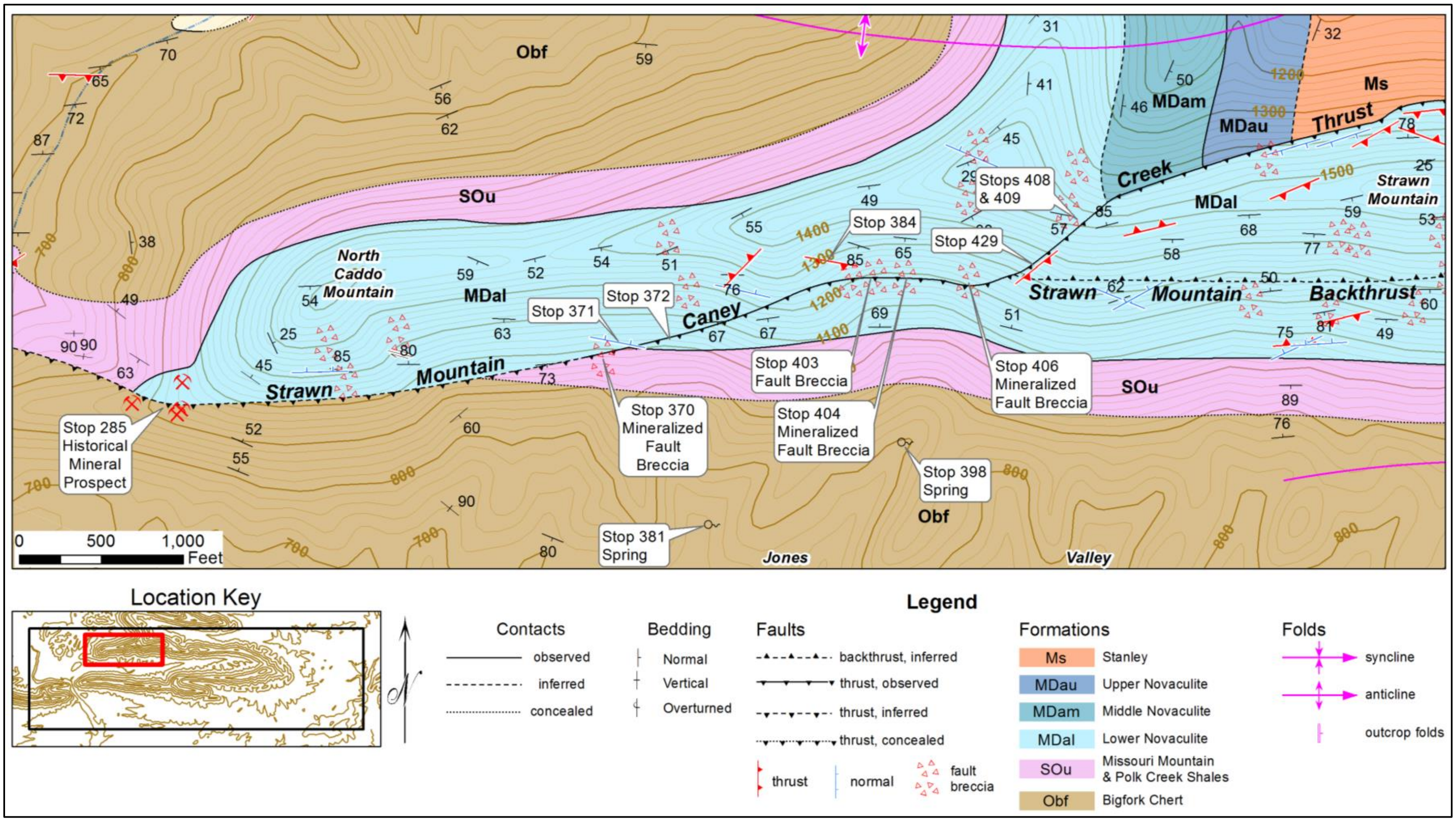


Figure 5.10. Geologic map of North Caddo Mountain showing field evidence (i.e., mineralized fault breccia, slickenlines, etc) for the Strawn Mountain – Caney Creek Thrust.

The cross sections constructed from the geologic map (Figure 4.9; Figure 4.14) interpret the Strawn Mountain – Caney Creek Thrust to be a major, steep-dipping thrust fault which may have cut and refolded the Nelson Mountain Anticline (NMA). In this "break-thrust fold" model (van der Pluijm and Marshak, 2004), the NMA formed by an initial phase of compression and folding. As compression continued and the fold could no longer accommodate the strain, a break-forward thrust cut the NMA, refolding the hanging wall portion of the fold and transporting it towards the foreland (Figure 5.11). This is similar to one of the possible sequences of folding and faulting proposed by Roths (1988) in the western Caddo Mountains. The geometry of the Strawn Mountain – Caney Creek Thrust and the NMA in the cross sections compare well with the style of fold and thrust faulting shown in the subsurface models of Evansin (1976) (Figure 1.11) and Godo et al. (2011) (Figure 4.10).

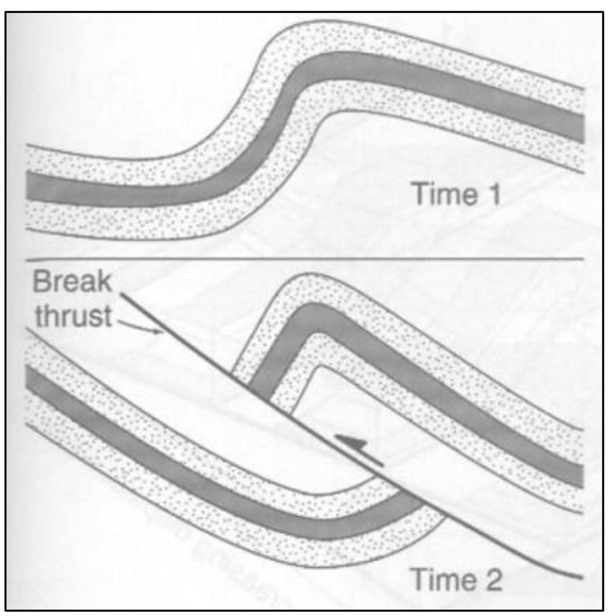


Figure 5.11. Formation of a "break-thrust fold." An asymmetric fold begins to form and tighten. As compression continues, a thrust fault breaks through the fold, refolding the hanging wall anticline (van der Pluijm and Marshak, 2004).

Backthrust Faulting – Strawn Mountain Ridge

The backthrust interpretation of Haley et al. (2009) for the structure of Strawn Mountain was confirmed in this study, but detailed (1:6,000 scale) field mapping of the mountain found that this feature is comprised of a complex series of backthrust faults and related folds in the Arkansas Novaculite (Figure 4.12). The backthrusts are obviously younger than the Nelson Mountain Anticline as they cut and deform the north limb of the fold, providing further insight into the structural evolution of the Caddo Mountains that will be discussed below.

Due to thick soil and heavy vegetation, the main backthrusts are concealed, but they are inferred based on the intense deformation and the frequent changes in bedding orientation. Therefore, this study was only able to infer the approximate location and configuration of the backthrust network based on bedding measurements, float observations of fault breccia, loose boulders with slickenlines, and analysis of topographic maps and aerial imagery.

Strike-Slip Faulting

The previously unmapped strike-slip faulting found in the Arkansas Novaculite on the South Ridge adjacent to the South Caddo Mountain fishhook fold differs from the thrust faulting models of the Caddo Gap area (Evansin, 1976; Haley et al., 2009). The subhorizontal to horizontal slickenlines on these steep to vertical, planar fault surfaces suggest they have not been folded or deformed by the early phases of compression associated with the Ouachita orogeny – that they are younger than the structures forming the Caddo Mountains and formed during a later stage of deformation. The concentration and location of these strike-slip faults adjacent to the South Caddo Mountain fishhook fold (Figure 4.24) strongly suggest they are related to the formation of that structure.

The strike-slip faults appear to be confined to the Lower Member of the Arkansas Novaculite, although the fault found at Stop 919 does offset Lower Novaculite against Middle Chert and Shale (requiring left-lateral relative movement), suggesting significant displacement (Figure 4.31). The large amount of fault breccia found in this area also suggests substantial movement on these faults. However, these faults do not appear to extend southwestward into younger Upper Novaculite or Stanley Shale, although exposure of these rocks is poor compared with the Lower Novaculite. Bedding measurements in the Upper Novaculite and Stanley Shale on this part of the South Ridge only show relatively minor variations in strike. With the thick soil cover, lack of conspicuous marker beds and intense deformation in the Lower Novaculite in this area, the amount of displacement on these faults cannot be quantified. The origin of the strike-slip faults will be discussed in the following section.

<u>Reactivated Basement Faults, An Alternative Interpretation</u>

This study provides an alternative hypothesis to explain the fishhook folds, orientation of the Nelson Mountain Anticline (relative to other macroscopic folds in the Caddo Mountains) and the Strawn Mountain Ridge backthrusts, which is that late stage, northwest-directed compression and/or shear stress reactivated pre-existing northwest-trending basement faults that were formed during the rifting of Rodinia (Figure 3.1). Using this hypothesis, the following is a possible sequence of events for the study area.

Following initial compression and folding of the Ouachita orogeny, the present-day eastern terminus of the South Ridge and the western terminus of the Nelson Mountain Anticline (South Caddo Mountain) were originally connected as one fold limb. Likewise, the eastern terminus of the east-west Novaculite ridge in the southwestern corner of the study area and Arrowhead Mountain were also connected as the same linear fold limb.

After the initial east-west folding and northward-directed thrust faulting, a change in orientation to northwest-directed compression (deformation phase 3 of Buthman, 1982) and/or left-lateral shear stress reactivated northwest-trending Late Precambrian basement rift faults, and possibly transform faults, at depth (Figure 5.12). In the overlying, tightly folded supracrustal rocks of the Ouachita Fold Belt, the Caddo Gap area fold limbs mentioned above were cut by these reactivated basement strike-slip faults, with left-lateral movement, and the eastern portion of the Nelson Mountain Anticline was transported northwesterly, as probably was much of the Caddo Mountain range. Similarly, the same fold limb was cut by another strike-slip basement fault at Caddo Gap. Fault drag occurred on the western ends of the detached limbs as they moved northwestward and slid to the north side of the corresponding ridge; this drag caused the beds to fold around about 120-140 degrees, forming the South Caddo Mountain and Arrowhead Mountain synclinal folds – the “fishhook” folds – mapped in this study.

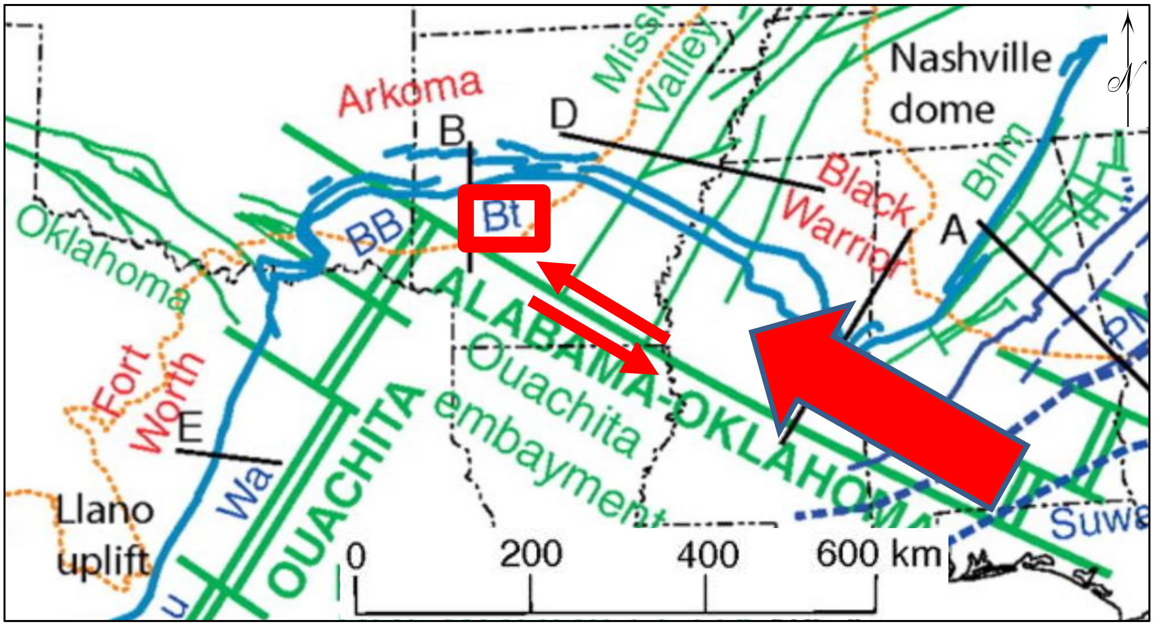


*Figure 5.12. Enlarged view of the map in Figure 3.1 (modified from Thomas, 2011) showing a possible change in the direction of compression relative to the remnant basement faults from the Iapetan rifted margin (**green**). The Benton uplift is highlighted by the red box, showing its proximity to the NW-oriented Alabama-Oklahoma transform basement fault. Small **red** arrows show possible left-lateral movement caused by a later phase of NW-directed compression (large **red** arrow) and shear stress.*

Likewise, if bedding at the eastern terminus of the South Ridge experienced left-lateral strike-slip movement, then it may have also been subject to fault drag. Field work shows that the strike of bedding does rotate from about east-west to northeast at the eastern terminus of the South Ridge in both the Arkansas Novaculite and the Stanley Shale (Figure 4.7; Figure 4.28). Large fault breccia outcrops in the Lower Novaculite were also found here, providing further evidence that the South Ridge is faulted out.

As the south limb of the NMA was transported westward with left-lateral relative movement, synthetic (left-lateral) and antithetic (right-lateral) strike-slip faults (Riedel shears) formed on the South Ridge in response to the main fault (Figure 4.31). While it might be expected that strike-slip faults would be prevalent along the eastern end of the

South Ridge, field mapping and high resolution aerial photography (Google Earth, 2017) show the Lower Novaculite beds are planar and relatively undeformed across the this section of the South Ridge. Alternatively, there may have been a pre-existing fault or fracture system (perhaps extensional cross-fold normal faults formed during initial folding of the NMA) at the present location of the strike-slip faults that was reactivated and the eastern block of the South Ridge rotated with very little deformation to the Lower Novaculite beds east of the strike-slip faults.

On the steepened north limb of the NMA, east- and northeast-striking backthrusts off the Strawn Mountain – Caney Creek Thrust cut through the limb with up-to-south movement (Figure 4.12; Figure 4.14) to accommodate the NW-directed compression.

Returning to the question stated in Chapter 2: why does the NMA have more of a east-west orientation compared with the northwest-southeast orientations of the macroscopic folds in the Novaculite to the north (i.e., White Mountain)? It may be that the NMA formed contemporaneously with the second tectonic phase of NE-directed compression described by Evansin (1976) and Buthman (1982), and like the folded ridges to the north, with an initial northwest orientation. During the third tectonic phase of NW-directed compression, the NMA was cut by the left-lateral strike-slip faults discussed previously and rotated counterclockwise in map view to its present east-west trend and topographic expression.

CHAPTER 6

Conclusions

Summary

The main objectives of this study were to better understand the types of structures and their evolution in the vicinity of the Caddo Gap area. To accomplish these goals, detailed field mapping was done to produce a 1:12,000 scale digital geologic map of the southern portion of the Caddo Gap quadrangle using Geographic Information Systems (ArcGIS). Cross sections were constructed from the geologic map to interpret the subsurface structure of the study area. This helped to determine the timing, style and kinematics of the folding and faulting that have deformed the Early to Middle Paleozoic rocks comprising the study area.

The major map-scale structures of the study area, such as the Nelson Mountain Anticline, were mapped in great detail to better understand the nature and evolution of the structures. This led to the discovery of new and sometimes smaller structures which have aided in interpreting the structural evolution and tectonic history of the area. Structural analysis objectives included correlation of the observed features in the study area with the tectonic evolution of the Caddo Mountain range and with the regional structural framework of the Benton Uplift. Results and interpretations were compared and contrasted with other structural studies of the Ouachita Mountains, especially those of nearby areas.

Structural analysis of the Nelson Mountain Anticline shows it is an asymmetric, north-vergent, steeply inclined map-scale fold with a gently plunging axis to the east-southeast . The north limb of the fold dips very steep towards the north and is possibly overturned at depth; the westward extension of the north limb has been cut and deformed by backthrusts off of the Strawn Mountain – Caney Creek Thrust. The south limb of the fold dips moderately towards the south and terminates along strike towards the west at South Caddo Mountain.

Field observations from this study support the backthrust interpretation of Haley et al. (2009) for the structure of Strawn Mountain Ridge, but the backthrust was found to be more complex than previously thought and has cut much of the north limb of the Nelson Mountain Anticline, suggesting that the faulting post-dates the folding.

Field mapping found previously unmapped structures and better delineated other suspected features such as the South Caddo Mountain and Arrowhead Mountain fishhook folds where bedding has been folded around sharply, resembling a fishhook in map view. Structural analysis of these two synclinal folds shows they have very similar geometries and orientations, suggesting they formed by the same mechanism. South Caddo Mountain forms the western end of the south limb of Nelson Mountain Anticline, suggesting the South Caddo Mountain fold is a younger structure. The map-view geometry of the fishhook folds is reminiscent of fault drag folding, suggesting they formed adjacent to northwest-trending strike-slip faults via left-lateral shear. Previously the fishhook folds were interpreted to be associated with thrust faults. However, detailed field mapping revealed no evidence of thrusts in these areas.

Instead, another significant discovery was a dense network of northeast-oriented strike-slip faults in the Arkansas Novaculite on the South Ridge immediately adjacent to the South Caddo Mountain fishhook fold. Structural analysis and interpretation of these faults, coupled with their location adjacent to South Caddo Mountain, suggest they may be related to the fishhook folding.

This study provides an alternative interpretation for the formation of the fishhook folds, the South Ridge strike-slip faults, and post-folding deformation of the Nelson Mountain Anticline, namely that a change in the direction of tectonic transport from due north to a more northwesterly direction caused reactivation of remnant northwest-trending basement faults from the Late Precambrian rifting of the supercontinent Rodinia. These reactivated basement faults cut up section and offset the east-west structures in the Caddo Gap area. Left-lateral shear on these faults better explains the drag fold geometry of the fishhook folds and the South Ridge strike-slip faults as synthetic and antithetic faults to the northwest-trending fault that formed South Caddo Mountain, with the Strawn Mountain Ridge backthrust accommodating the north- to northwest-directed compressional stress in the north limb of the Nelson Mountain Anticline.

Future work

Future studies proposed in the area include detailed field mapping and structural analysis to the west, north, and east of the study area, especially the ridges of folded Arkansas Novaculite from White Mountain northward to Sharp Top Mountain. Delineating the geometry of these map-scale folds and suspected faults crossing this area may help further constrain the subsurface interpretation of this study and structural style of the Caddo Mountains.

LIDAR data covering the area was acquired during Winter 2016/2017 and will be available sometime in 2018 (NOAA, 2018). LIDAR coverage will likely be a very useful tool for future mapping efforts by delineating subtle geologic structures that are not easily identified on existing topographic maps or elevation models. LIDAR may aid in identifying lineaments that may represent fault zones; or, mapping individual sandstone beds of the Stanley Shale in the South Fork Valley. Offsets or truncations of these sandstone beds may be visible on LIDAR and may improve mapping of the structures in this shale-dominated formation.

Continued mapping to the east in the Bonnerdale quadrangle may help constrain the regional structure of the Caddo Mountains and result in better understanding of the northeast-trending thrust faults and related structures forming Pigeon Roost Ridge shown on existing regional-scale maps (Haley et al., 2009). This would also provide insight into the timing and magnitude of this faulting and whether or not it affected the structures forming the Caddo Mountains.

The rocks in the study area are moderately to intensely jointed but due to limited field time and the difficult hiking environment a joint analysis was not conducted as part of this study. Such an analysis might provide additional information about the structural evolution of the Caddo Mountains. Joint analysis would also benefit the hydrogeologic knowledge of the Gap Creek Natural Research Area that covers the eastern portion of Jones Valley. This area has not been significantly altered by human activity in more than half a century and therefore contains a high quality of water (Arkansas Natural Heritage Commission, 2017).

A detailed stratigraphic and petrographic study of the black chert/Novaculite pebble conglomerate beds observed near the Upper Novaculite – Stanley contact may provide further information on the sedimentary origin and environment of deposition of this key marker bed, and if it is related to any sort of tectonic activity in the region during the early Mississippian.

Detailed mapping and structural analysis of the Stanley Shale exposures in the Certainteed Quarry would likely provide additional information about the mechanics of folding and faulting in this area.

CHAPTER 7

References

Allison, M.D., Willis, W.H., and Suneson, N.H., 2012, The geology and deep structure of the Oklahoma Ouachita Mountains – the SOPC 1-22 Weyerhaeuser Well: The Shale Shaker, March-April 2012, p. 362-374.

Arkansas Geological Survey, 2014, Digital Geologic Map File Footprints: http://www.geology.ar.gov/dgm_browse/county_dgm.htm (July 2017).

Arkansas Geological Survey, 2017, Stratigraphic Summary of the Arkansas River Valley and Ouachita Mountains: accessed October 2017 at URL http://geology.arkansas.gov/geology/strat_arkvalley_ouachita.htm.

Arkansas Natural Heritage Commission, 2017, Gap Creek Natural Area: Department of Arkansas Heritage website accessed October 9, 2017 at URL http://www.naturalheritage.com/natural-areas/gap-creek-natural-area.

Arbenz, J.K., 2008, Structural framework of the Ouachita Mountains, in Suneson, N.H., editor, Stratigraphic and structural evolution of the Ouachita Mountains and Arkoma Basin, southeastern Oklahoma and west-central Arkansas: applications to petroleum exploration – the Arbenz – Misch/Oles volume: 2004 field symposium: Oklahoma Geological Survey Circular 112A, p. 1-40.

Arbenz, J.K., 1989, The Ouachita System: *in* Bally, A.W.; and Palmer, A.R. (eds), The geology of North America – an overview, v. A: Geological Society of America, Boulder, Colorado, The Geology of North America, P. 371-396.

Beaty, D.S., 1989, Syndepositional manganese deposits in the Arkansas Novaculite [M.S. thesis]: Nacogdoches, Stephen F. Austin State University, 149 p.

Bickford, M.E., Soegaard, K., Nielson, K.C., McLelland, J.M., 2000, Geology and geochronology of Grenville-age rocks in the Van Horn and Franklin Mountains, West Texas – implications for the tectonic evolution of Laurentia during the Grenville: Geological Society of America Bulletin, v. 112, p. 1134–1148.

Blakey, R., 2013, Paleogeographic and Tectonic History of North America: CP Geosystems Inc website accessed at URL http://cpgeosystems.com/namkeypaleogeography.html.

Blythe, A.E., Sugar, A., and Phipps, A.S., 1988, Structural Profiles of Ouachita Mountains, Western Arkansas: AAPG Bulletin, v. 72, pp. 810-819.

Briggs, G. and Roeder, D.H., 1975, Sedimentation and plate tectonics, Ouachita Mountains and Arkoma Basin In Briggs, G., McBride, E.F., and Moiola, F.J., eds., Sedimentology of Paleozoic flysch and associated deposits, Ouachita Mountains and Arkoma Basin, Oklahoma: Dallas Geological Society, p. 1-22.

Buthman, D.B., 1982, Stratigraphy and Structural Style of the Mazarn, Blakely, and Womble Formations in the Ouachita core near Norman, Oklahoma: The Shale Shaker Digest XI, Volumes XXXIII-XXXV (1982-1985), p. 289-310.

Cox, R.T., 2009, Ouachita, Appalachian, and Ancestral Rockies deformations recorded in mesoscale structures on the foreland Ozark plateaus: Tectonophysics, v. 474, p. 674-683.

EFS GeoTechnologies, 2010, 2010 Montgomery County One Foot Orthos: digital raster data downloaded from Arkansas GIS Office at URL https://gis.arkansas.gov/product/montgomery-county-one-foot-orthos-2010-raster/.

Ewing, T.E., 2009, The ups and downs of the Sabine uplift and the northern Gulf of Mexico Basin – Jurassic basement blocks, Cretaceous thermal uplifts, and Cenozoic flexure: Gulf Coast Association of Geological Societies Transactions, v. 59, p. 253-269.

Environmental Systems Research Institute, 2017, ArcGIS for Desktop version 10.5.

Evansin, D.P., 1976, Structural style of the Ouachita core near Caddo Gap, Arkansas: [M.S. thesis]: Carbondale, Southern Illinois University, 94 p.

Godo, T.J., Li, P., and Ratchford, M.E., 2011, Exploration for the Arkansas Novaculite Reservoir in the Southern Ouachita Mountains, Arkansas: AAPG Search and Discovery Article #10337, 23 slides.

Haley, B.R., Stone, C.G., Clardy, B.F., and Hanson, W.D., 2009, Geologic map of the Arkadelphia 30'x60' quadrangle, Clark, Garland, Hempstead, Hot Spring, Howard, Montgomery, Pike, and Polk Counties, Arkansas: Arkansas Geological Survey Digital Geologic Quadrangle Map DGM-AR-01100, 1 map, scale 1:100,000.

Haley, B.R., Glick, E.E., Bush, W.V., Clardy, B.F., Stone, C.G., Woodward, M.B., and Zachry, D.L., 1993, Geologic map of Arkansas: U.S. Geological Survey, 1 map, scale 1:500,000.

Haley, B.R. and Stone, C.G., 1991, Caddo Gap Quadrangle: Arkansas Geological Survey unpublished field worksheet.

Harry, D.L., and Londono, J., 2004, Structure and evolution of the central Gulf of Mexico continental margin and coastal plain, southeast United States: Geological Society of America Bulletin, v. 116, no. ½, p. 188–199.

Hass, W.H., 1951, Age of the Arkansas Novaculite: Bulletin of the American Association of Petroleum Geologists, v. 35, no. 12, pp. 2526-2541.

Hildenbrand, T.G., and Hendricks, J.D., 1995, Geophysical setting of the Reelfoot rift and relations between rift structures and the New Madrid seismic zone: U.S. Geological Survey Professional Paper 1538-E, 30 p.

Hoffman, P.F., 1997, Tectonic genealogy of North America: *in* van der Pluijm, B.A. and Marshak, S., eds., Earth Structure (second edition): McGraw-Hill, New York, p. 607-614.

Howard, J.M., 2007, Finding Diamonds in Arkansas: Arkansas Geological Survey Brochure Series 002, 8 p.

Howard, J.M. and Chandler, A., 2007, Magnet Cove – A synopsis of its geology, lithology and mineralogy: Arkansas Geological Survey Brochure Series 004, 11 p.

Hudec, M.R., Norton, I.O., Jackson, Martin P.A., and Peel, F.J., 2013, Jurassic Evolution of the Gulf of Mexico Salt Basin: AAPG Bulletin, vol. 97, no. 10, p. 1683-1710.

Keller, W.D., Stone, C.G., & Hoersch, A.L., 1985, Textures of Paleozoic chert and novaculite in the Ouachita Mountains of Arkansas and Oklahoma and their geological significance: Geological Society of America Bulletin, vol. 96, no. 11, p. 1353-1363.

Keller, G.R., Braile, L.W., McMechan, G.A., Thomas, W.A., Harder, S.H., Change, W., and Jardine, W.G., 1989, Paleozoic continent-ocean transition in the Ouachita Mountains imaged from PASSCAL wide-angle seismic reflection-refration data: Geology, v. 17, p. 119-122.

Keng, R.V., 2011, Field-based constraints on the origin of the Benton Uplift, Ouachita Mountains [M.S. thesis]: Fayetteville, University of Arkansas, 51 p.

Li, Z.X., Bogdanova, S.V., Collins, A.S., Davidson, A., De Waele, B., Ernst, R.E., Fitzsimons, I.C.W., Fuck, R.A., Gladkochub, D.P., Jacobs, J., Karlstrom K.E., Lu, S., Natapov, L.M., Pease, V., Pisarevsky, S.A., Thrane, K., and Vernikovsky, V., 2008, Assembly, configuration, and break-up history of Rodinia - a synthesis: Precambrian Research, v. 160, p. 179-210.

Lillie, R.J., Nelson, K.D., de Voogd, B., Brewer, J.A., Oliver, J.E., Brown, L.D., Kaufman, S., and Viele, G.W., 1983, Crustal structure of Ouachita Mountains, Arkansas:

a model based on integration of COCORP reflection profiles and regional geophysical data: American Association of Petroleum Geologists Bulletin, v. 67, p. 907-931.

Lowe, D.R., 1975, Regional Controls on Silica Sedimentation in the Ouachita System: Geological Society of America Bulletin, v. 86, p. 1123-1127.

Misch, P. and Oles, K.F., 1956, Stratigraphic and Structural Studies in the Ouachita Mountains, Oklahoma and Arkansas: Oklahoma Geological Survey Circular 112A, 85 p.

Miser, H.D., and Purdue, A.H., 1929, Geology of the DeQueen and Caddo Gap quadrangles: U.S. Geological Survey Bulletin 808, 195 p.

Miser, H.D., 1917, Manganese deposits of the Caddo Gap and DeQueen quadrangles, Arkansas: U.S. Geological Survey Bulletin 660-C, p. 59-122.

Nance, R. D., Gutiérrez-Alonso, G., Keppie, J. D., Linnemann, U., Murphy, J. B., Quesada, C., Strachan, R.A., and Woodcock, N. H., 2012, A brief history of the Rheic Ocean: Geoscience Frontiers, v. 3, no. 2, p. 125-135.

Nicholas, R.L., and Waddell, D.E., 1989, The Ouachita system in the subsurface of Texas, Arkansas, and Louisiana: *in* Hatcher, R.D., Jr., Thomas, W.A., and Viele, G.W., (eds), The Appalachian-Ouachita Orogen in the United States, v. F-2: Geological Society of America, Boulder, Colorado, The Geology of North America, p. 661-672.

National Oceanic and Atmospheric Administration, 2018, United State Interagency Elevation Inventory: https://coast.noaa.gov/inventory/ (April 2018).

Park, D.E., Jr., and Croneis, C., 1969, Origin of the Caballos and Arkansas Novaculite Formations: AAPG Bulletin, v. 53, p. 94-111.

Philbrick, J.S., 2016, A Geochemical Analysis of the Arkansas Novaculite and Comparison to the Siliceous Deposits of the Boone Formation: M.S. Thesis, University of Arkansas.

Roths, P.J., 1988, Geologic Mapping and Structural Analysis of the Caddo Mountains in Western Montgomery County, Arkansas: [M.S. Thesis], Southern Illinois University, 73 p.

Shaulis, B.J., Lapen, T.J., Casey, J.F., Reid, D.R., 2012, Timing and Rates of Flysch Sedimentation In the Stanley Group, Ouachita Mountains, Oklahoma and Arkansas, U.S.A.: Constraints from U-Pb Zircon Ages of Subaqueous Ash-Flow Tuffs: Society for Sedimentary Geology v. 82, p. 833-840.

Sholes, M., 1977, Arkansas novaculite stratigraphy: in C.G. Stone, and others, (eds.) Symposium on the geology of the Ouachita Mountains, v. 1: Arkansas Geological Commission, v. MP-13, p. 139-145.

Thomas, W.A., 2011, The Iapetan rifted margin of southern Laurentia: Geosphere, v. 7, no. 1, p. 97-120, doi:10.1130/GES00574.1; 12 figures.

Thomas, W.A., 1991, The Appalachian-Ouachita rifted margin of southeastern North America: Geological Society of America Bulletin, v. 103, p. 415-431.

Thomas, W.A., 1985, The Appalachian-Ouachita Connection – Paleozoic Orogenic Belt at the Southern Margin of North America: Annual Review of Earth and Planetary Sciences, v. 13, p. 175-199.

U.S. Geological Survey, 2000, 1/3 arc-second digital elevation model, Caddo Gap quadrangle, Arkansas.

Van der Pluijm, B. A., & Marshak, S., 2004, *Earth structure*. New York.

Viele, G.W., and Thomas, W.A., 1989, Tectonic synthesis of the Ouachita orogenic belt: *in* Hatcher, R.D., Jr., Thomas, W.A., and Viele, G.W., (eds), The Appalachian-Ouachita Orogen in the United States, v. F-2: Geological Society of America, Boulder, Colorado, The Geology of North America, p. 695-728.

Weber, J.C., 1986, Bedrock geology and structural analysis on portions of the Cossatot Mountains, Athens Plateau, and Mazarn Basin, Pike and Montgomery Counties, Arkansas: [M.S. Thesis], Southern Illinois University, 111 p.

Whitaker, A.E., and Engleder, T., 2006, Plate-scale stress fields driving the tectonic evolution of the central Ouachita salient, Oklahoma and Arkansas: Geological Society of America Bulletin, v. 118, no. 5/6, p. 710-723.

Whitmeyer, S.J., Karlstrom, K.E., 2007, Tectonic model for the Proterozoic growth of North America: Geosphere, v.3, no. 4, p. 220-259.

Zimmerman, J., 1984, Geometry and origin of folds and faults in the Arkansas Novaculite at Caddo Gap: *in* Stone, C.G. and Haley, B.R. (eds.), A guidebook to the geology of the central and southern Ouachita Mountains, Arkansas: Arkansas Geological Commission Guidebook 84-2 (1984): 111-115.

Zimmerman, J., Sverdrup, K.A., Evansin, D.P., and Ragan, V.S., 1984, Reconnaissance structural geology in the western Mazarn Basin, southeastern Benton Uplift, Arkansas: *in* McFarland, J.D., III, and Bush, W.V. (eds.), Contributions to the geology of Arkansas –

Volume II: Arkansas Geological Commission Miscellaneous Publication 18-B (1984): p. 161-177.

Appendix A

Field Data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
1	34.380400	-93.60350	Bedding	N90E	88S			Ms			gray to black, well indurated, hard, thin bedded (inches), fine grained shale to slate; tension fractures filled with quartz (no HCl fizz)
1	34.380400	-93.60350	Fault	N24W	82NE			Ms		normal	very prominent fault plane w/ well-developed slickenlines; chatter marks and slickenlines suggest normal dip-slip faulting; fault surface trends about same as course of Caddo River
1	34.380400	-93.60350	Slickenlines			81	N70E	Ms		normal	very prominent fault plane w/ well-developed slickenlines; chatter marks and slickenlines suggest normal dip-slip faulting; fault surface trends about same as course of Caddo River
1	34.380400	-93.60350	Tension_Joint	N10W	66NE			Ms			tension joint orientation suggests right-lateral shear w/ respect to fault surface, but chatter marks and slickenlines suggest dip slip
1	34.380400	-93.60350	Tension_Joint	N16W	76NE			Ms			tension joint orientation suggests right-lateral shear w/ respect to fault surface, but chatter marks and slickenlines suggest dip slip
1	34.380400	-93.60350	Tension_Joint	N05W	86NE			Ms			tension joint orientation suggests right-lateral shear w/ respect to fault surface, but chatter marks and slickenlines suggest dip slip
1	34.380400	-93.60350	Tension_Joint	N29W	71NE			Ms			tension joint orientation suggests right-lateral shear w/ respect to fault surface, but chatter marks and slickenlines suggest dip slip
1	34.380400	-93.60350	Tension_Joint	N11W	77NE			Ms			tension joint orientation suggests right-lateral shear w/ respect to fault surface, but chatter marks and slickenlines suggest dip slip
1	34.380400	-93.60350	Tension_Joint	N00E	41W			Ms			tension joint orientation suggests right-lateral shear w/ respect to fault surface, but chatter marks and slickenlines suggest dip slip
2	34.385000	-93.60566	Bedding	N81W	55NE			MDa	Middle		tan to dark gray, alternating thin beds of fine grained shale and dense well indurated blocky chert
3	34.385246	-93.60595	Bedding	N81E	83NW			MDa	Middle		approximate limb 1
3	34.385246	-93.60595	Bedding	N19W	61NE			MDa	Middle		approximate limb 2
3	34.385246	-93.60595	Fold_Axis			47	S65E	MDa	Middle		(?) calculated fold axis from limbs 1 and 2; unsure of this calculation
3	34.385246	-93.60595	Fault	N26E	45SE			MDa	Middle	unknown	
3	34.385246	-93.60595	Slickenlines			45	S52E	MDa	Middle	unknown	
4	34.385296	-93.60615	Fold_Axial_Plane	N15E	86SE			MDa	Middle		S-shape fold
4	34.385296	-93.60615	Fold_Axis			79	N35E	MDa	Middle		
5	34.385550	-93.60654	Bedding	N51E	54NW			MDa	Lower		fault-bounded block of Lower Novaculite as sketched by Zimmerman (1984)
5	34.385550	-93.60654	Fault	N65E	67SE			MDa	Lower	thrust	approximate measurement using clipboard on fault surface; interpreted as thrust fault by Zimmerman (1984)
5	34.385550	-93.60654	Fault	N32E	60SE			MDa	Lower	thrust	approximate measurement using clipboard on fault surface; interpreted as thrust fault by Zimmerman (1984)
6	34.386000	-93.60704	Fault					MDa	Upper	normal	zone of intense shear and deformation in Upper Novaculite; sigmoidal structures indicate normal faulting; breccia zone continues about 25 to 30 ft to the north before outcrop dies out
7	34.386411	-93.60705	Bedding	N80E	71NW			Ms			thin-bedded shale in stream gully on east side of Highway 8
8	34.386770	-93.60763	Vertical_Bedding	N85E	90			Ms			tan to brown to dark gray, thin bedded, laminated to blocky shale; hammer "thuds"
8	34.386770	-93.60763	Fault	N85E	90			Ms		normal	bedding plane fault - flexural slip; chatter marks indicate normal sense of shear

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
8	34.386770	-93.60763	Slickenlines			88	S05E	Ms		normal	bedding plane fault - flexural slip; chatter marks indicate normal sense of shear
8	34.386770	-93.60763	Joint	N10E	87NW			Ms			prominent and dense jointing
9	34.387889	-93.60842	Fold					MDa	Middle		location was started but interrupted by passing motorists, had to move on due to time constraints
10	34.392715	-93.60385	Bedding	N80E	64SE			Opc			approx GPS location estimated from map point; weathered, thinly bedded siltstone and shale in washout
11	34.390645	-93.60800	Bedding	N87E	80SE			Smm			tan to light brown, weathered, fissile, finely bedded, shale adjacent to abandoned mining structure; old Missouri Mountain Slate (maroon shale) prospect on hillside
12	34.380300	-93.55320	Bedding	N87E	54SE			Ms			tan to dark brown, weathered, blocky to thin bedded, micaceous, very fine grained siltstone; bedding slightly undulates
13	34.380500	-93.55300	Bedding	N41E	59SE			Ms			tan to dark gray, thin bedded fine grained shale exposed on cut bank; prominent joint sets
13	34.380500	-93.55300	Joint	N69W	70NE			Ms			more prominent joint set
13	34.380500	-93.55300	Joint	N40W	72SW			Ms			less prominent joint set
14	34.381800	-93.55200	Bedding	N85E	38SE			Ms			stream cut bank exposure of Stanley Shale
15	34.383600	-93.55150	Bedding	N28E	45SE			Ms			dark brown (weathered) to gray (fresh), laminated, thin (1 - 6 inches) bedded, fine grained shale w/ slight hammer "ping"
15	34.383600	-93.55150	Joint	N66W	79SW			Ms			1-5mm wide joints filled with quartz
15	34.383600	-93.55150	Joint	N82E	67NW			Ms			1-5mm wide joints filled with quartz
16	34.384300	-93.55160	Bedding	N32E	32SE			Ms			gray to tan, poorly laminated to massive, thin bedded fine grained shale
16	34.384300	-93.55160	Joint	N63E	41NW			Ms			joint set 1
16	34.384300	-93.55160	Joint	N87W	88SW			Ms			joint set 2
17	34.384600	-93.55540	Bedding	N82E	71SE			MDa	Upper		off-white to light gray, hard, dense, fine grained quartz and novaculite - Upper Novaculite "flatiron"
18	34.386300	-93.55880	Bedding	N75E	44SE			MDa	Lower		east end of "south" Lower Novaculite ridge
19	34.386900	-93.56270	Bedding	N89W	75SW			MDa	Lower		Lower Novaculite ridge
20	34.383211	-93.55590	Bedding	N82E	88SE			Ms			stream gully exposure of brown to tan, thin bedded platy shale to slate
21	34.383000	-93.55640	Bedding	N88E	69SE			Ms			poor exposure of gray to black, thin bedded, laminated to platy to blocky shale, sandstone, and chert
22	34.379800	-93.55740	Bedding	N88E	87NW			Ms			greenish-gray (fresh), well indurated, thick to massively bedded, well sorted, very fine grained quartzitic sandstone
22	34.379800	-93.55740	Bedding	N71E	85NW			Ms			greenish-gray (fresh), well indurated, thick to massively bedded, well sorted, very fine grained quartzitic sandstone
22	34.379800	-93.55740	Bedding	N70E	84NW			Ms			greenish-gray (fresh), well indurated, thick to massively bedded, well sorted, very fine grained quartzitic sandstone
22	34.379800	-93.55740	Bedding	N83W	71SW			Ms			greenish-gray (fresh), well indurated, thick to massively bedded, well sorted, very fine grained quartzitic sandstone
22	34.379800	-93.55740	Joint	N00E	76W			Ms			greenish-gray (fresh), well indurated, thick to massively bedded, well sorted, very fine grained quartzitic sandstone
22	34.379800	-93.55740	Joint	N04W	77SW			Ms			greenish-gray (fresh), well indurated, thick to massively bedded, well sorted, very fine grained quartzitic sandstone

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
22	34.379800	-93.55740	Joint	N05W	80SW			Ms			greenish-gray (fresh), well indurated, thick to massively bedded, well sorted, very fine grained quartzitic sandstone
22	34.379800	-93.55740	Joint	N05E	81NW			Ms			greenish-gray (fresh), well indurated, thick to massively bedded, well sorted, very fine grained quartzitic sandstone
22	34.379800	-93.55740	Joint	N04E	78NW			Ms			greenish-gray (fresh), well indurated, thick to massively bedded, well sorted, very fine grained quartzitic sandstone
22	34.379800	-93.55740	Joint	N04E	84NW			Ms			greenish-gray (fresh), well indurated, thick to massively bedded, well sorted, very fine grained quartzitic sandstone
23	34.379802	-93.56354	Bedding	N66W	50SW			Ms			brown to tan, moderately sorted, fine to medium grained quartz sandstone w/ thin interbedded shales; beds 1 to 1.5 ft thick
23	34.379802	-93.56354	Bedding	N85W	56SW			Ms			50 ft upstream
23	34.379802	-93.56354	Joint	N05W	84SW			Ms			quartz filled joint 1/2 to 1 cm wide
24	34.381200	-93.56320	Bedding	N80E	52SE			Ms			excellent exposure of Stanley: gray, laminated to finely bedded platy to fissile shale
24	34.381200	-93.56320	Joint	N25W	90			Ms			
25	34.383300	-93.56160	Fault	N82W	70SW			Ms		thrust	deformed Stanley Shale beds; signmoid structure suggests up-to-the-north displacement
26	34.384000	-93.56171	Vertical_Bedding	N80W	90			MDa	Middle		(?) lots of SLUMPING observed here
27	34.384502	-93.56138	Bedding	N80E	60SE			MDa	Middle		excellent outcrop of Middle Chert and Shale
28	34.392698	-93.60382	Bedding	N88E	69SE			MDa	Middle		stream cut black chert red and black shale
29	34.380200	-93.56370	Bedding	N70W	85SW			Ms			road cut exposure of Stanley Shale; agrees well with nearby STOP 23
30	34.382100	-93.56820	Bedding	N90W	75S			Ms			cut bank exposure of greenish gray, weathered, platy to fissle clay rich shale
31	34.384829	-93.56720	Bedding	N81W	76SW			MDa	Upper		
32	34.384700	-93.56540	Bedding	N79W	71SW			MDa	Upper		
33	34.382100	-93.56530	Bedding	N82W	55NE			Ms			
34	34.381975	-93.56552	Breccia					Ms			extremely contorted and brecciated shale - fault gouge
35	34.380880	-93.56575	Bedding	N90W	45S			Ms			Stanley Shale beds underwater - approximate eye measurement
36	34.384700	-93.57000	Bedding	N68W	66SW			Ms			tan to light brown bedded crenulated Stanley shale
37	34.385202	-93.56944	Bedding	N52W	77SW			MDa	Upper		brown to brownish-pink, massive, dense, well indurated, very hard, subrounded, well sorted, very fine grained sandstone - local sandstone bed in Upper Novaculite?
38	34.386120	-93.56880	Bedding	N76W	58SW			MDa	Middle		white to gray, extremely hard, thin bedded (1 - 2 inch) chert beds w/ minor shale partings - probably Middle Novaculite Mbr
39	34.387230	-93.56740	Bedding	N82W	56SW			MDa	Lower		white to buff to gray, hard, resistant, very thick bedded to massive Lower Novaculite
39	34.387230	-93.56740	Joint	N86W	38NE			MDa	Lower		joint in Lower Novaculite
40	34.387880	-93.56920	Bedding	N77W	54SW			MDa	Lower		
40	34.387880	-93.56920	Joint	N00E	62E			MDa	Lower		
40	34.387880	-93.56920	Joint	N17W	50NE			MDa	Lower		
40	34.387880	-93.56920	Joint	N15W	55NE			MDa	Lower		
41	34.390220	-93.57065	Bedding	N70E	37SE			MDa	Lower		
42	34.389401	-93.57087	Joint	N52E	59NW			MDa	Lower		white to gray, massive Lower Novaculite breccia; probably a joint surface due to "fish-hook" folding

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
42	34.389401	-93.57087	Joint	N60E	90			MDa	Lower		white to gray, massive Lower Novaculite breccia; probably a joint surface due to "fish-hook" folding
43	34.388300	-93.57120	Bedding	N71W	50NE			MDa	Lower		brownish-maroon, hard, dense, poorly bedded Lower Novaculite
44	34.388300	-93.57210	Bedding	N56W	60SW			MDa	Lower		off-white (fresh) to gray-maroon (weathered) Lower Novaculite
45	34.388300	-93.57420	Bedding	N79W	56SW			MDa	Lower		
46	34.388500	-93.57720	Joint	N83E	46NW			MDa	Lower		probably a joint apprx perpendicular to bedding
47	34.385034	-93.57208	Bedding	N68W	68SW			Ms			gray to brown platy Stanley Shale exposed in cut bank
47	34.385034	-93.57208	Joint	N28E	65NW			Ms			gray to brown platy Stanley Shale exposed in cut bank
47	34.385034	-93.57208	Joint	N22E	70NW			Ms			gray to brown platy Stanley Shale exposed in cut bank
47	34.385034	-93.57208	Joint	N32E	70SE			Ms			gray to brown platy Stanley Shale exposed in cut bank
47	34.385034	-93.57208	Joint	N19E	84SE			Ms			gray to brown platy Stanley Shale exposed in cut bank
47	34.385034	-93.57208	Joint	N66W	11NE			Ms			gray to brown platy Stanley Shale exposed in cut bank
47	34.385034	-93.57208	Joint	N73W	11NE			Ms			gray to brown platy Stanley Shale exposed in cut bank
48	34.386167	-93.57267	Drainage					Ms			spring of dark red to brown colored sediment; digging into stream bank finds weathered pale green to brown clay, probably Stanley Shale
49	34.386533	-93.57284	lineralization_Float					MDa	Lower		boulder and cobble float of Middle and Lower Novaculite w/ grey to black metallic mineralization (1-2 mm veins); larger Lower Novaculite boulder float w/ slickenlines but not in place
50	34.387008	-93.57298	Fault	N65E	87SE			MDa	Lower	left-lateral strike-slip	large fault surface; chatter marks indicate left-lateral shear; large breccia outcrop on north side of fault indicating significant displacement
50	34.387008	-93.57298	Fault	N64E	82SE			MDa	Lower	left-lateral strike-slip	weathered slicks on large fault surface; chatter marks indicate left-lateral shear
50	34.387008	-93.57298	Slickenlines			07	S64W	MDa	Lower	left-lateral strike-slip	weathered slicks on large fault surface; chatter marks indicate left-lateral shear
50	34.387008	-93.57298	Slickenlines			04	S64W	MDa	Lower	left-lateral strike-slip	weathered slicks on large fault surface; chatter marks indicate left-lateral shear
50	34.387008	-93.57298	Slickenlines			03	S64W	MDa	Lower	left-lateral strike-slip	weathered slicks on large fault surface; chatter marks indicate left-lateral shear
50	34.387008	-93.57298	Slickenlines			03	S64W	MDa	Lower	left-lateral strike-slip	weathered slicks on large fault surface; chatter marks indicate left-lateral shear
51	34.387336	-93.57385	Breccia					MDa	Lower		light gray to white, massive brecciated Lower Novaculite; large outcrop is about 15 ft high
52	34.387925	-93.57428	Breccia					MDa	Lower		light gray to white, massive brecciated Lower Novaculite; 3 small NE-trending fault surfaces spaced 25-35 ft across breccia outcrop
52	34.387820	-93.57424	Fault	N15E	70SE			MDa	Lower	strike-slip	western-most fault in breccia outcrop, very planar surface but too weathered to determine sense of slip
52	34.387820	-93.57424	Slickenlines			16	S15W	MDa	Lower	strike-slip	slickenlines are faint and too weathered for sense of slip
52	34.387880	-93.57414	Fault	N24E	80NW			MDa	Lower	right-lateral strike-slip	middle fault in breccia outcrop w/ fault gouge lines; possible tension joints on east block may suggest right-lateral shear
52	34.387880	-93.57414	Slickenlines			23	S24W	MDa	Lower	right-lateral strike-slip	faint slickenlines; possible tension joints suggest right-lateral shear
52	34.387880	-93.57414	Tension_Joint	N72E	71NW			MDa	Lower		tension joint on east block
52	34.387890	-93.57405	Fault	N33E	81SE			MDa	Lower	right-lateral strike-slip	slickenlines; tension joints on west side of fault suggest right-lateral shear

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
52	34.387890	-93.57405	Slickenlines			02	S33W	MDa	Lower	right-lateral strike-slip	very faint slickenlines; tension joints on west side of fault suggest right-lateral shear
52	34.387890	-93.57405	Tension_Joint	N70E	89SE			MDa	Lower		tension joint on west side of fault
53	34.387490	-93.57403	Bedding	N73W	55SW			MDa	Lower		possible loading casts suggest stratigraphic up is to the south
54	34.386000	-93.57430	Bedding	N90W	53S			MDa	Upper		off-white to light gray, hard, dense Upper Novaculite beds
55	34.379200	-93.54990	Bedding	N79E	67SE			Ms			tan (weathered) to brown (fresh), well indurated, hard, well-sorted, quartzitic sublitharenite in Stanley Shale exposed in stream channel
55	34.379200	-93.54990	Joint	N02W	70SW			Ms			tan (weathered) to brown (fresh), well indurated, hard, well-sorted, quartzitic sublitharenite in Stanley Shale exposed in stream channel
55	34.379200	-93.54990	Joint	N12E	64NW			Ms			tan (weathered) to brown (fresh), well indurated, hard, well-sorted, quartzitic sublitharenite in Stanley Shale exposed in stream channel
55	34.379200	-93.54990	Joint	N03E	73NW			Ms			tan (weathered) to brown (fresh), well indurated, hard, well-sorted, quartzitic sublitharenite in Stanley Shale exposed in stream channel
56	34.389700	-93.60253	Bedding	N86E	62SE			MDa	Lower		
57	34.389600	-93.60070	Bedding	N81W	69SW			MDa	Lower		
58	34.389690	-93.59751	Bedding	N85W	51SW			MDa	Lower		
59	34.389580	-93.59722	Fault	N00E	61W			MDa	Lower	strike-slip	extremely weathered fault surface in Lower Novaculite; sense of shear unresolvable
59	34.389580	-93.59722	Slickenlines			28	180	MDa	Lower	strike-slip	extremely weathered fault surface in Lower Novaculite; sense of shear unresolvable
59	34.389580	-93.59722	Joint	N05E	89SE			MDa	Lower		outcrop has appearance of fault breccia; fault-parallel joints?
59	34.389580	-93.59722	Joint	N10E	87SE			MDa	Lower		outcrop has appearance of fault breccia; fault-parallel joints?
59	34.389580	-93.59722	Joint	N11E	88SE			MDa	Lower		outcrop has appearance of fault breccia; fault-parallel joints?
60	34.389320	-93.59735	Fault	N26E	86SE			MDa	Lower	left-lateral strike-slip	left-lateral shear sense is interpreted from offset Lower Novaculite beds in high-res Google Earth photography
60	34.389320	-93.59735	Slickenlines			19	26	MDa	Lower	left-lateral strike-slip	left-lateral shear sense is interpreted from offset Lower Novaculite beds in high-res Google Earth photography
61	34.389788	-93.59693	Breccia					MDa	Lower		old mineral prospect w/ boreholes drilled into off-white to buff Lower Novaculite fault breccia; mineralization filling fractures and voids has metallic luster when fresh, probably old manganese prospect
62	34.389644	-93.59713	Fault	N14E	31NW			MDa	Lower	thrust	excellent slickensided fault surface on underside of south-facing outcrop; fault drag indicates thrust faulting
62	34.389644	-93.59713	Slickenlines			31	N80W	MDa	Lower	thrust	excellent slickensided fault surface on underside of south-facing outcrop; fault drag indicates thrust faulting
63	34.385000	-93.58840	Breccia					Ms			tan to greenish-brown, weathered, soft, micaceous Stanley Shale - just weathered out or faulted?
64	34.385500	-93.58810	Bedding	N88E	74NW			Ms			reddish-brown (weathered) to gray (fresh), laminated, platy, clay-rich Stanley Shale beds; folded or overturned?
65	34.389270	-93.59226	Bedding	N71W	70SW			MDa	Lower		
65	34.389270	-93.59226	Joint	N24E	76SE			MDa	Lower		large joint and void
66	34.389250	-93.59365	Bedding	N81W	60SW			MDa	Lower		
67	34.389710	-93.59579	Bedding	N71W	67SW			MDa	Lower		
68	34.387120	-93.58892	Fault	N86W	15SW			MDa	Upper	unknown	small fault surface undulates about 2-3 inches in wavelength
68	34.387120	-93.58892	Slickenlines			15	S03W	MDa	Upper	unknown	small fault surface undulates about 2-3 inches in wavelength

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
68	34.387120	-93.58892	Joint	N04E	90			MDa	Upper		
68	34.387120	-93.58892	Fault	N57W	25SW			MDa	Upper	unknown	about 20 feet upslope from STOP 68 lat/long but oriented much differently
68	34.387120	-93.58892	Slickenlines			04	N77W	MDa	Upper	unknown	about 20 feet upslope from STOP 68 lat/long but oriented much differently
68	34.387120	-93.58892	Joint	N70W	65NE			MDa	Upper		about 20' upslope from STOP 68 lat long
68	34.387120	-93.58892	Joint	N05E	83NW			MDa	Upper		about 20' upslope from STOP 68 lat long
69	34.388499	-93.58884	Bedding	N70W	81SW			MDa	Lower		top of Lower Novaculite
70	34.389076	-93.58891	Bedding	N51E	29NW			MDa	Lower		(?) strike and dip do not agree with surrounding data (STOPS 69 and 71)
70	34.389076	-93.58891	Joint	N11E	61SE			MDa	Lower		Joint Set 1
70	34.389076	-93.58891	Joint	N09E	83SE			MDa	Lower		Joint Set 1
70	34.389076	-93.58891	Joint	N67W	60SW			MDa	Lower		Joint Set 2
70	34.389076	-93.58891	Joint	N78E	68NW			MDa	Lower		Joint Set 3 - Dr. Barker measurement
71	34.389118	-93.58916	Bedding	N73W	78SW			MDa	Lower		buff to white, massive to medium bedded Lower Novaculite
72	34.389249	-93.58970	Joint	N53E	79NW			MDa	Lower		
72	34.389249	-93.58970	Joint	N50E	72NW			MDa	Lower		
73	34.389403	-93.59203	Bedding	N78W	62SW			MDa	Lower		
74	34.388927	-93.58734	Bedding	N67W	63SW			MDa	Lower		gray (weathered) to off-white (fresh), medium bedded Lower Novaculite
75	34.388648	-93.58488	Bedding	N76W	56SW			MDa	Lower		
75	34.388648	-93.58488	Joint	N70E	39NW			MDa	Lower		oxidized mineralization on joint surface
76	34.388512	-93.58136	Bedding	N84W	62SW			MDa	Lower		
77	34.388353	-93.57980	Bedding	N74E	62SE			MDa	Lower		
78	34.388467	-93.57740	Bedding	N88W	60SW			MDa	Lower		
79	34.386529	-93.58100	Bedding	N83W	66SW			MDa	Upper		tan to maroon, moderately hard, tripolitic Upper Novaculite
79	34.386529	-93.58100	Joint	N08E	90			MDa	Upper		
80	34.385112	-93.57670	Bedding	N87W	88SW			Ms			brownish-red (weathered) to purple to gray (fresh), hard, quartzitic, resistant sandstone
81	34.386315	-93.57756	Bedding	N89W	78SW			MDa	Upper		in stream gully, poor exposure of reddish-brown (weathered) to gray to black (fresh), thin bedded, fractured, very fine grained chert
81	34.386090	-93.57756	Bedding	N87E	72SE			MDa	Upper		100 ft to the south, excellent exposure of buff to tan, thin bedded, laminated, well-indurated chert and shale beds; hammer (thuds)
82	34.385773	-93.57783	Bedding	N83W	64SW			MDa	Upper		buff (weathered) to pale-white (fresh), thick bedded, resistant, hard, tripolitic Upper Novaculite
82	34.385773	-93.57783	Joint	N19E	75NW			MDa	Upper		prominent joint set
82	34.385773	-93.57783	Joint	N06E	76NW			MDa	Upper		prominent joint set
82	34.385773	-93.57783	Joint	N67E	48NW			MDa	Upper		minor joint set
83	34.384038	-93.60748	Bedding	N84E	68SE			MDa	Middle		thinly (1 - 4 inch) bedded, fractured chert w/ black to greenish gray platy shale
83	34.384038	-93.60748	Bedding	N78E	68SE			MDa	Middle		thinly (1 - 4 inch) bedded, fractured chert w/ black to greenish gray platy shale
84	34.383626	-93.61142	Bedding	N78E	72SE			MDa	Middle		greenish-gray to maroon to brown to tan, thin bedded, fractured, blocky, very fine grained chert w/ thin shale partings
84	34.383626	-93.61142	Joint	N06E	55NW			MDa	Middle		greenish gray to maroon to brown to tan thin bedded fractured blocky chert

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
85	34.384623	-93.61365	Bedding	N78W	71SW			MDa	Lower		gray (weathered) to white (fresh), hard, dense, thick to massively bedded Lower Novaculite
85	34.384623	-93.61365	Joint	N05W	90			MDa	Lower		gray (weathered) to white (fresh), hard, dense, thick to massively bedded Lower Novaculite
85	34.384623	-93.61365	Joint	N00W	90			MDa	Lower		gray (weathered) to white (fresh), hard, dense, thick to massively bedded Lower Novaculite
86	34.384890	-93.61370	Bedding	N78E	64SE			MDa	Lower		Lower Novaculite bedding very pronounced here
87	34.385058	-93.61032	Bedding	N81E	57SE			MDa	Lower		
87	34.385058	-93.61032	Joint	N09E	90			MDa	Lower		
87	34.385058	-93.61032	Joint	N02E	75NW			MDa	Lower		
87	34.385058	-93.61032	Joint	N06E	84NW			MDa	Lower		
87	34.385058	-93.61032	Joint	N08E	83NW			MDa	Lower		
88	34.385095	-93.61004	Bedding	N66E	72SE			MDa	Lower		
89	34.383641	-93.60917	Bedding	N71E	65SE			MDa	Middle		brown (weathered) to light gray (fresh), laminated, thin bedded, clay-rich shale
89	34.383641	-93.60917	Joint	N04W	68SW			MDa	Middle		brown (weathered) to light gray (fresh), laminated, thin bedded, clay-rich shale
89	34.383641	-93.60917	Joint	N04W	55SW			MDa	Middle		brown (weathered) to light gray (fresh), laminated, thin bedded, clay-rich shale
90	34.385826	-93.57822	Bedding	N62W	62SW			MDa	Upper		brown to reddish-brown (weathered) to blue-gray (fresh), extremely hard, resistant, medium bedded Upper Novaculite
90	34.385826	-93.57822	Joint	N19E	64SE			MDa	Upper		brown to reddish-brown (weathered) to blue-gray (fresh), extremely hard, resistant, medium bedded Upper Novaculite
90	34.385826	-93.57822	Joint	N15E	68SE			MDa	Upper		brown to reddish-brown (weathered) to blue-gray (fresh), extremely hard, resistant, medium bedded Upper Novaculite
90	34.385826	-93.57822	Joint	N20E	89SE			MDa	Upper		joint in shale beds at this stop
91	34.385663	-93.57889	Bedding	N76W	82SW			Ms			brown (weathered) to gray (fresh), laminated, thin bedded, jointed Stanley Shale
91	34.385663	-93.57889	Joint	N04E	68SE			Ms			brown (weathered) to gray (fresh), laminated, thin bedded, jointed Stanley Shale
91	34.385663	-93.57889	Joint	N05E	61SE			Ms			brown (weathered) to gray (fresh), laminated, thin bedded, jointed Stanley Shale
92	34.386558	-93.57904	Bedding	N74W	62SW			MDa	Upper		buff to gray (weathred) to pale tan (fresh), thick bedded, blocky, tripolitic Upper Novaculite; "sandy" texture
92	34.386558	-93.57904	Joint	N39E	54NW			MDa	Upper		closely (1 to 12 inch) spaced joint set across outcrop
92	34.386558	-93.57904	Joint	N41E	45NW			MDa	Upper		closely (1 to 12 inch) spaced joint set across outcrop
92	34.386558	-93.57904	Joint	N42E	51NW			MDa	Upper		closely (1 to 12 inch) spaced joint set across outcrop
93	34.387134	-93.57891	Bedding	N81E	64SE			MDa	Middle		thick chert bed; very planar bedding
94	34.387178	-93.57905	Bedding	N84E	79SE			MDa	Middle		small-scale fold limb 1
94	34.387178	-93.57905	Bedding	N61W	70SW			MDa	Middle		small-scale fold limb 2
94	34.387178	-93.57905	Bedding	N89W	78SW			MDa	Middle		small-scale fold limb 3
94	34.387178	-93.57905	Fold_Axial_Plane	N18E	83NW			MDa	Middle		axial plane of fold 1-2
94	34.387178	-93.57905	Fold_Axis			70	S18W	MDa	Middle		fold axis of fold 1-2
94	34.387178	-93.57905	Fold_Axial_Plane	N18E	82NW			MDa	Middle		axial plane of fold 2-3

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
94	34.387178	-93.57905	Fold_Axis			71	S18W	MDa	Middle		fold axis of fold 2-3
95	34.387254	-93.57899	Bedding	N85E	64SE			MDa	Middle		in stream gully, black to reddish-black, thin bedded chert beds
96	34.386660	-93.58150	Breccia					MDa	Upper		reddish-brown to yellow-orange, massived brecciated Upper Novaculite; old mineralization prospects
97	34.386896	-93.58175	Prospectors_Pit					MDa	Upper		6 ft x 10 ft pit about 3 to 6 ft deep; yellowish-orange soil
98	34.385908	-93.58160	Bedding	N80E	64SE			Ms			brown to tan, thin bedded, laminated, somewhat platy Stanley Shale
99	34.385941	-93.58169	Bedding	N81W	73SW			Ms			brown, thick to medium bedded, well-sorted, very fine grained wacke; dark matrix > 10 percent of rock
99	34.385941	-93.58169	Joint	N10W	48NE			Ms			
99	34.385941	-93.58169	Joint	N11W	39NE			Ms			
99	34.385941	-93.58169	Joint	N11W	45NE			Ms			
99	34.385941	-93.58169	Joint	N09W	74SW			Ms			
99	34.385941	-93.58169	Bedding	N85W	64SW			Ms			brownish-red to gray, thick bedded to massive, well to medium sorted, very fine grained wacke; dark matrix > 10 percent of rock
100	34.385628	-93.58216	Bedding	N70W	72SW			Ms			black to gray, thinly bedded, laminated, cherty to slaty Stanley Shale
101	34.386192	-93.56931	Bedding	N59W	62SW			MDa	Middle		gray to black, thin bedded, highly fractured chert and shale
102	34.386622	-93.56896	Bedding	N58W	71SW			MDa	Lower		very thick bedded to massive Lower Novaculite
103	34.386947	-93.56961	Bedding	N49W	84SW			MDa	Lower		very planar Lower Novaculite beds in open grassy area
104	34.387161	-93.56938	Bedding	N81W	65SW			MDa	Lower		
104	34.387161	-93.56938	Joint	N05E	83NW			MDa	Lower		
105	34.387926	-93.56979	Bedding	N86W	57SW			MDa	Lower		same bed as STOP 40, about 150 ft to the west
106	34.387894	-93.57008	Bedding	N80E	46SE			MDa	Lower		same bed as STOP 40 and 105
107	34.387456	-93.57030	Bedding	N61W	65SW			MDa	Lower		
107	34.387456	-93.57030	Joint	N23E	87NW			MDa	Lower		Joint A
107	34.387456	-93.57030	Joint	N55E	59NW			MDa	Lower		Joint B
107	34.387456	-93.57030	Joint	N19E	85NW			MDa	Lower		Joint C
107	34.387456	-93.57030	Joint	N58E	66NW			MDa	Lower		Joint D
108	34.387779	-93.57059	Fault	N61E	24NW			MDa	Lower	normal	small (1'x6") slickensided surface exposed in stream wash, probably internal shear zone in Lower Novaculite, beds below and above fault are not deformed or offset
108	34.387779	-93.57059	Slickenlines			24	N61W	MDa	Lower	normal	small (1'x6") slickensided surface exposed in stream wash, probably internal shear zone in Lower Novaculite, beds below and above fault are not deformed or offset
108	34.387779	-93.57059	Breccia_Bed	N25E	77SE			MDa	Lower		eyeball measurement of brecciated "plug-like" feature that is nearly perpendicular to bedding
108	34.387779	-93.57059	Bedding	N68W	68SW			MDa	Lower		about 15 ft uphill of fault; undisturbed Lower Novaculite bedding
109	34.387500	-93.57083	Bedding	N56W	62SW			MDa	Lower		beds downhill are highly brecciated
110	34.387128	-93.57070	Bedding	N50W	61SW			MDa	Lower		fractured beds above (uphill) of brecciated Lower Novaculite
110	34.387128	-93.57070	Fault	N50E	80SE			MDa	Lower	unknown	interpreted fault - eyeball measurement on trend of eroded zone through breccia outcrop; slickenlines observed in deep crevice on breccia cliff but not safely reachable
110	34.387128	-93.57070	Fault	N64E	85SE			MDa	Lower	right-lateral strike-slip	extremely flat/smooth fault surface in breccia with faint slickenlines; no chatter marks but tension joints suggest right-lateral shear

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
110	34.387128	-93.57070	Slickenlines			00	N65E	MDa	Lower	right-lateral strike-slip	extremely flat/smooth fault surface in breccia with faint slickenlines; no chatter marks but tension joints suggest right-lateral shear
110	34.387128	-93.57070	Bedding	N56W	76SW			MDa	Lower		bedding preserved directly downhill of brecciated Lower Novaculite
110	34.387128	-93.57070	Tension_Joint	N71E	44NW			MDa	Lower		tension joints on west block indicate right-lateral shear
110	34.387128	-93.57070	Tension_Joint	N85E	49NW			MDa	Lower		tension joints on west block indicate right-lateral shear
110	34.387128	-93.57070	Tension_Joint	N64W	51NE			MDa	Lower		tension joints on east block indicate right-lateral shear
110	34.387128	-93.57070	Tension_Joint	N67W	69NE			MDa	Lower		tension joints on east block indicate right-lateral shear
111	34.387528	-93.57100	Fault	N71E	72SE			MDa	Lower	right-lateral strike-slip	excellent fault surface about 5 ft long by 2 ft high exposed on SE-facing outcrop; pronounced chatter marks strongly indicate right-lateral shear
111	34.387528	-93.57100	Slickenlines			09	S72W	MDa	Lower	right-lateral strike-slip	excellent fault surface about 5 ft long by 2 ft high exposed on SE-facing outcrop; pronounced chatter marks strongly indicate right-lateral shear
112	34.385997	-93.57198	Bedding	N63W	56SW			MDa	Upper		brown to tan, medium medded, blocky weathered (tripolitic) Upper Novaculite
112	34.385997	-93.57198	Joint	N18E	75SE			MDa	Upper		
113	34.389945	-93.60800	Bedding	N73W	65SW			Smm			tan to brown, thin bedded, platy Missouri Mountain Shale above old slate prospect
114	34.390180	-93.60746	Contact					Smm-MDa			contact between Missouri Mountain Shale and Lower Novaculite exposed along utility right-of-way
115	34.389757	-93.60367	Bedding	N80W	51SW			MDa	Lower		off-white to light gray, hard, resistant, thick bedded Lower Novaculite on ridge top
116	34.389942	-93.60317	Bedding	N80W	71SW			MDa	Lower		Lower Novaculite beds appear brecciated here and beds terminate along strike just a few ft towards the east
116	34.389942	-93.60317	Fault	N10E	88SE			MDa	Lower	reverse	fault 1 (western-most); tension joints suggest thrust faulting (up-to-the-east); small scale fault
116	34.389942	-93.60317	Fault	N10E	86SE			MDa	Lower	reverse	fault 2 (middle); tension joints suggest thrust faulting (up-to-the-east); small scale fault
116	34.389942	-93.60317	Fault	N08E	85NW			MDa	Lower	subvertical	eye measurement of fault 3 (eastern-most);subvertical fault
117	34.390109	-93.60213	Bedding	N80E	44SE			MDa	Lower		
118	34.389912	-93.60088	Bedding	N79W	57SW			MDa	Lower		Lower Novaculite beds appear to terminate along strike towards the east here
118	34.389912	-93.60088	Joint	N09E	87SE			MDa	Lower		very planar joint face at termination of Lower Novaculite bed
119	34.390118	-93.60039	Bedding	N90E	57S			MDa	Lower		Lower Novaculite beds "reappear" from STOP 118; breccia zone here
119	34.390118	-93.60039	Fault	N23E	90			MDa	Lower	left-lateral strike-slip	possible fault or fault-parallel joint surface interpreted from termination of bedding; no slickenlines observed; left lateral shear based on interpretation of Google Earth photography
120	34.392279	-93.60490	Bedding	N81W	50SW			Opc			in small stream exposure: gray, thin bedded, hard, blocky, fractured shale but lacks graptolites; could be black shale of Bigfork Chert
121	34.387090	-93.57284	Fault	N42E	72SE			MDa	Lower	left-lateral strike-slip	lots of brecciated Lower Novaculite here; chatter marks on planar fault surface and possible fault drag indicate left-lateral shear
121	34.387090	-93.57284	Slickenlines			09	S42W	MDa	Lower	left-lateral strike-slip	weathered slickenlines, but chatter marks on planar fault surface and possible fault drag indicate left-lateral shear
122	34.387241	-93.57262	Bedding	N65W	68SW			MDa	Lower		tan to brown, hard, dense, medium bedded Lower Novaculite
123	34.387257	-93.57290	Breccia					MDa	Lower		large outcrop of white to light gray, massive, intensely brecciated Lower Novaculite; no bedding preserved

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
124	34.387718	-93.57257	Breccia					MDa	Lower		large outcrop of white to light gray, massive, intensely beddingted Lower Novaculite; no bedding preserved
125	34.387833	-93.57243	Bedding	N55W	68SW			MDa	Lower		
126	34.388281	-93.57243	Bedding	N53W	72SW			MDa	Lower		off-white to reddish-brown, medium to thick bedded, hard, resistant Lower Novaculite; red-brown to gray to black mineralization on bedding surfaces
127	34.388457	-93.57280	Bedding	N66W	57SW			MDa	Lower		white to gray, medium bedded, hard, dense, resistant Lower Novaculite
128	34.388450	-93.57315	Joint	N00E	81E			MDa	Lower		planar joint surface at termination of beds here moving from STOP 127; boulder (float) of Lower Novaculite has slickenlines but recon found no fault plane
129	34.389321	-93.57331	Bedding	N51E	58SE			Smm			brown (weathered) to tan (fresh), thin bedded, clay-rich shale in stream gully - probably weathered Missouri Mountain Shale
129	34.389321	-93.57331	Fault	N50W	47NE			Smm		left-lateral strike-slip	small scale (inches) fault; drag on shale laminations suggests left-lateral shear
130	34.389524	-93.57356	Bedding	N90E	77S			Smm			same desc as STOP 129, edges weathered black
131	34.389728	-93.57385	Bedding	N75E	66SE			Smm			brown (weathered) to greenish-gray (fresh), finely laminated, platy, clay-rich shale - probably Missouri Mountain Shale
132	34.390069	-93.57448	Bedding	N64W	62SW			Opc			brown to black (weathered) to dark black (fresh), laminated, thin bedded, clay-rich shale - probably Polk Creek Shale
133	34.390710	-93.57450	Bedding	N19E	52SE			Opc			buff-tan (weathered) to black (fresh), thin bedded, platy shale - probably Polk Creek Shale
134	34.391071	-93.57476	Bedding	N45W	70NE			Sb?			brown to gray (weathered) to gray (fresh), well-indurated, very hard, very fine grained sandstone - Blaylock Sandstone? - single bed exposed in stream cut bank is about 1.5 ft thick
135	34.392764	-93.57496	Bedding	N66W	80SW			Obf			weathered Bigfork Chert beds in stream channel; red-orange drainage from shale beds
136	34.387608	-93.57414	Bedding	N66W	51SW			MDa	Lower		Novaculite
136	34.387608	-93.57414	Joint	N04E	90			MDa	Lower		joints spaced 6-12 inches
136	34.387608	-93.57414	Joint	N01E	85NW			MDa	Lower		joints spaced 6-12 inches
136	34.387608	-93.57414	Joint	N11E	88SE			MDa	Lower		joints spaced 6-12 inches
137	34.386545	-93.56908	Fault	N19W	70SW			MDa	Lower	strike-slip	gray to tan to white, dense, resistant, blocky to brecciated Lower Novaculite; fault is prominent fracture traceable for at least 12 ft up south face of outcrop; sense of slip unknown
137	34.386545	-93.56908	Slickenlines			12	S19E	MDa	Lower	strike-slip	very weathered slicks; sense of slip unknown
138	34.386639	-93.56911	Fault	N15W	79SW			MDa	Lower	strike-slip	same fault as STOP 137; sense of slip unknown
138	34.386639	-93.56911	Slickenlines			13	S15E	MDa	Lower	strike-slip	well-developed slickenlines; sense of slip unkonwn
139	34.390104	-93.57077	Bedding	N36E	33SE			MDa	Lower		light gray to off-white, resistant Lower Novaculite
140	34.390079	-93.57104	Bedding	N40E	41SE			MDa	Lower		
140	34.390079	-93.57104	Joint	N83W	85SW			MDa	Lower		
140	34.390079	-93.57104	Joint	N80W	83SW			MDa	Lower		
141	34.389657	-93.57115	Fault	N43E	31NW			MDa	Lower	unknown	small (2 ft by 2 ft) fault surface w/ slickenlines; sense of slip unknown; probably internal shear resulting from folding of Lower Novaculite
141	34.389657	-93.57115	Slickenlines			12	N30E	MDa	Lower	unknown	small (2 ft by 2 ft) fault surface w/ slickenlines; sense of slip unknown; probably internal shear resulting from folding of Lower Novaculite

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
141	34.389657	-93.57115	Fault	N30W	73NE			MDa	Lower	unknown	fault interpreted from termination of tension cracks which suggest left-lateral shear; probably internal shear resulting from folding of Lower Novaculite
141	34.389657	-93.57115	Tension_Joint	N68W	67SW			MDa	Lower		dense network of tension joints terminate on single surface (fault?)
141	34.389657	-93.57115	Tension_Joint	N73W	58SW			MDa	Lower		dense network of tension joints terminate on single surface (fault?)
142	34.389536	-93.57099	Bedding	N41W	70NE			MDa	Lower		
143	34.389470	-93.57037	Bedding	N05W	71NE			MDa	Lower		
143	34.389470	-93.57037	Joint	N64E	71NW			MDa	Lower		
144	34.389239	-93.57027	Bedding	N50W	54NE			MDa	Lower		
145	34.388770	-93.56942	Bedding	N51W	87NE			MDa	Lower		
146	34.384842	-93.55227	Bedding	N20W	45NE			Ms			brown (weathered) to dark purple (fresh), very fine grained, well indurated, quartzitic sandstone in Stanley Shale
147	34.385380	-93.55360	Fault	N81W	70SW			MDa	Upper	unknown	unsure if this is a fault or just bedding at base of Upper Novaculite; brecciated novaculite suggests faulting
148	34.385478	-93.55367	Fault	N79W	73SW			MDa	Upper	unknown	unsure if this is a fault or just bedding at base of Upper Novaculite; but prominence of breccia above and below this smooth, planar surface suggests fault
149	34.386577	-93.55439	Bedding	N70W	80NE			Ms			Shale
150	34.386712	-93.55521	Bedding	N75W	78SW			Ms			
151	34.387476	-93.55454	Float					Ms			boulders (float) of black to dark gray, subangular to angular, poorly sorted, very fine to medium to coarse pebble congomerate
152	34.388085	-93.55403	Prospectors_Pit					MDa	Upper		several prospector's pits 3-4 ft deep, 4-6 ft wide
153	34.387804	-93.55332	Bedding	N71W	76SW			MDa	Upper		gray (weathered) to off-white (fresh), dense, hard, resistant, thick to massive bedded Upper Novaculite
154	34.387664	-93.55260	Bedding	N88W	65SW			MDa	Upper		gray (weathered) to off-white (fresh), dense, hard, resistant, thick to massive bedded Upper Novaculite; beds 1 to 2 ft thick
154	34.387664	-93.55260	Joint	N00E	58E			MDa	Upper		
154	34.387664	-93.55260	Joint	N12E	51SE			MDa	Upper		
154	34.387664	-93.55260	Joint	N12E	74SE			MDa	Upper		
155	34.389039	-93.55263	Bedding	N72W	55SW			MDa	Lower		
155	34.389039	-93.55263	Joint	N08E	88NW			MDa	Lower		
156	34.389440	-93.55241	Bedding	N81W	52SW			MDa	Lower		lots of Lower Novaculite breccia between STOPS 155 and 156; brecciated member of Lower Novaculite?
157	34.389791	-93.55242	Bedding	N84W	50SW			MDa	Lower		gray to off-white, hard, dense, medium bedded Lower Novaculite
157	34.389791	-93.55242	Joint	N03E	88SE			MDa	Lower		
158	34.387062	-93.55301	Bedding	N68W	71SW			Ms			stream-cut exposure of tan to brown to gray, thin bedded Stanley Shale
159	34.387113	-93.55559	Bedding	N84W	75SW			Ms			cut-bank exposure of brown (weathered) to gray (fresh), thin-bedded to laminated, weathred shale
160	34.387812	-93.55635	Bedding	N80W	75SW			MDa	Upper		gray to off-white, hard, resistant, thick bedded to massive Upper Novaculite
161	34.388686	-93.55771	Bedding	N85W	74SW			MDa	Middle		red to brown to tan to black, thin bedded, well-uniform bedded, chert and shale
162	34.388941	-93.55978	Fold_Limb	N80W	90			MDa	Middle		broad fold in Middle Novaculite beds in stream cut - hard to access for detailed measurements; approximate eye measurements

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
162	34.388941	-93.55978	Fold_Limb	N55W	80NE			MDa	Middle		broad fold in Middle Novaculite beds in stream cut - hard to access for detailed measurements; approximate eye measurements
163	34.389024	-93.56044	Bedding	N74W	77SW			MDa	Middle		cut-bank exposure of black to gray thin bedded chert and shale
163	34.389024	-93.56044	Float					MDa	Lower		in stream, orange-brown boulder of Lower Novaculite w/ slickenlines; slickensided surface is well developed and about 8 by 6 inches across
164	34.388990	-93.56065	Fault	N42W	22SW			MDa	Lower	unknown	(?) boulder-sized "outcrop" of tan to brown to white L. Novaculite with slickenlines, probably not in place
164	34.388990	-93.56065	Slickenlines			14	S10E	MDa	Lower	unknown	(?) boulder-sized "outcrop" of tan to brown to white L. Novaculite with slickenlines, probably not in place
164	34.388990	-93.56065	Bedding	N83W	74SW			MDa	Middle		black to dark gray, thin bedded chert and shale
165	34.389137	-93.56115	Bedding	N86W	64SW			MDa	Middle		cut-bank exposure of black, thin bedded, well indurated slate (hammer ping), very planar surface in stream
165	34.389137	-93.56115	Joint	N36E	87SE			MDa	Middle		cut-bank exposure of black, thin bedded, well indurated slate (hammer ping), very planar surface in stream
166	34.389860	-93.56078	Bedding	N79W	55SW			MDa	Lower		
166	34.389860	-93.56078	Joint	N77W	58NE			MDa	Lower		
167	34.390648	-93.56086	Bedding	N85W	51SW			MDa	Lower		gray to off-white, massive to poorly bedded Lower Novaculite
168	34.391082	-93.55876	Bedding	N87E	59SE			MDa	Lower		Lower Novaculite ridge
169	34.391057	-93.55808	Bedding	N85W	67SW			MDa	Lower		beds undulate, average eyeball measurement
170	34.391155	-93.56024	Bedding	N86E	54SE			MDa	Lower		
170	34.391155	-93.56024	Joint	N08W	80SW			MDa	Lower		
171	34.389252	-93.56186	Bedding	N84W	50SW			MDa	Middle		pitch black, hard, dense, thin bedded, fine-grained chert with thin shale interbeds
172	34.389307	-93.56254	Bedding	N86W	63SW			MDa	Middle		black to brown to gray to rust colored, thin uniform/parallel bedded chert and shale
173	34.389519	-93.56313	Float					MDa	Middle		lost Middle Chert and Shale beds, significant increase in bldrs, float, and talus of Lower Novaculite
174	34.388324	-93.56237	Bedding	N85W	73SW			MDa	Upper		Dr. Barker measurement; strike and dip agrees well with STOP 160 to the east, mostly ruble and float covered slope here
175	34.388660	-93.56190	Bedding?	N50W	22NE			MDa	Lower?		Novaculite
176	34.389634	-93.56432	Float					MDa	Lower		tan to brown to off white Lower Novaculite boulder in stream w/ slickenlines but NOT IN PLACE
177	34.389693	-93.56507	Joint	N29E	51SE			MDa	Lower		(?) tan to brown to off white L Novac in stream, may not be in place
178	34.389849	-93.56696	Bedding	N88E	55SE			MDa	Middle		stream cut exposure of brown to gray to light gray, very thin bedded, extremely hard chert and shale
179	34.389891	-93.56718	Bedding	N86E	63NW			MDa	Lower		(?) Dr. Barker measurement; probably bedding but very different
179	34.389891	-93.56718	Joint	N50E	14SE			MDa	Lower		(?) Dr. Barker measurement; probably a joint
180	34.389813	-93.56807	Float					MDa	Middle		black and white chert and shale bit in overturned tree stump, no beds
181	34.389982	-93.56859	Bedding	N68E	48SE			MDa	Lower		
182	34.389985	-93.56913	Bedding	N61E	56SE			MDa	Lower		
183	34.389669	-93.56929	Fold_Axial_Plane	N82W	63SW			MDa	Lower		possible small scale fold
183	34.389669	-93.56929	Fold_Axis			34	S80W	MDa	Lower		possible small scale fold
184	34.386915	-93.57321	Fault	N29W	63NE			MDa	Lower	unknown	(?) faint slicks observed on small folded surface - fault? - may not be in place

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
184	34.386915	-93.57321	Fault	N22W	31NE			MDa	Lower	unknown	(?) faint slicks observed on small folded surface - fault? - may not be in place
184	34.386915	-93.57321	Slickenlines			22	S29E	MDa	Lower	unknown	(?) faint slicks observed on small folded surface - fault? - may not be in place
184	34.386915	-93.57321	Slickenlines			15	S22E	MDa	Lower	unknown	(?) faint slicks observed on small folded surface - fault? - may not be in place
184	34.386915	-93.57321	Bedding	N50W	59NE			MDa	Lower		20' west of first measurements, about 4 beds with NE dips
185	34.387402	-93.57256	Joint	N46E	22NW			MDa	Lower		large outcrop of heavily jointed and fractured Lower Novaculite, joints are spaced 2-12 inches
186	34.387698	-93.57224	Bedding	N52W	51SW			MDa	Lower		
186	34.387698	-93.57224	Fault	N34E	83NW			MDa	Lower	right-lateral strike-slip	(?) possible small scale shear zone in Lower Novaculite - tension joints appear to terminate on single planar surface and surrounding outcrop is brecciated
187	34.387750	-93.57253	Fault	N52W	63SW			MDa	Lower	unknown	(?) faint slicks - unsure; strike matches STOP 186, possible chatter marks are inconsistent; may just be fault breccia
187	34.387750	-93.57253	Slickenlines			35	S32E	MDa	Lower	unknown	(?) faint slicks - unsure; strike matches STOP 186, possible chatter marks are inconsistent; may just be fault breccia
189	34.387829	-93.57262	Fault	N49W	90			MDa	Lower	left-lateral strike-slip	(?) possible fault surface, no slicks; "wedge" of Lower Novaculite in outcrop w/ tension joints suggests left-lateral shear
190	34.387717	-93.57229	Fault	N35E	86NW			MDa	Lower	right-lateral strike-slip	small-scale curviplanar fault surface; dense tension joints; tension joints suggest right-lateral shear
190	34.387717	-93.57229	Fault	N32E	89NW			MDa	Lower	right-lateral strike-slip	small-scale curviplanar fault surface; dense tension joints; tension joints suggest right-lateral shear
190	34.387717	-93.57229	Fault	N10E	77NW			MDa	Lower	right-lateral strike-slip	small-scale curviplanar fault surface; dense tension joints; tension joints suggest right-lateral shear
190	34.387717	-93.57229	Slickenlines			27	S22W	MDa	Lower	right-lateral strike-slip	small-scale curviplanar fault surface; dense tension joints; tension joints suggest right-lateral shear
191	34.387991	-93.57195	Bedding	N63W	58SW			MDa	Lower		
192	34.388033	-93.57142	Fault	N60E	78SE			MDa	Lower	thrust	possible fault in Lower Novaculite, no slickenline but chatter marks suggest HW moved up relative to FW
193	34.388791	-93.57084	Float					MDa	Lower		bldrs and float with slickenlines and chatter marks
194	34.389034	-93.57066	Fault	N77E	73NW			MDa	Lower	strike-slip	slickenlines and chatter marks on several surfaces, but conflicting chatter marks
194	34.389034	-93.57066	Slickenlines			17	S80W	MDa	Lower	strike-slip	slickenlines and chatter marks on several surfaces, but conflicting chatter marks
194	34.389034	-93.57066	Fault	N70E	74NW			MDa	Lower	left-lateral strike-slip	Dr. Barker measurement 5' away, consistent chatter marks indicate left-lateral shear
194	34.389034	-93.57066	Slickenlines			11	S74W	MDa	Lower	left-lateral strike-slip	Dr. Barker measurement 5' away, consistent chatter marks indicate left-lateral shear
195	34.389469	-93.57080	Bedding	N30W	64NE			MDa	Lower		Dr. Barker measurement
196	34.389383	-93.57082	Fault	N51E	72NW			MDa	Lower	normal	small (1 by 3 ft) fault surface w/ faint slicks, chatter marks suggest HW moved down
196	34.389383	-93.57082	Slickenlines			50	N35E	MDa	Lower	normal	small (1 by 3 ft) fault surface w/ faint slicks, chatter marks suggest HW moved down

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
197	34.389005	-93.52948	Bedding	N62E	48SE			MDa	Upper		cut-bank exposure of light gray to maroon (weathered), medium bedded (1-2 ft), hard, dense, resistant Upper Novaculite
198	34.391872	-93.52947	Bedding	N10E	34SE			MDa	Middle		Dr. Barker measurement
199	34.392617	-93.53184	Bedding	N32E	44NW			MDa	Lower		possible parasitic fold here may explain NW dip direction
200	34.392770	-93.53279	Bedding	N20E	19SE			MDa	Lower		
200	34.392770	-93.53279	Bedding	N16E	23SE			MDa	Lower		
201	34.392917	-93.53428	Bedding	N55E	24SE			MDa	Lower		
202	34.393102	-93.53808	Bedding	N65E	31SE			MDa	Lower		
203	34.388954	-93.53109	Float					MDa	Upper		lots of bldrs and talus of Upper Novaculite
204	34.388372	-93.53092	Float					Ms			bldrs of black to dark gray, hard, subangular to angular, poorly sorted, medium to fine pebble chert conglomerate
205	34.388146	-93.53074	Float					Ms			float of gray (weathered) to tan to yellow-orange (fresh), subrounded to subangular, well sorted quartz arenite
206	34.382747	-93.55529	Float					Ms			lone boulder of light to dark gray to black, subangular to subrounded, poorly sorted, medium to coarse pebble chert conglomerate
207	34.384195	-93.55290	Bedding	N45E	39SE			Ms			(?) possible bedding surface but not be in place
208	34.384388	-93.55245	Bedding	N01W	45NE			Ms			in place beds of dark gray to black, subangular to subrounded, poorly sorted, medium to coarse pebble chert conglomerate
209	34.384462	-93.55226	Bedding	N52E	40SE			Ms			slickensides
209	34.384462	-93.55226	Joint	N85E	83NW			Ms			joint?
209	34.384462	-93.55226	Joint	N83E	84NW			Ms			joint?
210	34.384496	-93.55229	Fault	N86W	74NE			Ms		left-lateral strike-slip	planar north-facing surface in black chert cgl w/ faint gouges - possible fault
210	34.384496	-93.55229	Slickenlines			14	N90E	Ms		left-lateral strike-slip	slumped bldr about 6 ft away has very smooth "polished" surface - if "rotating" this boulder back into its apparent place then chatter marks would suggest left-lateral shear
211	34.384922	-93.55293	Joint	N43W	73NE			MDa	Upper		tripolitic Upper Novaculite; prominent surface in several places; parallels direction of stream downhill
212	34.385097	-93.55298	Bedding	N72E	65SE			MDa	Middle		brown to reddish-brown, thin to medium bedded, blocky to fractured chert with thin shale interbeds
213	34.384909	-93.55298	Prospectors_Pit					MDa	Upper		prospect pit in Upper Novaculite; boulders are reddish-orange to metallic colored with bands of dark minerals (manganese?); three loose boulders about 15 ft to the east with prominent slickenlines
214	34.384686	-93.55311	Fault	N87W	30SW			MDa	Upper	normal	polished and slickensided fault surface in Upper Novaculite; chatter marks suggest normal faulting; footwall is brecciated
214	34.384686	-93.55311	Slickenlines			10	S55W	MDa	Upper	normal	polished and slickensided fault surface in Upper Novaculite; chatter marks suggest normal faulting; footwall is brecciated
215	34.385126	-93.55385	Prospectors_Pit					MDa	Upper		large prospect pit in Upper Novaculite that is black to rust colored and brecciated w/dense jointing; pit is about 20 ft deep into north-facing hillside and about 12 ft wide
216	34.385273	-93.55429	Bedding	N61E	70SE			MDa	Upper		
217	34.384486	-93.55443	Bedding	N74E	69SE			MDa	Upper		
218	34.384429	-93.55601	Bedding	N88E	78SE			MDa	Upper		beds undulate slightly

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
219	34.383886	-93.55593	Bedding	N82E	69SE			Ms			black chert cgl beds much higher in elevation than stop 206; cgl here can be observed "peeking" out along strike here, suggesting this is in place
220	34.382831	-93.55746	Bedding	N87E	73SE			Ms			thin bed of brown (weathered) to greenish-brown (fresh) well-sorted, very fine grained graywacke in Stanley Shale
221	34.384234	-93.55771	Bedding	N75E	61SE			MDa	Upper		
221	34.384234	-93.55771	Joint	N50E	46NW			MDa	Upper		joints spaced about 4-8 inches
222	34.384629	-93.55789	Bedding	N67E	62SE			MDa	Upper		
223	34.385928	-93.55638	Bedding	N45W	75NE			MDa	Middle		thin bedded chert with thin interbedded shale (slate?); beds now dip NE, probably a fold in Middle Novaculite beds here
224	34.386536	-93.55542	Bedding	N84W	83NE			Ms			stream bed exposure of reddish-brown to tan to pale gray, soft, weathered, thin bedded Stanley Shale
225	34.387145	-93.55682	Float					Ms			Overturned tree stumps reveal float of tan and brown to rust colored, platy to blocky, fractured, clay-rich Stanley Shale
226	34.386983	-93.55729	Float					MDa	Lower		Lower Novaculite cobble (float) w/ polished slickenlines suggesting faulting in this area; no beds observed nearby
227	34.386860	-93.55722	Talus					MDa	Lower		Lower Novaculite talus exposed in overturned tree stump; one cobble has slickenlines suggesting faulting in this area
228	34.386385	-93.55720	Joint	N15W	87NE			MDa	Lower		Lower Novaculite breccia w/ dense fractures and joints; joint (sub)parallel to faulting?
229	34.387167	-93.55892	Fault	N60W	14NE			MDa	Lower	normal	smooth fault surface; chatter marks suggest normal faulting
229	34.387167	-93.55892	Slickenlines			11	N10E	MDa	Lower	normal	smooth fault surface; chatter marks suggest normal faulting
230	34.386974	-93.55906	Bedding	N78E	50SE			MDa	Lower		thick bedded Lower Novaculite
231	34.386366	-93.55943	Fault	N14E	39NW			MDa	Lower	thrust	Large breccia outcrop of Lower Novaculite w/ slickensided surfaces; west face has small faint chatter marks indicating thrust faulting
231	34.386366	-93.55943	Slickenlines			20	N20W	MDa	Lower	thrust	Large breccia outcrop of Lower Novaculite w/ slickensided surfaces; west face has small faint chatter marks indicating thrust faulting
231	34.386366	-93.55943	Fault	N05E	38NW			MDa	Lower	thrust	prominent chatter marks on this fault surface also suggest thrust faulting
231	34.386366	-93.55943	Slickenlines			15	N23W	MDa	Lower	thrust	prominent chatter marks on this fault surface also suggest thrust faulting
231	34.386366	-93.55943	Bedding	N68E	62SE			MDa	Lower		normal bedding surrounding "pod" of Lower Novaculite breccia; localized faulting?
232	34.386708	-93.55846	Bedding	N13E	31SE			MDa	Lower		
233	34.386681	-93.55792	Observation					MDa	Lower		Lower Novaculite beds appear to disappear along strike towards the east close to this stop; faulted out
234	34.386343	-93.55743	Breccia					MDa	Lower		
235	34.385871	-93.55745	Breccia					MDa	Lower		
236	34.384494	-93.56010	Bedding	N88W	64SW			MDa	Middle		black to gray to brown, thin bedded (1-3 inches), hard, blocky, fractured chert and shale
238	34.400519	-93.60179	Bedding	N07W	38NE			Obf			gray (weathered) to dark gray (fresh), thin to thick bedded, hard chert with thin interbeds of gray to pale gray, platy shale
239	34.399377	-93.60208	Bedding	N52W	49NE			Opc			hillside exposure of dark gray (weathered) to black (fresh), platy to fissile, very thin bedded, clay-rich shale; probably Polk Creek Shale
240	34.398595	-93.59988	Fault	N43W	45SW			MDa	Lower	unknown	conflicting chatter marks
240	34.398595	-93.59988	Slickenlines			21	S10E	MDa	Lower	unknown	conflicting chatter marks
240	34.398595	-93.59988	Joint	N15E	90SE			MDa	Lower		closely spaced joints

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
240	34.398595	-93.59988	Joint	N15E	83SE			MDa	Lower		closely spaced joints
240	34.398595	-93.59988	Bedding	N89E	69SE			MDa	Lower		(?) unsure what this surface is; if bedding is it overturned? Or is this a joint?
241	34.398699	-93.59946	Bedding	N00E	39E			MDa	Lower		possible varves?
242	34.399698	-93.59825	Bedding	N66E	50NW			MDa	Lower		not sure if this is bedding or a joint surface
243	34.399761	-93.59818	Bedding	N88E	54SE			MDa	Lower		possible varves?
243	34.399761	-93.59818	Joint	N65E	51NW			MDa	Lower		this agrees with STOP 242; joint?
243	34.399761	-93.59818	Joint	N42W	81NE			MDa	Lower		
243	34.399761	-93.59818	Joint	N40W	79NE			MDa	Lower		
244	34.400103	-93.59646	Joint	N17E	76NW			MDa	Lower		prominent joint set
244	34.400103	-93.59646	Bedding	N84W	69NE			MDa	Lower		(?) unsure if this is truly bedding
245	34.399510	-93.59675	Fault	N17W	49NE			MDa	Lower	unknown	slip
245	34.399510	-93.59675	Slickenlines			27	S45E	MDa	Lower	unknown	slip
245	34.399510	-93.59675	Joint	N24W	38SW			MDa	Lower		probably a joint; surface covered w/ very fine quartz crystals (no HCl fizz)
245	34.399510	-93.59675	Joint	N84W	50NE			MDa	Lower		
246	34.399012	-93.59639	Breccia					MDa	Lower		massive Lower Novaculite reccia with heavy mineral staining and veins
247	34.398650	-93.59636	Fault	N75W	68NE			MDa	Lower	right-lateral strike-slip	chatter marks suggest right-lateral shear
247	34.398650	-93.59636	Slickenlines			26	S85E	MDa	Lower	right-lateral strike-slip	chatter marks suggest right-lateral shear
247	34.398650	-93.59636	Joint	N75W	55NE			MDa	Lower		fault-parallel joint
247	34.398650	-93.59636	Joint	N85W	51NE			MDa	Lower		fault-parallel joint
248	34.400193	-93.59480	Bedding	N67W	59SW			MDa	Lower		unsure if this is bedding or a joint surface, agrees with beds to the east, but not the west
249	34.400901	-93.59484	Bedding	N73W	81NE			MDa	Lower		common surface here; unsure if bedding or joints
250	34.402373	-93.59530	Float					Obf			in overturned tree stump, tan to white to purple blocky, angular chert float; Bigfork Chert float? Unsure
251	34.402630	-93.59540	Bedding	N68E	62SE			Obf			black to tan, thin bedded chert and shale exposed in stream channel; probably Bigfork Chert
252	34.403136	-93.59554	Bedding	N68E	56SE			Obf			in stream cut, gray to rust colored, hard, thin bedded chert with thin shale interbeds
253	34.404922	-93.59855	Tension_Joint	N75W	69NE			Ow			calcite-filled tension fractures (strong HCL fizz) run parallel through and cut across black shale layers, but are not present in gray to tan layers
253	34.404922	-93.59855	Fold_Axial_Plane	N45E	50SE			Ow			folded Womble Shale
253	34.404922	-93.59855	Fold_Axis			20	N60E	Ow			folded Womble Shale
253	34.404922	-93.59855	Joint	N08E	75NW			Ow			joint not filled with calcite
254	34.404881	-93.59865	Bedding	N73E	69SE			Ow			beds on south bank of stream
254	34.404881	-93.59865	Bedding	N60W	85NE			Ow			beds in stream channel are disturbed, this is bedding on north bank of stream
254	34.404881	-93.59865	Fault	N80E	35SE			Ow		thrust	chatter marks suggest thrust faulting
254	34.404881	-93.59865	Slickenlines			32	S15E	Ow		thrust	chatter marks suggest thrust faulting
254	34.404881	-93.59865	Fault	N59E	23SE			Ow		thrust	best fault surface - chatter marks suggest thrust faulting
254	34.404881	-93.59865	Slickenlines			23	S22E	Ow		thrust	best fault surface - chatter marks suggest thrust faulting
255	34.404805	-93.59895	Bedding	N75E	56SE			Ow			uniform, parallel, undeformed Womble shale beds in strea
256	34.404633	-93.59908	Fault	N36E	23SE			Ow		thrust	small fault surface on nose of broad open fold that plunges steeply - chatter marks suggest thrust fault

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
256	34.404633	-93.59908	Slickenlines			15	S01W	Ow		thrust	small fault surface on nose of broad open fold that plunges steeply - chatter marks suggest thrust fault
256	34.404633	-93.59908	Fold_Axial_Plane	N15E	80SE			Ow			
256	34.404633	-93.59908	Fold_Axis			88	N16E	Ow			
257	34.404500	-93.59952	Bedding	N86E	82SE			Ow			
258	34.404173	-93.60061	Bedding	N76E	71SE			Ow			two samples taken of dark blue-gray limestone (EXTREME! HCL fizz)
259	34.403879	-93.60108	Bedding	N76E	70SE			Obf			gray to rust colored thin bedded platy to fissile black shale and thin chert beds - base of Bigfork Chert
260	34.403438	-93.60243	Bedding	N83E	65SE			Obf			light to dark gray to rust colored thin bedded chert and shale
261	34.403332	-93.60290	Fault	N89W	57SW			Obf		thrust	large fault surface in Bigfork Chert exposed along stream
261	34.403332	-93.60290	Slickenlines			57	S05W	Obf		thrust	large fault surface in Bigfork Chert exposed along stream
262	34.402807	-93.60293	Bedding	N83E	72SE			Obf			gray to dark gray, thin bedded highly fractured chert
263	34.402027	-93.60360	Bedding	N88E	87NW			Obf			
264	34.401380	-93.60425	Bedding	N89W	87NE			Obf			
265	34.400651	-93.60410	Bedding	N90E	60S			Obf			orange-yellow drainage on south side of stream, causing intense green to multi-colored algae growth, pH ≈ 6
266	34.400298	-93.60436	Bedding	N62W	45NE			Opc?			black thin bedded shale w/ minor quartz-filled fractures (no HCL fizz), rust-colored drainage from shale
267	34.393848	-93.61022	Bedding	N88W	54SW			Obf			gray to black to rust colored thin bedded hard chert with thin shale interbeds
268	34.394379	-93.61029	Bedding	N80E	46SE			Ow?			black to dark gray thin bedded slaty shale - Womble?
269	34.395798	-93.61010	Bedding	N74W	70NE			Ow?			dark gray to rust colored thin bedded hard to dense metamorphosed(?) shale - Womble?
270	34.396958	-93.60827	Bedding	N80W	71SW			Ow?			stream channel exposure of dark gray to black thin bedded hard to dense slate (hammer ping)
271	34.398078	-93.60684	Bedding	N45W	60NE			Ow?			black to buff thin bedded shale w/ minor chert interbeds (slight hammer ping)
272	34.399253	-93.60576	Fold_Axial_Plane	N86E	84NW			Opc?			black to dark gray platy clay-rich weathered shale
272	34.399253	-93.60576	Fold_Axis			19	N90E	Opc?			black to dark gray platy clay-rich weathered shale
272	34.399253	-93.60576	Fold_Axial_Plane	N87W	82NE			Opc?			black to dark gray platy clay-rich weathered shale
272	34.399253	-93.60576	Fold_Axis			32	N90E	Opc?			black to dark gray platy clay-rich weathered shale
273	34.399616	-93.60504	Bedding	N88E	70NW			Opc?			black (fresh) to rust-colored (weathered) thin bedded blocky to fractured slate (hammer ping) - brown-orange drainage on south bank of stream (pH ≈ 5-6)
274	34.400085	-93.60439	Bedding	N71W	48NE			Opc?			some relatively undisturbed bedding in deformed outcrop
274	34.400085	-93.60439	Fault	N56E	28SE			Opc?		thrust	some small polished surfaces in black shale, chatter marks suggest thrust faulting
274	34.400085	-93.60439	Slickenlines			18	S10E	Opc?		thrust	some small polished surfaces in black shale, chatter marks suggest thrust faulting
275	34.399455	-93.60358	Observation					Opc?			cut-bank exposure of tan to black to gray thin bedded brecciated shale w/ very thin quartz veins (no HCL fizz), beds are highly deformed
276	34.399308	-93.60330	Float					Opc?			stream float of pale green to tan to buff platy shale - no bedding in place
277	34.399238	-93.60321	Observation					Opc?			stream exposure of black to tan, very thin bedded deformed shale

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
278	34.398984	-93.60305	Vertical_Bedding	N90E	90			Smm			cut-bank exposure of brown to tan (weathered) to pale green (fresh) platy very thin bedded clay-rich shale
279	34.398921	-93.60296	Joint	N11W	68SW			MDa	Lower		NOT IN PLACE
280	34.398597	-93.60267	Vertical_Bedding	N82W	90			Smm			tan to brown (weathered) thin bedded intensely fractured shale
280	34.398597	-93.60267	Joint	N15E	87NW			Smm			tan to brown (weathered) thin bedded intensely fractured shale
281	34.398477	-93.60223	Float					MDa	Lower		L. Novaculite boulder w/ slicked surface but not in place
282	34.398519	-93.60208	Observation					Smm			extremely deformed shale beds exposed on cut-bank
283	34.398530	-93.60166	Bedding	N58W	63SW			Smm			tan to brown platy deformed shale beds in stream cut
283	34.398530	-93.60166	Float	N57W	75NE			MDa	Lower		large boulder of Lower Novaculite w/ slickenlines, but doubt it is in place
283	34.398530	-93.60166	Float			07	S60E	MDa	Lower		large boulder of Lower Novaculite w/ slickenlines, but doubt it is in place
284	34.398471	-93.60140	Observation					Smm?			cut-bank exposure of tan to gray platy shale rubble and talus - bedding obliterated
285-1	34.398180	-93.60076	Prospectors_Pit					MDa	Lower		flattened area about 2 acres in size - old exploration pit
285-2	34.397729	-93.60078	Prospectors_Pit					MDa	Lower		L. Novaculite boulders with dark gray mineralization (dentritic pattern) and slickenlines
285-3	34.397771	-93.60028	Bedding	N80E	40NW			MDa	Lower		unsure if this is bedding or a joint; strike agrees w/ topographic trend of the ridge
285-3	34.397771	-93.60028	Bedding	N80E	70NW			MDa	Lower		unsure if this is bedding or a joint; strike agrees w/ topographic trend of the ridge
285-4	34.397643	-93.60087	Prospectors_Pit					MDa	Lower		old access road to workings from the west
286	34.397823	-93.60177	Prospectors_Pit					MDa	Lower		exploratory trench in Lower Novaculite about 20 ft long by 15 ft wide by 6 ft deep
287	34.397502	-93.60484	Bedding	N84W	80NE			Obf			road cut exposure of gray to rust colored thin bedded hard chert w/ thin shale interbeds
288	34.396204	-93.60752	Bedding	N51W	49SW			Obf			light gray thin chert beds poorly exposed on hillside
289	34.393797	-93.60850	Bedding	N68W	66NE			Obf			gray to buff thin bedded hard dense chert bed exposed on utility easement
290	34.405202	-93.59794	Observation					Ow			massively deformed fractured Womble shale w/ dense network of calcite-filled fractures - bedding completely obliterated, outcrop has "flowing" appearance
291	34.405768	-93.59713	Observation					Ow			Womble shale exposures in stream are chaotic and deformed w/ dense network of calcite-filled fractures, "flowage" appearance
292	34.405937	-93.59665	Bedding	N83W	61SW			Ow			possible Womble bedding, surrounding exposures are highly deformed
293	34.405954	-93.59635	Bedding	N36W	53NE			Ow			cut-bank exposure of tan to light gray weathered thin bedded shale
293	34.405954	-93.59635	Fold_Axial_Plane	N81W	65SW			Ow			
293	34.405954	-93.59635	Fold_Axis			53	S60E	Ow			
294	34.406364	-93.59554	Fault	N64W	76NE			Ow		normal	deformed Womble shale extending from cut-bank - north side has calcite slickensides
294	34.406364	-93.59554	Slickenlines			54	S84E	Ow		normal	deformed Womble shale extending from cut-bank - north side has calcite slickensides
294	34.406364	-93.59554	Fault	N90E	80S			Ow		normal	deformed Womble shale extending from cut-bank - north side has calcite slickensides
294	34.406364	-93.59554	Slickenlines			80	S05E	Ow		normal	deformed Womble shale extending from cut-bank - north side has calcite slickensides

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
294	34.406364	-93.59554	Bedding	N71W	76NE			Ow			bedding about 12 ft downstream
295	34.406657	-93.59394	Bedding	N40W	51NE			Ow			Womble shale exposed in stream channel
296	34.406548	-93.59188	Bedding	N48W	45NE			Obf			probably beds near Womble-Bigfork contact
297	34.405700	-93.59101	Bedding	N44W	27NE			Obf			stream-cut exposure of black to rust colored to tan to gray thin bedded chert and shale beds
298	34.404754	-93.58732	Float					MDa	Lower		Lower Novaculite boulder w/ slickenlines in stream gully, NOT IN PLACE
299	34.404770	-93.58660	Bedding	N30W	68NE			Obf			stream-cut exposure of gray to blue-gray thin bedded fractured chert and shale
300	34.404703	-93.58586	Bedding	N68W	59NE			Obf			black to rust-colored thin bedded chert beds
301	34.405459	-93.58451	Fault	N56E	78NW			MDa	Lower	oblique left-lateral thrust	tension joints suggest left lateral thrust faulting
301	34.405459	-93.58451	Slickenlines			44	N55E	MDa	Lower	oblique left-lateral thrust	tension joints suggest left lateral thrust faulting
302	34.405380	-93.58434	Fault	N07E	40NW			MDa	Lower	unknown	conflicting chatter marks
302	34.405380	-93.58434	Slickenlines			23	N23W	MDa	Lower	unknown	conflicting chatter marks
303	34.405096	-93.58321	Observation					MDa	Lower		top of saddle w/ lots of L. Novaculite talus but no outcrops or beds
304	34.404792	-93.58300	Fault	N87W	84NE			MDa	Lower	thrust	chatter marks suggest hanging wall moved up relative to footwall
304	34.404792	-93.58300	Slickenlines			87	N45W	MDa	Lower	thrust	chatter marks suggest hanging wall moved up relative to footwall
305	34.403604	-93.58347	Fault	N55E	85NW			MDa	Lower	thrust	chatter marks suggest hanging wall moved up relative to footwall
305	34.403604	-93.58347	Slickenlines			88	N72W	MDa	Lower	thrust	chatter marks suggest hanging wall moved up relative to footwall
306-1	34.401284	-93.58486	Breccia					MDa	Lower		large "pod" of Lower Novaculite breccia
306-2	34.401367	-93.58500	Fault	N02W	69SW			MDa	Lower	right-lateral strike-slip	chatter marks suggest right-lateral shear; small (3 ft x 2 ft) surface; probably a local internal shear zone
306-2	34.401367	-93.58500	Slickenlines			16	S14W	MDa	Lower	right-lateral strike-slip	chatter marks suggest right-lateral shear; small (3 ft x 2 ft) surface; probably a local internal shear zone
306-3	34.401381	-93.58476	Fault	N87W	41SW			MDa	Lower	thrust	no slickenlines but chatter marks perpendicular to surface suggest thrust faulting
307	34.401489	-93.58500	Bedding	N70E	40SE			MDa	Lower		
308	34.401539	-93.58574	Bedding	N79E	50SE			MDa	Lower		
309	34.401450	-93.58686	Bedding	N83E	49SE			MDa	Lower		
310	34.400988	-93.58943	Bedding	N62E	55SE			MDa	Lower		
311	34.403053	-93.59101	Float					Smm			float of red to maroon platy shale in washout
312	34.403815	-93.59139	Bedding	N85W	59SW			Obf			tan to brown to gray thin bedded blocky fractured shale with minor chert interbeds
313	34.404600	-93.59333	Bedding	N90E	52S			Obf			gray to rust colored blocky fractured chert beds with shale interbeds
314	34.404577	-93.58505	Float					Smm			in overturned tree stump, tan to gray to pale purple platy weathered shale
315	34.404398	-93.58469	Float					Smm			in overturned tree stump, tan to gray to pale purple platy weathered shale
316	34.404342	-93.58449	Float					Smm			in overturned tree stump, tan to gray to pale purple platy weathered shale
317	34.404332	-93.58345	Bedding	N40E	31SE			MDa	Lower		highly jointed Lower Novaculite
317	34.404332	-93.58345	Joint	N51W	85SW			MDa	Lower		highly jointed Lower Novaculite, joints spaced 1-6"
318	34.403316	-93.58362	Fault	N75W	74SW			MDa	Lower	right-lateral strike-slip	fold
319	34.403274	-93.58358	Float					MDa	Lower		Lower Novaculite boulder w/ slickenlines, NOT IN PLACE

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
320	34.403111	-93.58377	Fault	N60W	68SW			MDa	Lower	thrust	zone of intense fracturing and brecciated novaculite, chatter marks suggest thrust faulting
320	34.403111	-93.58377	Slickenlines			66	S40W	MDa	Lower	thrust	zone of intense fracturing and brecciated novaculite, chatter marks suggest thrust faulting
321	34.403192	-93.58361	Bedding	N04E	41SE			MDa	Lower		common surface here
322	34.402892	-93.58378	Observation					MDa	Lower		outcrops to south and west are much less pronounced
323	34.402780	-93.58379	Bedding	N02E	44SE			MDa	Lower		common surface here
324	34.402607	-93.58397	Bedding	N23E	30SE			MDa	Lower		common surface here
325	34.402184	-93.58430	Bedding	N71E	47SE			MDa	Lower		
326	34.402453	-93.58425	Bedding	N47E	45SE			MDa	Lower		
327	34.402148	-93.58467	Breccia					MDa	Lower		intensely fractured to brecciated Lower Novaculite - bedding obliterated
328	34.401978	-93.58478	Fault	N67W	59NE			MDa	Lower	normal	tension joints suggest normal faulting, no slickenlines
329	34.401844	-93.58487	Bedding	N68E	29SE			MDa	Lower		Lower Novaculite - maybe slumped
330	34.403346	-93.58529	Float					Smm			in overturned tree stump, tan to maroon to light purple platy shale - Missouri Mountain
331	34.394005	-93.59132	Bedding	N87W	58SW			Ow			cut-bank exposure of black to dark gray thin bedded to laminated platy shale
332	34.394109	-93.59134	Prospectors_Pit					Ow			10 ft deep pit dug into hillside - shale float is tan to pale maroon, platy
333	34.398279	-93.59201	Float					MDa	Lower		in stream gully, Lower Novaculite talus float, one cobble has black to dark red lustrious metallic mineralization
334	34.400227	-93.59364	Bedding	N76E	52SE			MDa	Lower		
335	34.400411	-93.59230	Bedding	N80E	54SE			MDa	Lower		
336	34.400619	-93.59093	Breccia					MDa	Lower		large outcrops of Lower Novaculite breccia - bedding obliterated
337	34.400362	-93.59094	Bedding	N68E	51SE			MDa	Lower		
338	34.399720	-93.59052	Breccia					MDa	Lower		no apparent bedding
339	34.399284	-93.59039	Float					MDa	Lower		Lower Novaculite boulder with VERY prominent slickenlines - but NOT IN PLACE
340	34.395991	-93.60001	Float					Smm			in stream gully, float of gray to tan to purplish-maroon, platy weathered shale
341	34.396706	-93.59963	Bedding	N68W	55NE			MDa	Lower		gray to black, thin bedded chert w/ thin shale interbeds - lowermost MDa?
342	34.397194	-93.59955	Bedding	N66W	52NE			MDa	Lower		thin to medium bedded, gray to black to rust colored fractured chert beds - outcrop has rust-colored to black semi-lustrious mineralization
342	34.397194	-93.59955	Joint	N02E	90			MDa	Lower		
343	34.398442	-93.59968	Bedding	N08W	33NE			MDa	Lower		Lower Novaculite is highly fractured and brecciated around this location
343	34.398442	-93.59968	Joint	N10E	83NW			MDa	Lower		
344	34.398277	-93.59937	Bedding	N55W	45NE			MDa	Lower		
345	34.398844	-93.59892	Bedding	N25W	24NE			MDa	Lower		probable bedding surface in Lower Novaculite breccia field making up "North Caddo Mountain"
346	34.398283	-93.59825	Bedding	N81E	52SE			MDa	Lower		possible bedding surface in Lower Novaculite - numerous steep dipping surfaces at this location
346	34.398283	-93.59825	Fault	N83E	73SE			MDa	Lower	oblique left-lateral normal	bedding plane fault? - surface is about 1 ft wide by 2 ft tall, not positive it is in place, chatter marks are faint but suggest HW moved down relative to FW

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
346	34.398283	-93.59825	Slickenlines			45	S80E	MDa	Lower	oblique left-lateral normal	bedding plane fault? - surface is about 1 ft wide by 2 ft tall, not positive it is in place, chatter marks are faint but suggest HW moved down relative to FW
347	34.398348	-93.59798	Bedding	N50E	29NW			MDa	Lower		
347	34.398348	-93.59798	Bedding	N81E	84SE			MDa	Lower		
347	34.398348	-93.59798	Fault	N89E	67NW			MDa	Lower	normal	about 25 ft north of GPS measurement - possible chatter marks suggest HW moved down relative to FW
347	34.398348	-93.59798	Slickenlines			70	N15W	MDa	Lower	normal	fault grooves; about 25 ft north of GPS measurement - possible chatter marks suggest HW moved down relative to FW
347-2	34.398417	-93.59777	Fault	N87E	83NW			MDa	Lower	unknown	small fault surface about 1 ft by 1.5 ft tall w/ faint slickenlines, no chatter marks obs
347-2	34.398417	-93.59777	Slickenlines			83	N55W	MDa	Lower	unknown	small fault surface about 1 ft by 1.5 ft tall w/ faint slickenlines, no chatter marks obs
348	34.398838	-93.59784	Breccia					MDa	Lower		poor outcrops and boulders of Lower Novaculite breccia
349	34.399021	-93.59780	Float					MDa	Middle		float of black chert - middle chert and shale member?
350	34.398412	-93.59755	Bedding	N88W	84NE			MDa	Lower		large "wall" of Lower Novaculite extends for 60 ft, center has collapsed
350	34.398412	-93.59755	Bedding	N81W	85NE			MDa	Lower		large "wall" of Lower Novaculite extends for 60 ft, center has collapsed
350	34.398412	-93.59755	Fault	N75E	54NW			MDa	Lower	unknown	small fault surface on west end of large Lower Novaculite outcrop; small scale internal shear
350	34.398412	-93.59755	Slickenlines			39	N40W	MDa	Lower	unknown	small fault surface on west end of large Lower Novaculite outcrop; small scale internal shear
351	34.398205	-93.59745	Breccia					MDa	Lower		brecciated to densely fractured Lower Novaculite "plug" w/ talus field downslope
352	34.398356	-93.59704	Bedding	N85E	88NW			MDa	Lower		common surface here
353	34.398507	-93.59618	Bedding	N90E	80N			MDa	Lower		common surface since STOP 352
354	34.398549	-93.59575	Bedding	N85E	76NW			MDa	Lower		
355	34.398977	-93.59427	Float					MDa	Middle		float of black to red blocky fractured chert - Middle Chert and Shale Member
356	34.399214	-93.59427	Bedding	N88W	63SW			MDa	Lower		
357	34.399522	-93.59405	Bedding	N60W	80SW			MDa	Lower		large outcrop of Lower Novaculite trends N60W
358	34.399664	-93.59458	Bedding	N84W	78SW			MDa	Lower		
359	34.399757	-93.59512	Bedding	N55W	74NE			MDa	Lower		outcrops less prominent here than previous stops
360	34.399578	-93.59550	Talus_Slope					MDa	Lower		Novaculite
361	34.398872	-93.59558	Float					MDa	Middle		float of black to rust colored blocky chert - Middle Chert and Shale Member?
362	34.397601	-93.59516	Bedding	N50E	60SE			Obf			
363	34.395997	-93.59527	Vertical_Bedding	N51W	90			Obf			black undulating shaly limestone beds (strong HCl fizz); probably limestone bed in Bigfork Chert
364	34.394974	-93.59582	Bedding	N70W	58NE			Obf			in stream channel, tan to gray thin bedded very weathered chert and shale beds
365	34.394153	-93.59297	Bedding	N88W	74SW			Ow			stream channel exposure of black (fresh) platy to weathered thin bedded shale - Womble?
366	34.394887	-93.59276	Float					Obf			(?) float of brown to brownish red, platy, weathered shale - fresh surfaces are more maroon in color

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
367	34.395544	-93.59329	Bedding	N68W	80SW			Obf			(?) black (weathered) to blue-gray (fresh) thin bedded very hard (hammer ping) dense limestone (very strong HCL fizz - vapors)
368	34.396918	-93.59273	Bedding	N85W	85NE			unsure			(?) gray to metallic black (fresh) massive to poorly bedded phyllitic shale
368	34.396918	-93.59273	Fault	N84W	83NE			unsure		unknown	(?) bedding plane fault
368	34.396918	-93.59273	Slickenlines			04	S88E	unsure		unknown	(?) bedding plane fault
369	34.398458	-93.59339	Bedding	N85E	73SE			MDa	Lower		
370	34.398573	-93.59224	Breccia					MDa	Lower		gray to metallic-colored, angular, coarse sand to coarse pebble Lower Novaculite Breccia - probably fault through this location
371	34.398846	-93.59196	Fault	N80W	74NE			MDa	Lower	normal	large fault surface in Lower Novaculite, no slicks, but chatter marks suggest HW moved down relative to FW
371	34.398846	-93.59196	Fault	N79W	78NE			MDa	Lower	normal	small (1.5 ft x 1 ft) fault surface on west end of outcrop parallel to main fault, chatter marks suggest normal faulting
371	34.398846	-93.59196	Slickenlines			45	N60W	MDa	Lower	normal	small (1.5 ft x 1 ft) fault surface on west end of outcrop parallel to main fault, chatter marks suggest normal faulting
371	34.398846	-93.59196	Fault	N40E	46SE			MDa	Lower	unknown	large (12 ft x 12 ft) fault surface on SE face of Lower Novaculite outcrop, conflicting chatter marks
371	34.398846	-93.59196	Slickenlines			39	S10E	MDa	Lower	unknown	large (12 ft x 12 ft) fault surface on SE face of Lower Novaculite outcrop, conflicting chatter marks
372	34.398918	-93.59091	Fault	N82E	85SE			MDa	Lower	unknown	steeply dipping slickensided surface in Lower Novaculite, no sense of shear
372	34.398918	-93.59091	Slickenlines			72	S80W	MDa	Lower	unknown	steeply dipping slickensided surface in Lower Novaculite, no sense of shear
373	34.399028	-93.59023	Fault	N15E	34SE			MDa	Lower	DUAL	two sets of slickenlines overprinted on fault surface
373	34.399028	-93.59023	Slickenlines			25	S23E	MDa	Lower	normal	Ls1: chatter marks perpendicular to this set suggest normal fauling
373	34.399028	-93.59023	Slickenlines			32	S60E	MDa	Lower	thrust	Ls2: chatter marks perpendicular to this set suggest thrust faulting
373-2	34.398984	-93.59024	Fault	N73E	45SE			MDa	Lower	unknown	conflicting chatter marks
373-2	34.398984	-93.59024	Slickenlines			45	S11E	MDa	Lower	unknown	conflicting chatter marks
374	34.398984	-93.58997	Bedding	N75E	80SE			MDa	Lower		
375	34.398907	-93.58952	Bedding	N70E	78SE			MDa	Lower		
376	34.399221	-93.58891	Bedding	N82E	67SE			MDa	Lower		
377	34.399704	-93.58943	Fault	N77W	42NE			MDa	Lower	normal	apprx. 8 ft x 1.5 ft tall fault surface; chatter marks suggest HW moved down relative to FW
377	34.399704	-93.58943	Slickenlines			33	N34W	MDa	Lower	normal	apprx. 8 ft x 1.5 ft tall fault surface; chatter marks suggest HW moved down relative to FW
378	34.399949	-93.58963	Bedding	N89W	76SW			MDa	Middle		
379	34.400076	-93.58943	Fault	N44E	53NW			MDa	Lower	thrust	(?) sigmoidal feature suggests thrust faulting
380	34.399164	-93.58994	Bedding	N86E	67SE			MDa	Lower		
380	34.399164	-93.58994	Joint	N23W	64SW			MDa	Lower		
381	34.395783	-93.59003	Observation					unsure			possible hot spring; intense growth of green to orange to yellow filamentous algae
382	34.399198	-93.58848	Bedding	N87E	76SE			MDa	Lower		
382	34.399198	-93.58848	Joint	N15E	90			MDa	Lower		
383	34.399790	-93.58798	Float					MDa	Middle		float of dark gray to black gravel to cobble sized blocky chert

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
384	34.400202	-93.58761	Fault	N80W	77SW			MDa	Middle	thrust	faint weathered slickenlines on lone, small outcrop of Middle Novaculite - bedding plane fault? Chatter marks suggest thrust faulting
384	34.400202	-93.58761	Slickenlines			68	S34E	MDa	Middle	thrust	faint weathered slickenlines on lone, small outcrop of Middle Novaculite - bedding plane fault? Chatter marks suggest thrust faulting
385	34.400446	-93.58709	Bedding	N72W	85SW			MDa	Lower		
386	34.400568	-93.58614	Bedding	N84W	65SW			MDa	Lower		
387	34.400971	-93.58559	Bedding	N85E	71SE			MDa	Lower		
387	34.400971	-93.58559	Joint	N17E	88NW			MDa	Lower		
388	34.401183	-93.58544	Bedding	N84W	86NE			MDa	Lower		
389	34.401254	-93.58524	Bedding	N89E	57SE			MDa	Lower		
390	34.401327	-93.58421	Bedding	N78W	50SW			MDa	Lower		
391	34.400944	-93.58251	Joint	N49E	85SE			MDa	Lower		on ridge just east of West Strawn Mountain; Lower Novaculite breccia w/ very few in place outcrops, joint surface on one visible outcrop
392	34.400967	-93.58298	Bedding	N75W	53SW			MDa	Lower		VERY CLOSE TO STOP 408
392	34.400967	-93.58298	Joint	N32E	71NW			MDa	Lower		VERY CLOSE TO STOP 408
393	34.400911	-93.58383	Bedding	N85W	57SW			MDa	Lower		
394	34.400934	-93.58477	Bedding	N61E	38SE			MDa	Lower		common surface at this location
395	34.400530	-93.58478	Bedding	N80E	52SE			MDa	Lower		about 15' downslope, 4 ft x 2 ft boulder of Lower Novaculite w/ slickenlines but NOT IN PLACE
396	34.400439	-93.58497	Bedding	N84W	61SW			MDa	Lower		
397	34.400012	-93.58509	Bedding	N74W	67SW			MDa	Lower		(?) large cliff face of Lower Novaculite - lots of black-metallic to red to rust colored mineralization here over much of outcrop - sample gathered from possible shear zone
398	34.397165	-93.58612	Observation					unsure			red-orange drainage in stream w/ yellow-green algae growth; hot spring seep?
399	34.395504	-93.58728	Float					Obf			light gray to off white coarse sand to gravel-size chert talus - Obf?
400	34.393830	-93.58839	Bedding	N81W	60SW			Ow			(?) stream channel exposure of weathered pinkish-brown, thin bedded to laminated shale
401	34.399133	-93.58664	Bedding	N90E	69N			MDa	Lower		densely fractured to brecciated Lower Novaculite; common surface at this location
401	34.399133	-93.58664	Fault	N12E	68SE			MDa	Lower	left-lateral strike-slip	chatter marks suggest left lateral shear
401	34.399133	-93.58664	Slickenlines			07	N15E	MDa	Lower	left-lateral strike-slip	chatter marks suggest left lateral shear
402	34.399434	-93.58670	Fault	N21E	67SE			MDa	Lower	normal	large Lower Novaculite boulder with prominent slickensides; unsure if in place; chatter marks suggest normal faulting
402	34.399434	-93.58670	Slickenlines			62	S86E	MDa	Lower	normal	large Lower Novaculite boulder with prominent slickensides; unsure if in place; chatter marks suggest normal faulting
0403-1	34.399954	-93.58674	Breccia					MDa	Lower		large outcrop of densely fractured Lower Novaculite; breccia extends laterally for about 100' along trend (N72E)
0403-2	34.399892	-93.58723	Breccia					MDa	Lower		west end of breccia outcrop
403-3	34.399969	-93.58711	Fault	N75W	51SW			MDa	Lower	unknown	small (4 ft x 2 ft) surface with slickenlines; conflicting chatter marks
403-3	34.399969	-93.58711	Slickenlines			57	S12E	MDa	Lower	unknown	small (4 ft x 2 ft) surface with slickenlines; conflicting chatter marks
403-4	34.399972	-93.58699	Fault	N90E	45S			MDa	Lower	unknown	large surface "cutting" through Lower Novaculite breccia - fault?
404	34.399935	-93.58614	Breccia					MDa	Lower		Lower Novaculite breccia outcrop w/ yellow-orange to black mineralization for several 10's of ft

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
405	34.399943	-93.58516	Bedding	N77W	69SW			MDa	Lower		large steep cliff face in Lower Novaculite - bedding
406	34.399890	-93.58485	Breccia					MDa	Lower		Lower Novaculite breccia w/ yellow-orange to rust-colored mineralization; breccia is very angular, medium sand to coarse gravel - fault gouge?
407	34.400091	-93.58421	Bedding	N52E	40NW			MDa	Lower		yellow-orange to metallic black mineralization
408	34.400967	-93.58298	Bedding	N79W	57SW			MDa	Lower		nearby cobble has polished slickensided surface
408	34.400967	-93.58298	Fault	N85W	37SW			MDa	Lower	unknown	boulder of Lower Novaculite w/ slickensides; unsure if in place; no chatter marks obs
408	34.400967	-93.58298	Slickenlines			37	S15W	MDa	Lower	unknown	boulder of Lower Novaculite w/ slickensides; unsure if in place; no chatter marks obs
409	34.401062	-93.58283	Breccia					MDa	Lower		densely fractured to brecciated Lower Novaculite; two "linear" outcrops trend about N65E
410	34.401179	-93.58262	Float					MDa	Lower		Lower Novaculite boulder with prominent slickensides (2 ft x 2 ft boulder) but NOT IN PLACE; surrounded by brecciated outcrops of Lower Novaculite
411	34.401568	-93.58271	Joint	N40E	84SE			MDa	Lower		large field (about 1 acre) of densely fractured and brecciated Lower Novaculite; bedding obliterated; closely spaced joints)
412	34.401811	-93.58264	Breccia					MDa	Lower		Lower Novaculite breccia
413	34.402820	-93.58170	Bedding	N08E	46SE			MDa	Middle		white to brown to black, hard, dense, thin bedded chert and shale beds; Middle MDa
414	34.403052	-93.58126	Fault	N80W	77NE			MDa	Middle	unknown	highly weathered (altered?) fault zone in novaculite; fault gouge in FW abuts very planar surface
415	34.403397	-93.58077	Bedding	N23E	50SE			MDa	Middle		black to gray thin to medium bedded densely fractured chert w/ minor shale interbeds; large exposure of Middle Novaculite beds here
416	34.405025	-93.58030	Bedding	N31W	39NE			MDa	Middle		black to gray thin bedded chert and shale beds exposed in stream bed
417	34.405592	-93.58041	Bedding	N15W	43NE			MDa	Middle		
418	34.406501	-93.58056	Bedding	N50W	39NE			MDa	Upper		maroon to rust colored hard dense thick bedded (6 to 8 ft) Upper Novaculite
418	34.406501	-93.58056	Joint	N69W	58SW			MDa	Upper		maroon to rust colored hard dense thick bedded (6 to 8 ft) Upper Novaculite
418	34.406501	-93.58056	Joint	N51E	80NW			MDa	Upper		maroon to rust colored hard dense thick bedded (6 to 8 ft) Upper Novaculite
419	34.407532	-93.57926	Float					Ms			cobble of black chert conglomerate
419-2	34.407249	-93.57928	Float					Ms			cobbles and boulders of black chert conglomerate
420	34.406935	-93.57920	Bedding	N49W	50NE			MDa	Upper		buff (weathered) to pinkish-white (fresh) hard thin bedded Upper Novaculite
421	34.404471	-93.57933	Bedding	N42W	64NE			MDa	Upper		
422	34.401931	-93.57881	Breccia					MDa	Lower		north side of Strawn Mountain ridge; breccia and densely fractured Lower Novaculite; no bedding preserved
423	34.401441	-93.57822	Fault	N67E	52SE			MDa	Lower	thrust	fault surface in Lower Novaculite about 1 ft tall x 6 ft long; chatter marks suggest thrust faulting
423	34.401441	-93.57822	Slickenlines			48	S07W	MDa	Lower	thrust	fault surface in Lower Novaculite about 1 ft tall x 6 ft long; chatter marks suggest thrust faulting
424	34.401502	-93.57635	Bedding	N86E	37SE			MDa	Lower		common surface here

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
425	34.401253	-93.57710	Bedding	N77E	59SE			MDa	Lower		
426	34.398609	-93.58422	Bedding	N35W	27SW			MDa	Lower		(?) unsure if in place
427	34.399113	-93.58398	Observation					MDa	Lower		black coral-type feature in Lower Novaculite, yellow to pale orange coloring on fracture surfaces - diagenetic?
427	34.399113	-93.58398	Bedding	N76W	51NE			MDa	Lower		bedding?
428	34.400090	-93.58377	Fault	N71W	36SW			MDa	Lower	unknown	conflicting chatter marks
428	34.400090	-93.58377	Slickenlines			24	S40E	MDa	Lower	unknown	conflicting chatter marks
429-1	34.400087	-93.58353	Surface	N87E	84NW			MDa	Lower		planar surface in fault gouge
429-1	34.400087	-93.58353	Surface	N75E	68NW			MDa	Lower		planar surface in fault gouge about 25 ft to the east
429-1	34.400087	-93.58353	Surface	N52E	78NW			MDa	Lower		planar surface in fault gouge about 25 ft to the east
429-2	34.400114	-93.58346	Fault	N52E	65SE			MDa	Lower	thrust	faint slickenlines and grooves in Lower Novaculite fault gouge, chatter marks suggest reverse faulting
429-2	34.400114	-93.58346	Slickenlines			60	S06W	MDa	Lower	thrust	faint slickenlines and grooves in Lower Novaculite fault gouge, chatter marks suggest reverse faulting
430	34.400842	-93.58207	Bedding	N75E	85NW			MDa	Lower		bedding surface extends laterally for about 50 ft
431	34.400728	-93.58120	Fault	N76E	40NW			MDa	Lower	thrust	fault surface cuts through outcrop, chatter marks suggest thrust faulting, brecciated FW and HW
431	34.400728	-93.58120	Slickenlines			40	N01W	MDa	Lower	thrust	fault surface cuts through outcrop, chatter marks suggest thrust faulting, brecciated FW and HW
432	34.400908	-93.58041	Bedding	N78E	50SE			MDa	Lower		common surface here
433	34.400955	-93.57918	Bedding	N87E	68SE			MDa	Lower		
434	34.400722	-93.57891	Bedding	N80E	64SE			MDa	Lower		
435	34.400459	-93.57905	Bedding	N85E	72SE			MDa	Lower		
436	34.400430	-93.58007	Bedding	N90E	63S			MDa	Lower		
437	34.400549	-93.58073	Bedding	N90E	58S			MDa	Lower		
438	34.399481	-93.58094	Bedding	N76W	59NE			MDa	Lower		
439-1	34.399551	-93.58191	Fault	N10E	28NW			MDa	Lower	unknown	no chatter marks observed
439-1	34.399551	-93.58191	Slickenlines			08	N05W	MDa	Lower	unknown	no chatter marks observed
439-2	34.399586	-93.58181	Fault	N68W	9NE			MDa	Lower	normal	fault surface w/ 2 sets of slickenlines; chatter marks on both sets indicate normal faulting
439-2	34.399586	-93.58181	Slickenlines			08	N10W	MDa	Lower	oblique left-lateral normal	fault surface w/ 2 sets of slickenlines; chatter marks on both sets indicate normal faulting
439-2	34.399586	-93.58181	Slickenlines			06	N40W	MDa	Lower	oblique left-lateral normal	fault surface w/ 2 sets of slickenlines; chatter marks on both sets indicate normal faulting
439-2	34.399586	-93.58181	Bedding	N71E	62NW			MDa	Lower		bedding just below outcrop w/ fault surface
439-3	34.399577	-93.58154	Fault	N34E	14NW			MDa	Lower	unknown	no chatter marks observed
439-3	34.399577	-93.58154	Slickenlines			08	N03W	MDa	Lower	unknown	no chatter marks observed
439-4	34.399613	-93.58144	Fault	N61E	10NW			MDa	Lower	normal	chatter marks suggest normal faulting
439-4	34.399613	-93.58144	Slickenlines			08	N03W	MDa	Lower	normal	chatter marks suggest normal faulting
440	34.399002	-93.58286	Bedding	N83W	72NE			MDa	Lower		
441	34.399600	-93.57954	Bedding	N68E	76NW			MDa	Lower		large outcrop of Lower Novaculite
441	34.399600	-93.57954	Joint	N54W	70SW			MDa	Lower		dense jointing here
441	34.399600	-93.57954	Joint	N21W	48NE			MDa	Lower		dense jointing here

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
442	34.399563	-93.57912	Breccia					MDa	Lower		large outcrop of Lower Novaculite breccia, 20-30 ft high and trends apprx E-W
443	34.399734	-93.57874	Bedding	N83E	50NW			MDa	Middle		black to gray thin bedded chert and shale beds - Middle Novaculite
444	34.400089	-93.57850	Bedding	N71W	83SW			MDa	Middle		black thin bedded (4-6 inch) beds on talus slope
445	34.400373	-93.57842	Bedding	N73W	88SW			MDa	Lower		
446	34.400643	-93.57787	Bedding	N87W	77SW			MDa	Lower		
447	34.400622	-93.57734	Breccia					MDa	Lower		densely fractured to brecciated Lower Novaculite w/ yellow-orange mineral staining; large boulder w/ slickenlines but not in place
448	34.400845	-93.57658	Bedding	N78W	77SW			MDa	Lower		
449	34.400573	-93.57693	Breccia					MDa	Lower		large outcrop of brecciated Lower Novaculite - no bedding observed
450	34.400501	-93.57684	Bedding	N81E	68SE			MDa	Lower		
451	34.400401	-93.57737	Bedding	N86E	51SE			MDa	Lower		
452	34.399739	-93.57750	Float					MDa	Middle		lots of Middle Novaculite black chert float on hillside
453	34.399417	-93.57757	Breccia					MDa	Lower		12-15 ft thick Lower Novaculite breccia "bed"
454	34.399335	-93.57765	Bedding	N80E	81SE			MDa	Lower		
455	34.398973	-93.57768	Fault	N12W	13NE			MDa	Lower	unknown	(?) small fault surface; unsure of measurement
455	34.398973	-93.57768	Slickenlines			01	N12W	MDa	Lower	unknown	(?) small fault surface; unsure of measurement
456	34.398887	-93.57783	Bedding	N87W	77SW			MDa	Lower		
457-1	34.398749	-93.57808	Fault	N72W	33NE			MDa	Lower	normal and thrust	fault surface w/ 2 sets of slicks; one set has normal sense while other thrust
457-1	34.398749	-93.57808	Slickenlines			33	N12E	MDa	Lower	normal	fault surface w/ 2 sets of slicks; one set has normal sense while other thrust
457-1	34.398749	-93.57808	Slickenlines			30	N15W	MDa	Lower	thrust	fault surface w/ 2 sets of slicks; one set has normal sense while other thrust
457-2	34.398807	-93.57817	Fault	N86E	43NW			MDa	Lower	thrust	conflicting chatter marks but most suggets thrust
457-2	34.398807	-93.57817	Slickenlines			42	N15W	MDa	Lower	thrust	conflicting chatter marks but most suggets thrust
457-3	34.398754	-93.57820	Fault	N65E	14NW			MDa	Lower	normal	outcrop maybe slumped; some conflicting chatter marks but most suggest normal fault
457-3	34.398754	-93.57820	Slickenlines			11	N25W	MDa	Lower	normal	outcrop maybe slumped; some conflicting chatter marks but most suggest normal fault
458	34.398448	-93.57833	Float					Smm			in overturned tree stump on hillside: float of tan to red to maroon platy shale - Missouri Mountain
459	34.398097	-93.57833	Bedding	N90E	89S			Opc?			in stream channel: gray-blue to black weathered thin bedded chert and shale beds
460	34.397281	-93.57848	Bedding	N85E	76NW			Opc?			in cut-bank: tan to brown to black weathered platy thin bedded shale; lots of deformed beds here
461	34.394284	-93.58009	Bedding	N72W	82SW			Obf			in cut-bank: tan to gray thin bedded deformed chert and shale beds
462	34.393306	-93.58629	Bedding	N86E	58SE			Ow			in Gap Creek, outcrops of tan to gray (weathered) to pitch-black (fresh) thin bedded fissile to blocky shale
463	34.398814	-93.57842	Bedding	N87E	75NW			MDa	Lower		
464	34.398817	-93.57775	Fault	N86E	75NW			MDa	Lower	normal	chatter marks suggest HW moved down relative to FW - normal fault
464	34.398817	-93.57775	Slickenlines			74	N35W	MDa	Lower	normal	chatter marks suggest HW moved down relative to FW - normal fault
465	34.399175	-93.57732	Bedding	N83E	73SE			MDa	Lower		
466	34.399267	-93.57723	Fault	N77E	55SE			MDa	Lower	thrust	chatter marks suggest HW moved up relative to FW - thrust fault

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
466	34.399267	-93.57723	Slickenlines			55	S10E	MDa	Lower	thrust	chatter marks suggest HW moved up relative to FW - thrust fault
467	34.399213	-93.57640	Bedding	N88W	49SW			MDa	Lower		
468	34.399173	-93.57587	Bedding	N70W	43SW			MDa	Lower		
469	34.399434	-93.57582	Breccia					MDa	Lower		large outcrop of densely fractured Lower Novaculite - float of dark gray to black angular clast-supported gravel breccia w/ Mn mineralization
470	34.399567	-93.57587	Float					MDa	Middle		float of Middle Novaculite black chert
471	34.399951	-93.57512	Joint	N09W	86SW			MDa	Lower		Lower Novaculite Breccia
471	34.399951	-93.57512	Breccia					MDa	Lower		Lower Novaculite Breccia
472	34.399709	-93.57551	Bedding	N90E	60SW			MDa	Lower		possible bedding surface preserved in Lower Novaculite
473	34.400157	-93.57515	Float					MDa	Middle		float of black blocky fractured chert - Middle Novaculite
474	34.400737	-93.57527	Breccia					MDa	Lower		isolated outcrop of densely fractured Lower Novaculite breccia
475	34.400930	-93.57524	Bedding	N86E	53SE			MDa	Lower		
476	34.401386	-93.57566	Bedding	N90E	50S			MDa	Lower		on top of Strawn Mountain
477	34.401827	-93.57561	Bedding	N67E	25SE			MDa	Lower		
478	34.402300	-93.57565	Fault	N70W	75NE			MDa	Lower	thrust	faint chatter marks suggest thrust faulting; bedding plane fault?
478	34.402300	-93.57565	Slickenlines			74	N13W	MDa	Lower	thrust	faint chatter marks suggest thrust faulting; bedding plane fault?
478	34.402300	-93.57565	Bedding	N87W	68NE			MDa	Lower		bedding about 40 ft to west of fault measurements
479	34.401078	-93.57390	Bedding	N65E	29SE			MDa	Lower		agrees well with measurement taken on top of Strawn Mountain
480	34.400701	-93.57359	Breccia					MDa	Lower		large outcrop of intensely brecciated Lower Novaculite
481	34.400566	-93.57297	Bedding	N88E	49SE			MDa	Lower		possible bedding surface preserved in Lower Novaculite breccia
482	34.400323	-93.57287	Float					MDa	Middle		float and talus of black to gray, blocky, cobble-sized chert - Middle MDa?
483	34.399581	-93.57315	Bedding	N89E	69SE			MDa	Lower		
485	34.399407	-93.57319	Bedding	N88E	69SE			MDa	Lower		
486	34.399089	-93.57350	Bedding	N85W	64SW			MDa	Lower		
487	34.398985	-93.57438	Fault	N87W	36NE			MDa	Lower	unknown	small fault surface; only extends through Lower Novaculite for a few ft; conflicting chatter marks
487	34.398985	-93.57438	Slickenlines					MDa	Lower	unknown	small fault surface; only extends through Lower Novaculite for a few ft; conflicting chatter marks
488	34.398727	-93.57452	Bedding	N88E	68SE			MDa	Lower		
489	34.403483	-93.55659	Bedding	N78E	88SE			Ms			brown to tan thin bedded weathered platy to block shale
490	34.404434	-93.55930	Bedding	N72W	70NE			Ms			brown to gray to black thin bedded blocky sandstone and shale
491	34.404687	-93.56218	Bedding	N66W	55NE			Ms			tan (weathered) to dark gray (fresh) medium bedded hard well indurated massive vf grained sandstone
492	34.405145	-93.56673	Float					MDa	Lower		large boulder of Lower Novaculite w/ slickenlines, but not in place
493	34.404945	-93.56775	Bedding	N60W	58NE			Ms			
494	34.405146	-93.56821	Vertical_Bedding	N64W	90			Ms			
495	34.405001	-93.57574	Float					MDa	Lower		Float and boulders of Lower Novaculite - one boulder has slickenlines on 2 ft x 1 ft surface but NOT IN PLACE
496	34.404078	-93.57778	Bedding	N21E	32SE			Ms			in stream gully, gray to tan to buff, weathered thin bedded deformed shale and chert
497	34.402867	-93.57814	Fault	N65E	70SE			MDa	Lower	thrust	tension joints suggest thrust faulting; conflicting chatter marks
497	34.402867	-93.57814	Slickenlines			30	N84E	MDa	Lower	thrust	tension joints suggest thrust faulting; conflicting chatter marks
497	34.402867	-93.57814	Tension_Joint	N80W	52SW			MDa	Lower		tension joint in HW
497	34.402867	-93.57814	Tension_Joint	N68W	47SW			MDa	Lower		tension joint in HW

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
497	34.402867	-93.57814	Tension_Joint	N78W	53SW			MDa	Lower		tension joint in HW
497	34.402867	-93.57814	Tension_Joint	N69W	50SW			MDa	Lower		tension joint in HW
498	34.402526	-93.57813	Float					unsure			in overturned tree stump: float of weathered, gray-green to purplish-gray, platy to fissile clay rich shale - unsure of fm
499	34.402122	-93.57827	Fault	N74E	36SE			MDa	Lower	normal	tension joints suggest normal faulting
499	34.402122	-93.57827	Slickenlines			34	S75E	MDa	Lower	normal	tension joints suggest normal faulting
500	34.402275	-93.57725	Fault	N72E	48SE			MDa	Lower	normal	conflicting chatter marks, but most suggest normal faulting; fault extends through outcrop for 20 - 25 ft
500	34.402275	-93.57725	Slickenlines			25	S75E	MDa	Lower	normal	conflicting chatter marks, but most suggest normal faulting; fault extends through outcrop for 20 - 25 ft
501	34.402284	-93.57674	Bedding	N72W	60NE			MDa	Lower		
502	34.402355	-93.57659	Fault	N61E	67SE			MDa	Lower	thrust	well-polished slickensides; fault surface extends laterally at least 20 ft; chatter mark suggests thrust faulting
502	34.402355	-93.57659	Slickenlines			49	S21W	MDa	Lower	thrust	well-polished slickensides; fault surface extends laterally at least 20 ft; chatter mark suggests thrust faulting
502	34.402355	-93.57659	Tension_Joint	N38E	73SE			MDa	Lower		tension joint in HW; suggest thrust faulting
502	34.402355	-93.57659	Tension_Joint	N15E	32SE			MDa	Lower		tension joint in HW; suggest thrust faulting
502	34.402355	-93.57659	Tension_Joint	N63E	52SE			MDa	Lower		tension joint in HW; suggest thrust faulting
503	34.402865	-93.57128	Float					MDa	Middle		float of black to gray blocky fractured chert - Middle MDa
504	34.403119	-93.57014	Float					MDa	Upper		float of tan to buff blocky hard cobble to boulder sized Upper Novaculite
505	34.402521	-93.56947	Float					MDa	Upper		float of tan to buff blocky hard cobble to boulder sized Upper Novaculite
506	34.402290	-93.56857	Bedding	N63W	52NE			MDa	Upper		small (1-2 ft high, 5-6 ft long) bed of Upper Novaculite
507	34.403149	-93.56747	Float					Ms			float of black chert conglomerate on hillside
508	34.404068	-93.56842	Bedding	N70W	74NE			Ms			black to dark gray hard angular poorly sorted coarse sand to fine pebble chert conglomerate
509	34.403304	-93.56949	Bedding	N56W	53NE			MDa	Upper		Upper Novaculite beds
510	34.403390	-93.57170	Bedding	N86W	88NE			MDa	Upper		Upper Novaculite beds in stream gully; beds are 2-4 ft thick
511	34.403363	-93.57262	Breccia					MDa	Upper		Upper Novaculite breccia about 40 - 50 ft across w/ dense fracturing
511	34.403363	-93.57262	Joint	N03E	74NW			MDa	Upper		Upper Novaculite breccia about 40 - 50 ft across w/ dense fracturing; planar joint surface
512	34.403586	-93.57253	Fault	N51E	40SE			MDa	Upper	thrust	large planar surface may be a fault plane; tension joints in FW suggest thrust faulting
512	34.403586	-93.57253	Tension_Joint	N45E	29SE			MDa	Upper		tension joint in FW
512	34.403586	-93.57253	Tension_Joint	N45W	15SW			MDa	Upper		tension joint in FW
512	34.403586	-93.57253	Tension_Joint	N65W	04SW			MDa	Upper		tension joint in FW
513	34.403410	-93.57350	Bedding	N58W	61NE			MDa	Upper		
514	34.403363	-93.57413	Float					MDa	Upper		boulders
515	34.402738	-93.57547	Fault	N84E	83SE			MDa	Lower	thrust	main fault plane in Lower Novaculite; probable tension joints
515	34.402738	-93.57547	Tension_Joint	N81E	54SE			MDa	Lower		tension joint in HW
515	34.402738	-93.57547	Tension_Joint	N75E	64SE			MDa	Lower		tension joint in HW
516	34.402310	-93.57596	Bedding	N88E	78NW			MDa	Lower		
516	34.402310	-93.57596	Joint	N03W	78NE			MDa	Lower		
517	34.402180	-93.57629	Bedding	N88W	65NE			MDa	Lower		
517	34.402180	-93.57629	Joint	N08E	87SE			MDa	Lower		

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
518	34.402440	-93.57515	Vertical_Bedding	N90E	90			MDa	Lower		
518	34.402440	-93.57515	Joint	N08E	88SE			MDa	Lower		
519	34.402422	-93.57477	Bedding	N84W	73NE			MDa	Lower		lots of gently-dipping closely-spaced (1-2 inches) joints
519	34.402422	-93.57477	Joint	N15W	21SW			MDa	Lower		lots of gently-dipping closely-spaced (1-2 inches) joints
520	34.402159	-93.57456	Bedding	N73W	48NE			MDa	Lower		
521	34.402162	-93.57408	Bedding	N60W	76NE			MDa	Lower		
522	34.401913	-93.57353	Breccia					MDa	Lower		small outcrops of Lower Novaculite breccia; bedding not apparent here nor along strike to the east
523	34.401686	-93.57367	Bedding	N71W	63NE			MDa	Lower		
523-3	34.401595	-93.57380	Bedding	N67E	29SE			MDa	Lower		beds now dip south compared with north side of Strawn Mountain
524	34.401190	-93.57354	Bedding	N82W	33SW			MDa	Lower		unsure if bedding, outcrop is about 4 x 1.5 ft
525	34.400761	-93.57298	Bedding	N79E	45SE			MDa	Lower		
525	34.400761	-93.57298	Joint	N03W	82SW			MDa	Lower		
526	34.400695	-93.57225	Bedding	N81E	43SE			MDa	Lower		
527	34.400619	-93.57191	Bedding	N90E	57S			MDa	Lower		beds appear to "end" along strike about 200 ft to the east; last beds observed: N85W, 44SW
528	34.400533	-93.57115	Float					MDa	Middle		float of black cobble-sized chert - Middle Novaculite; one cobble has slickenlines but NOT IN PLACE
529	34.399844	-93.57079	Float					MDa	Middle		on top of ridge: float of black to gray blocky fractured chert; Middle Novaculite float but NO BEDS
530	34.399480	-93.57129	Bedding	N82W	87SW			MDa	Lower		beds undulate some
531	34.399291	-93.57056	Bedding	N90E	54N			MDa	Lower		beds now dip north compared with south side of Strawn Mountain
532	34.398907	-93.56946	Bedding	N82W	67NE			MDa	Lower		thick Lower Novaculite beds
533	34.398907	-93.56899	Bedding	N84E	70NW			MDa	Lower		
534	34.398949	-93.56870	Bedding	N80W	86NE			MDa	Lower		
535	34.398775	-93.56813	Bedding	N60W	55NE			MDa	Lower		
536	34.398573	-93.56789	Bedding	N78W	56NE			MDa	Lower		
537	34.398515	-93.56713	Bedding	N88E	64NW			MDa	Lower		
538	34.398578	-93.56647	Bedding	N85W	62NE			MDa	Lower		
539	34.398976	-93.56657	Bedding	N76W	61NE			MDa	Lower		
540	34.399033	-93.56724	Bedding	N80W	61NE			MDa	Lower		bedding surface in brecciated Lower Novaculite outcrops
541	34.398862	-93.56752	Bedding	N82W	35NE			MDa	Lower		slumped?
542	34.399131	-93.56786	Bedding	N72W	60NE			MDa	Lower		
543	34.399352	-93.56899	Bedding	N78W	60NE			MDa	Lower		
544	34.399354	-93.57008	Bedding	N89E	74NW			MDa	Lower		
545	34.399538	-93.57020	Float					MDa	Middle		on flat-topped ridge: float of cobble to gravel-sized black chert - Middle Novaculite
546	34.400495	-93.56987	Float					MDa	Middle		on steep northeast-facing slope: float and talus field of Middle Novaculite chert
547	34.400621	-93.56928	Fold_Axial_Plane	N80E	77SE			MDa	Middle		small, tight fold in Middle Novaculite beds exposed in stream gully
547	34.400621	-93.56928	Fold_Axis			17	N83E	MDa	Middle		small, tight fold in Middle Novaculite beds exposed in stream gully
548	34.400802	-93.56919	Bedding	N53W	43NE			MDa	Middle		
549	34.401210	-93.56897	Bedding	N72W	55NE			MDa	Middle		undisturbed Middle Novaculite beds
550	34.401278	-93.56886	Bedding	N66W	77NE			MDa	Middle		Middle Novaculite beds exposed in stream gully

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
551	34.401330	-93.56865	Bedding	N80W	49NE			MDa	Middle		
552	34.401407	-93.56734	Bedding	N63W	47NE			MDa	Upper		basal beds of 5-6 ft thick Upper Novaculite
553	34.402052	-93.56700	Bedding	N40W	38NE			MDa	Upper		Upper Novaculite bed exposed in stream channel
554	34.404285	-93.56552	Bedding	N63W	70NE			Ms			brown to rust colored thin bedded (2 - 6 ft thick) fractured chert and shale beds - Stanley
555	34.403533	-93.56614	Bedding	N71E	65SE			Ms			weathered Stanely beds in stream channel
556	34.403074	-93.56645	Bedding	N41W	50NE			Ms			cut-bank exposure of brown to tan to rust colored platy thin bedded to massive Stanley shale
557	34.401253	-93.56613	Bedding	N81E	40SE			MDa	Upper		poor exposure of Upper Novaculite - common surface here
558	34.401022	-93.56658	Bedding	N87W	72NE			MDa	Middle		Middle Novaculite beds exposed on cutbank
559	34.400975	-93.56694	Fold_Axial_Plane	N64E	78SE			MDa	Middle		
559	34.400975	-93.56694	Fold_Axis			01	S62W	MDa	Middle		
559	34.400975	-93.56694	Fold_Axial_Plane	N72E	81NW			MDa	Middle		
559	34.400975	-93.56694	Fold_Axis			04	S72W	MDa	Middle		
560	34.400081	-93.56657	Bedding	N89W	57SW			MDa	Middle		
561	34.399610	-93.56586	Bedding	N66W	75NE			MDa	Middle		
562	34.399633	-93.56504	Bedding	N76W	25NE			MDa	Upper		Upper Novaculite outcrops on hilltop - poor exposures
563	34.398873	-93.56449	Bedding	N75W	48NE			MDa	Lower		top beds of Lower Novaculite
564	34.398810	-93.56488	Bedding	N71W	36NE			MDa	Lower		
565	34.398829	-93.56528	Fault	N10E	19SE			MDa	Lower	unknown	faint, conflicting chatter marks on 2.5 ft x 3 ft fault surface
565	34.398829	-93.56528	Slickenlines			18	N70E	MDa	Lower	unknown	faint, conflicting chatter marks on 2.5 ft x 3 ft fault surface
566	34.398839	-93.56572	Bedding	N81W	55NE			MDa	Lower		
567	34.398579	-93.56546	Bedding	N85W	53NE			MDa	Lower		
567	34.398579	-93.56546	Fault	N05E	82NW			MDa	Lower	oblique right-lateral normal	chatter marks suggest oblique right-lateral normal faulting
567	34.398579	-93.56546	Slickenlines			45	N03W	MDa	Lower	oblique right-lateral normal	chatter marks suggest oblique right-lateral normal faulting
567	34.398579	-93.56546	Fault	N31E	65SE			MDa	Lower	oblique left-lateral normal	conflicting chatter marks, but two very prominent ones suggest oblique left-lateral normal faulting
567	34.398579	-93.56546	Slickenlines			30	N48E	MDa	Lower	oblique left-lateral normal	conflicting chatter marks, but two very prominent ones suggest oblique left-lateral normal faulting
568	34.398584	-93.56519	Float					MDa	Lower		Lower Novaculite talus slope
569	34.398557	-93.56458	Bedding	N88E	60NW			MDa	Lower		Lower Novaculite beds
570	34.398482	-93.56344	verturned_Beddi	N90W	75S			MDa	Lower		(?)
571	34.398503	-93.56386	Bedding	N86E	80NW			MDa	Lower		
572	34.398489	-93.56312	Fault	N71E	27SE			MDa	Lower	normal	small fault surface, chatter marks suggest normal faulting
572	34.398489	-93.56312	Slickenlines			27	S25E	MDa	Lower	normal	small fault surface, chatter marks suggest normal faulting
573	34.398500	-93.56294	Float					MDa	Lower		Lower Novaculite boulder w/ prominent slickenlines but NOT IN PLACE
574	34.398609	-93.56289	Bedding	N86W	87SW			MDa	Lower		beds undulate slightly
575	34.398679	-93.56301	Float					MDa	Lower		Talus of fine gravel to cobble to boulder sized Lower Novaculite
576	34.398835	-93.56311	Bedding	N73W	79NE			MDa	Lower		
577	34.398874	-93.56291	Bedding	N79W	84NE			MDa	Lower		
578	34.398787	-93.56224	Bedding	N70W	85NE			MDa	Lower		thick (6 ft) Lower Novaculite beds
579	34.398761	-93.56147	Bedding	N74E	66NW			MDa	Lower		
580	34.399037	-93.56131	Bedding	N90W	49N			MDa	Lower		very thick (up to 15 ft) Lower Novaculite beds
581	34.399121	-93.56191	Bedding	N87E	47NW			MDa	Lower		Lower Novaculite breccia beds

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
582	34.399047	-93.56207	Observation					MDa	Lower		Lower Novaculite beds appear to end here along strike to the west
583	34.399093	-93.56216	Fault	N15E	67SE			MDa	Lower	thrust	large chatter marks suggest HW moved up relative to FW
583	34.399093	-93.56216	Slickenlines			67	S62E	MDa	Lower	thrust	large chatter marks suggest HW moved up relative to FW
584	34.399393	-93.56231	Fault	N80W	57NE			MDa	Upper	unknown	conflicting chatter marks; probably a bedding plan fault
584	34.399393	-93.56231	Slickenlines			07	N76W	MDa	Upper	unknown	conflicting chatter marks; probably a bedding plan fault
585	34.399497	-93.56302	Bedding	N73W	47NE			MDa	Upper		
586	34.399575	-93.56399	Bedding	N86W	31NE			MDa	Upper		
586	34.399575	-93.56399	Joint	N04W	81SW			MDa	Upper		
587	34.400227	-93.56402	Bedding	N75W	73NE			MDa	Upper		
588	34.400260	-93.56339	Bedding	N80W	66NE			MDa	Upper		
589	34.400251	-93.56200	Bedding	N56W	48NE			MDa	Upper		poor outcrop exposures
590	34.400858	-93.56174	Float					MDa	Middle		float of black blocky chert - Middle Novaculite? Or are these chert beds of Upper Novaculite
591	34.401286	-93.56178	Bedding	N60W	58NE			MDa	Upper		
592	34.402413	-93.56151	Bedding	N78W	54SW			Ms			Stanley
593	34.402460	-93.56153	Bedding	N68W	68NE			Ms			Stanley Shale beds
594	34.402815	-93.56139	Bedding	N84W	62NE			Ms			
595	34.401174	-93.55960	Bedding	N85W	88SW			MDa	Upper		
595	34.401174	-93.55960	Fault	N28W	30SW			MDa	Upper	thrust	not sure if in place; planar slickenlines; chatter marks and tension joints suggest HW moved up relative to FW (thrust)
595	34.401174	-93.55960	Slickenlines			27	S35W	MDa	Upper	thrust	not sure if in place; planar slickenlines; chatter marks and tension joints suggest HW moved up relative to FW (thrust)
595	34.401174	-93.55960	Tension_Joint	N69E	43NW			MDa	Upper		tension joint in HW
596	34.401118	-93.56002	Bedding	N77W	81SW			MDa	Upper		6 - 8 ft thick Upper Novaculite bed
597	34.401157	-93.56102	Bedding	N76E	52SE			MDa	Upper		Upper Novaculite beds disappear along strike towards the west
0597-2	34.401312	-93.56084	Bedding	N74E	68SE			MDa	Upper		
0597-2	34.401312	-93.56084	Fault	N65E	80NW			MDa	Upper	normal	tension joints suggest HW moved down relative to FW; normal fault
0597-2	34.401312	-93.56084	Slickenlines			80	N18W	MDa	Upper	normal	tension joints suggest HW moved down relative to FW; normal fault
0597-2	34.401312	-93.56084	Tension_Joint	N90E	60S			MDa	Upper		
0597-2	34.401312	-93.56084	Tension_Joint	N79W	68SW			MDa	Upper		
0597-2	34.401312	-93.56084	Tension_Joint	N76W	57SW			MDa	Upper		
598	34.401316	-93.56123	Float					MDa	Upper		Upper Novaculite talus - no outcrops
599	34.401170	-93.56141	Fault	N73W	25SW			MDa	Upper	thrust	(?) small fault surface w/ slickenlines; chatter marks suggest normal faulting while tension joints suggest thrust faulting
599	34.401170	-93.56141	Slickenlines			25	S04W	MDa	Upper	thrust	(?) small fault surface w/ slickenlines; chatter marks suggest normal faulting while tension joints suggest thrust faulting
599	34.401170	-93.56141	Tension_Joint	N85E	14SE			MDa	Upper		(?) tension joint in footwall
599	34.401170	-93.56141	Tension_Joint	N23W	14SW			MDa	Upper		(?) tension joint in footwall
599	34.401170	-93.56141	Tension_Joint	N44E	14NW			MDa	Upper		(?) tension joint in footwall
600	34.401345	-93.56261	Bedding	N81W	86NE			MDa	Upper		
601	34.401293	-93.56310	Bedding	N79W	87NE			MDa	Upper		
602	34.401202	-93.56402	Bedding	N75W	78NE			MDa	Upper		large outcrop of thick (4 - 6 ft beds) Upper Novaculite, but beds are not present on east side of gully
603	34.401325	-93.56491	Bedding	N66W	49NE			MDa	Upper		

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
604	34.401191	-93.56521	Bedding	N64W	84NE			MDa	Upper		
605	34.401174	-93.56549	Bedding	N84W	84NE			MDa	Upper		
606	34.401340	-93.56581	Float					MDa	Upper		two Upper Novaculite boulders w/ slickenlines but NOT IN PLACE
607	34.401360	-93.56613	Bedding	N81E	61SE			MDa	Upper		Upper Novaculite bedding? Agrees with STOP 557
608	34.400402	-93.56505	Bedding	N86W	63NE			MDa	Upper		
608	34.400402	-93.56505	Joint	N90E	30S			MDa	Upper		
609	34.400595	-93.56438	Bedding	N86W	43SW			MDa	Upper		possible loading structure suggests stratigraphic up is towards the south
610	34.400610	-93.56415	Fault	N83E	65SE			MDa	Upper	thrust	very smooth planar surface in Upper Novaculite w/ slickensides; chatter marks suggest thrust faulting
610	34.400610	-93.56415	Slickenlines			65	S00E	MDa	Upper	thrust	very smooth planar surface in Upper Novaculite w/ slickensides; chatter marks suggest thrust faulting
611	34.400658	-93.56358	Bedding	N79W	53SW			MDa	Upper		beds appear to "end" along strike towards the east
612	34.400449	-93.56269	Bedding	N86E	43SE			MDa	Upper		(?) poor exposures but common surface here; DOES NOT AGREE with surrounding data points!
613	34.399454	-93.56213	Bedding	N69W	58NE			MDa	Upper		about 25 ft away, 8 ft x 3 ft x 4 ft prospect pit with black porous-like mineralization on bedding surface
613	34.399454	-93.56213	Joint	N12E	77NW			MDa	Upper		joint surface at old mineralization prospect
613	34.399454	-93.56213	Prospectors_Pit					MDa	Upper		8 ft x 3 ft x 4 ft prospect pit with black porous-like mineralization on bedding surface
614	34.399415	-93.56192	Breccia					MDa	Upper		Upper Novaculite breccia, no bedding preserved; black to rust colored mineralization
615	34.399398	-93.56174	Breccia					MDa	Upper		Upper Novaculite breccia, no bedding preserved; black to rust colored mineralization
616	34.399419	-93.56139	Float					MDa	Upper		fine to coarse cobbles of Upper Novaculite talus; no outcrops
617	34.399228	-93.56089	Bedding	N89E	49NW			MDa	Lower		Lower Novaculite beds extending east from STOP 580, appear brecciated; beds appear to "end" along strike to the east
618	34.398658	-93.56059	Bedding	N82W	62NE			MDa	Lower		
619	34.399173	-93.56102	Bedding	N72E	69NW			MDa	Lower		
620	34.399183	-93.56116	Breccia					MDa	Lower		large "pod" of Lower Novaculite breccia about 15 to 20 ft high
621	34.399107	-93.56117	Bedding	N85E	71NW			MDa	Lower		
622	34.399169	-93.56122	Breccia					MDa	Lower		Lower Novaculite breccia
623	34.399429	-93.56081	Float					MDa	Upper		Upper Novaculite boulders and talus
624	34.399372	-93.55976	verturned_Beddi	N64E	62SE			MDa	Lower		overturned?
625	34.399578	-93.55643	Vertical_Bedding	N88E	90			MDa	Lower		
626	34.399612	-93.55531	Bedding	N85W	78SW			MDa	Lower		
627	34.401219	-93.55585	Bedding	N45W	62SW			MDa	Upper		(?) possible Upper Novaculite bed in stream gully - NOT CONVINCED IT IS IN PLACE
628	34.403189	-93.55177	Bedding	N84E	85NW			Ms			Stanley Shale beds in stream
629	34.401504	-93.55257	Bedding	N86E	78SE			Ms			tan (weathered) to gray (fresh) thin bedded Stanley shale beds
630	34.400702	-93.55260	Bedding	N68E	67NW			Ms			Stanley Shale beds in stream gully
631	34.400246	-93.55218	Bedding	N78E	39NW			MDa	Upper		possible Upper Novaculite bedding in place
632	34.399558	-93.55384	Vertical_Bedding	N85W	90			MDa	Lower		Lower Novaculite beds on top of ridge
632	34.399558	-93.55384	Joint	N08E	89NW			MDa	Lower		Lower Novaculite beds on top of ridge

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
633	34.399555	-93.55304	Observation					MDa	Lower		Lower Novaculite beds disappear along strike towards the east here; agrees with aerial photos but no fault planes observed in the field
634	34.399377	-93.55254	verturned_Beddi	N86W	64SW			MDa	Lower		overturned Lower Novaculite beds on north limb of Nelson Mountain Anticline
635	34.399505	-93.55129	verturned_Beddi	N82W	61SW			MDa	Lower		overturned Lower Novaculite beds on north limb of Nelson Mountain Anticline
636	34.399525	-93.55065	verturned_Beddi	N76W	72SW			MDa	Lower		overturned Lower Novaculite beds on north limb of Nelson Mountain Anticline
637	34.399764	-93.54944	verturned_Beddi	N80W	69SW			MDa	Lower		overturned Lower Novaculite beds on north limb of Nelson Mountain Anticline
638	34.399725	-93.54808	Bedding	N89E	80NW			MDa	Lower		beds now "upright" compared with last 4 stops
639	34.399458	-93.54686	Bedding	N82W	82NE			MDa	Lower		
640	34.399071	-93.54479	Vertical_Bedding	N72W	90			MDa	Lower		beds undulate here; eyeball measurement
641	34.399156	-93.54424	Bedding	N65W	74NE			MDa	Lower		agrees very well with trend of topography
642	34.398547	-93.54272	Bedding	N59W	66NE			MDa	Lower		
643	34.398043	-93.54141	Bedding	N75W	79NE			MDa	Lower		
644	34.397449	-93.53990	Bedding	N64W	80NE			MDa	Lower		
645	34.396668	-93.53845	Bedding	N62W	68NE			MDa	Lower		
645	34.396668	-93.53845	Joint	N32E	80SE			MDa	Lower		
646	34.396027	-93.53794	Bedding	N64W	69NE			MDa	Lower		near base of Lower Novaculite
647	34.395560	-93.53706	Bedding	N76W	68NE			MDa	Lower		
648	34.395393	-93.53658	Bedding	N63W	55NE			MDa	Lower		
649	34.395214	-93.53562	Bedding	N38W	53NE			MDa	Lower		
650	34.395698	-93.53475	Bedding	N60W	62NE			MDa	Lower		
0650-2	34.396171	-93.53427	Bedding	N55W	38NE			MDa	Lower		near top of Lower Novaculite
651	34.396940	-93.53338	Bedding	N43W	50NE			MDa	Middle		black thin bedded chert beds in stream; very planar bedding
652	34.396917	-93.53194	Bedding	N42W	50NE			MDa	Middle		
653	34.396951	-93.53188	Bedding	N49W	45NE			MDa	Upper		base of Upper Novaculite
654	34.398058	-93.53158	Bedding	N55W	54NE			MDa	Upper		near top of Upper Novaculite
655	34.398685	-93.53174	Bedding	N55W	50NE			Ms			Stanley shale beds
656	34.399625	-93.53287	Bedding	N54W	52NE			Ms			
657	34.398685	-93.53404	Bedding	N63W	45NE			MDa	Upper		near top of Upper Novaculite member
658	34.398447	-93.53449	Bedding	N56W	49NE			MDa	Upper		near base of Upper Novaculite member
659	34.397180	-93.53805	Bedding	N68W	67NE			MDa	Lower		near top of Lower Novaculite member
660	34.399722	-93.53886	Bedding	N50W	58NE			MDa	Middle		Middle Novaculite beds in stream
661	34.400140	-93.53931	Bedding	N71W	65NE			MDa	Upper		base of Upper Novaculite member
662	34.400662	-93.53924	Bedding	N63W	61NE			MDa	Upper		tan to black thin bedded chert and shale beds of Upper Novaculite
663	34.400912	-93.53911	Bedding	N68W	63NE			MDa	Upper		near top of Upper Novaculite member
664	34.401374	-93.53907	Bedding	N75W	66NE			Ms			brown (fresh) hard well-indurated medium bedded (1-2 ft thick) vf grained sandstone
664	34.401374	-93.53907	Joint	N11E	88NW			Ms			
665	34.401295	-93.54263	Bedding	N68W	65NE			MDa	Upper		gray to pale gray hard dense medium bedded (3-4 ft thick) Upper Novaculite beds in stream channel
666	34.401003	-93.54260	Bedding	N77W	72NE			MDa	Upper		base of thick bedded Upper Novaculite

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
667	34.400457	-93.54307	Bedding	N64W	55NE			MDa	Middle		possible Middle Novaculite bed on hillside; measurement agrees w/ topography
668	34.399772	-93.54345	Bedding	N86W	58NE			MDa	Lower		top of Lower Novaculite
669	34.399742	-93.54381	Fault	N30W	unknown			MDa	Lower	unknown	(?) offset Lower Novaculite bedding
670	34.399927	-93.54458	Observation					MDa	Lower		Lower Novaculite talus slope - no beds or outcrops observed
671	34.399866	-93.54558	Bedding	N86W	76NE			MDa	Lower		near top of Lower Novaculite
672-1	34.401043	-93.54484	Bedding	N88W	72NE			MDa	Upper		base of Upper Novaculite
672-2	34.401360	-93.54502	Bedding	N88W	72NE			MDa	Upper		thick (6-10 ft thick) Upper Novaculite beds near base of member
673	34.401443	-93.54492	Bedding	N88W	68NE			MDa	Upper		thick bedded (10-12 ft thick) upper beds of Upper Novaculite - excellent outcrop
674	34.401943	-93.54509	Bedding	N79W	87NE			Ms			gray-purple (fresh) very hard blocky vf-grained sandstone in base of Stanley; maybe slumped
675	34.401839	-93.54527	Bedding	N80W	74NE			Ms			on hillside: black to dark gray med bedded (1-2 ft thick) angular, poorly sorted, med to coarse pebble chert cgl
676	34.401879	-93.54606	Bedding	N81W	71NE			Ms			black to gary, thin to med bedded (6" to 3 ft) hard dense angular to subangular poorly sorted fine to coarse pebble chert cgl
677	34.402393	-93.54757	Float					Ms			float of cobble-sized black chert conglomerate
678	34.401743	-93.54851	Bedding	N85W	59NE			Ms			thick (4-6 ft thick) bed of black chert cgl; measurement agrees w/ topography
678	34.401743	-93.54851	Joint	N32E	54SE			Ms			
679	34.401499	-93.54830	Bedding	N80E	48NW			MDa	Upper		(?) small outcrop of fractured Upper Novaculite - unsure of bedding here, surrounded by Upp Novac talus
679	34.401499	-93.54830	Joint	N17W	90			MDa	Upper		(?) small outcrop of fractured Upper Novaculite - unsure of bedding here, surrounded by Upp Novac talus
0679-2	34.401350	-93.54829	Vertical_Bedding	N86E	90			MDa	Upper		very small outcrop of Upper Novaculite surrounded by bldrs and talus
680	34.401242	-93.54814	Talus					MDa	Upper		last of Upper Novaculite talus observed moving uphill - contact with Middle Novaculite
681	34.400131	-93.54786	Contact					MDa	Middle		contact between Middle and Lower Novaculite
682	34.400811	-93.54953	verturned_Beddi	N65E	84SE			MDa	Upper		isolated outcrops of Upper Novaculite - overturned?
683	34.400471	-93.55037	Float					MDa	Upper		float of Upper Novaculite cobbles and bldrs
684	34.400301	-93.55062	verturned_Beddi	N70E	66SE			MDa	Upper		2-3 ft thick Upper Novaculite beds; overturned bedding; measurement agrees w/ other on ridge to the south
685	34.399724	-93.55081	verturned_Beddi	N84W	69SW			MDa	Lower		bed near top of Lower Novaculite
686	34.400050	-93.55151	verturned_Beddi	N56E	48SE			MDa	Upper		
687	34.400006	-93.55190	verturned_Beddi	N79E	35SE			MDa	Upper		Upper Novaculite outcrops w/ moderate mineralization; measurement agrees well w/ nearby STOP 631
688	34.404548	-93.54420	Bedding	N86E	83NW			Ms			north bank of Caney Creek: brown to tan medium bedded (1-3 ft thick) hard blocky subang to subrounded mod sorted fine to vf-grained quartzitic sandstone
688	34.404548	-93.54420	Joint	N16W	80SW			Ms			north bank of Caney Creek: brown to tan medium bedded (1-3 ft thick) hard blocky subang to subrounded mod sorted fine to vf-grained quartzitic sandstone
689	34.404772	-93.54232	Float					Ms			float of brown sandstone and tan weathered shale on hillside

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
690	34.403621	-93.54092	Bedding	N71E	89NW			Ms			gray-brown (weathered) to dark gray (fresh) very hard thick bedded quartzitic sandstone
691	34.403622	-93.54032	Bedding	N68E	36SE			Ms			black thin-bedded (1/4") to massively bedded shale; probably deformed
692	34.403520	-93.53977	Bedding	N89E	41SE			Ms			gray to black thin bedded (1/4 to 1 inch) platy shale
693	34.403782	-93.54077	Bedding	N78E	72NW			Ms			sandstone beds in Stanley on north side of Caney Creek opposite STOP 690
694	34.401407	-93.52472	Bedding	N60E	56SE			Ms			at intersection of Mtn Home and Burgess Roads: Stanley shale beds on west side of road
695	34.400545	-93.52732	Bedding	N06W	45NE			Ms			brown to tan med to thick bedded (2-4 ft) vf-grained sandstone beds
696	34.385770	-93.54432	Float					Ms			float of black chert cgl pebbles
0696-2	34.386101	-93.54369	Float					Ms			float of black chert cgl pebbles
697	34.386734	-93.54331	Bedding	N82E	64SE			MDa	Upper		gray to yellow-brown medium bedded (2') thick hard dense chert beds
698	34.386639	-93.54317	Bedding	N84W	58SW			Ms			black chert conglomerate beds 1-4' thick
699	34.385870	-93.54175	Bedding	N84E	70SE			Ms			Stanley shale beds
700	34.385915	-93.54039	Bedding	N81W	44SW			Ms			Stanley shale beds
701	34.386508	-93.54061	Bedding	N84E	66SE			Ms			Black chert conglomerate beds
702	34.386785	-93.54067	Bedding	N88E	55SE			MDa	Upper		top of Upper Novaculite
703	34.387080	-93.54063	Bedding	N87E	51SE			MDa	Upper		1-2 ft thick Upper Novaculite beds near base
704	34.387925	-93.54142	Bedding	N83E	51SE			MDa	Middle		
705	34.388439	-93.54143	Bedding	N81E	50SE			MDa	Lower		top of Lower Novaculite; conglomerate layer covering beds
706	34.389453	-93.54197	Bedding	N90E	39S			MDa	Lower		
707	34.390273	-93.54201	Bedding	N68E	32SE			MDa	Lower		Lower Novaculite beds cut by small scale fault
707	34.390273	-93.54201	Fault	N12W	81NE			MDa	Lower	right-lateral strike-slip	cross-cutting shear zone through Lower Novaculite beds
708	34.391187	-93.54203	Bedding	N86E	47SE			MDa	Lower		
708	34.391187	-93.54203	Joint	N32W	86SW			MDa	Lower		
709	34.391489	-93.54196	Bedding	N71E	35SE			MDa	Lower		
710	34.391807	-93.54206	Bedding	N78E	40SE			MDa	Lower		
711	34.392367	-93.54170	Bedding	N67E	36SE			Smm			small hillside exposure of tan (weathered) to gray-green (fresh?) platy shale
712	34.392105	-93.54163	Bedding	N76E	26SE			MDa	Lower		base of Lower Novaculite
713	34.392548	-93.53978	Bedding	N75E	43SE			MDa	Lower		
714	34.392495	-93.53901	Bedding	N67E	22SE			MDa	Lower		
715	34.391700	-93.53808	Bedding	N78E	40SE			MDa	Lower		
716	34.390918	-93.53803	Bedding	N70E	34SE			MDa	Lower		
717	34.390344	-93.53799	Bedding	N78E	34SE			MDa	Lower		
718	34.389923	-93.53770	Bedding	N83E	38SE			MDa	Lower		
719	34.389210	-93.53743	Bedding	N85W	35SW			MDa	Lower		top of Lower Novaculite beds?
720	34.390220	-93.53618	Bedding	N78E	31SE			MDa	Lower		
721	34.389617	-93.53553	Bedding	N53E	35SE			MDa	Lower		
722	34.388782	-93.53453	Bedding	N79E	53SE			MDa	Upper		base of Upper Novaculite
723	34.388461	-93.53439	Bedding	N79E	53SE			MDa	Upper		top of Upper Novaculite
724	34.387783	-93.53405	Bedding	N64E	50SE			Ms			black chert conglomerate bed
725	34.388071	-93.53260	Bedding	N72E	59SE			Ms			
726	34.390624	-93.53187	Bedding	N36E	73SE			MDa	Lower		unsure if outcrop is in place, maybe slumped or slid

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
727	34.391052	-93.53136	Bedding	N75E	36SE			MDa	Lower		fits well with topographic trends
728	34.391779	-93.53146	Bedding	N55E	30SE			MDa	Lower		
729	34.392724	-93.53338	Bedding	N36E	33SE			MDa	Lower		
730	34.393805	-93.53653	Bedding	N07W	27NE			MDa	Lower		possible bedding surface, unsure if in place
731	34.393662	-93.53724	Bedding	N47E	25SE			MDa	Lower		Lower Novaculite outcrops in place
731	34.393662	-93.53724	Joint	N79E	57NW			MDa	Lower		Lower Novaculite outcrops in place; large planar joint surface
732	34.394158	-93.53822	Float					Smm			float of Missouri Mountain shale in overturned tree stump
733	34.394898	-93.53925	Bedding	N28W	19NE			Smm			brown (maroon?) to tan thin bedded platy to fissile weathered shale; notable deformation in beds
734	34.395244	-93.53948	Bedding	N76W	71SW			Smm			brown (maroon?) to tan thin bedded platy to fissile weathered shale; notable deformation in beds
735	34.395656	-93.54033	Bedding	N12W	41NE			Smm			cut bank exposure of tan to gray platy to fissile weathered shale
736	34.395795	-93.54294	Float					Obf			gray, hard, blocky, pebble to cobble sized chert - Bigfork?
737	34.396390	-93.54375	Bedding	N60W	80NE			Obf			stream exposure of gray to black thin bedded (2-4 inches) chert beds
738	34.396509	-93.54731	Bedding	N70W	84NE			Obf			Bigfork beds exposed on large cut bank
738	34.396509	-93.54731	Joint	N30E	83NW			Obf			closely spaced joints (1-6 inches)
738	34.396509	-93.54731	Joint	N24E	86NW			Obf			closely spaced joints (1-6 inches)
739	34.399215	-93.54728	Bedding	N90E	86S			MDa	Lower		(?) first Lower Novaculite beds observed ascending from center of Jones Valley - does not agree w/ stops 638 and 639
740	34.399362	-93.54871	verturned_Beddi	N87W	75SW			MDa	Lower		overturned bedding
741	34.399127	-93.54869	verturned_Beddi	N75W	78SW			MDa	Lower		overturned basal beds of Lower Novaculite
742	34.397496	-93.54923	Float					unsure			float of gray to dark gray, blocky to platy, gritty, siliceous (?) shale in overturned tree stump - Opc? Obf?
743	34.396908	-93.54967	verturned_Beddi	N87W	80SW			Obf			Bigfork beds in cutbank - inferred to be overturned from overturned MDa on top of ridge to the north
744	34.396212	-93.55001	Bedding	N80W	75SW			Obf			Bigfork beds in cutbank
745	34.395280	-93.54864	Bedding	N57E	29SE			Obf			Bigfork beds in stream channel
746	34.394996	-93.54688	Bedding	N60E	41SE			Obf			
747	34.395949	-93.54469	Bedding	N55W	56NE			Obf			
748	34.395508	-93.54448	Bedding	N59W	86NE			Obf			
749	34.394766	-93.54375	Bedding	N27E	26SE			Obf			Bigfork beds in cutbank exposure
750	34.393948	-93.54306	Bedding	N22E	20SE			Obf			
751	34.394431	-93.54594	Bedding	N85W	13SW			Obf			
752	34.394232	-93.54691	Bedding	N64E	22SE			Obf			
753	34.393633	-93.54698	Bedding	N77E	21SE			Opc			brown to tan thin bedded blocky weathered shale - Polk Creek Shale?
754	34.393349	-93.54719	Bedding	N59E	37SE			Opc			brown to tan thin bedded blocky weathered shale - Polk Creek Shale?
755	34.392820	-93.54730	Float					Smm			float of brownish-maroon weathered shale in ovtrned tree stump - Missouri Mountain Shale
756	34.391594	-93.54722	Float					Smm			float of brownish-maroon weathered shale in ovtrned tree stump - Missouri Mountain Shale
757	34.391346	-93.54715	Bedding	N86E	47SE			MDa	Lower		base of Lower Novaculite beds
758	34.391039	-93.54725	Bedding	N78E	38SE			MDa	Lower		
759	34.390028	-93.54722	Bedding	N88W	51SW			MDa	Lower		
760	34.389458	-93.54738	Bedding	N89E	60SE			MDa	Lower		

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
761	34.388670	-93.54720	Bedding	N86W	50SW			MDa	Lower		near top of Lower Novaculite member
762	34.388528	-93.54742	Bedding	N85W	60SW			MDa	Middle		
763	34.387263	-93.54900	Bedding	N84W	54SW			MDa	Upper		near base of Upper Novaculite member
764	34.387111	-93.54907	Bedding	N84E	54SE			MDa	Upper		top of Upper Novaculite beds
765	34.386380	-93.54833	Bedding	N86W	61SW			Ms			Stanley Shale beds on cutbank; possibly slumped
766	34.392464	-93.59055	Bedding	N73W	70SW			Obf			gray (fresh) thin bedded (1-4 inches) hard fractured siliceous (no HCL fizz) blocky shale and chert
767	34.392620	-93.58716	Bedding	N79W	66SW			Obf			Bigfork Chert beds in Gap Creek
768	34.392929	-93.58311	Bedding	N69E	32SE			Obf			Bigfork Chert beds in Gap Creek
769	34.393638	-93.57723	Bedding	N85W	74NE			Obf			black thin beds of shale in Gap Creek
770	34.393157	-93.57500	Fold_Axial_Plane	N65W	70NE			Obf			(?) fold in Bigfork beds exposed on hillside
770	34.393157	-93.57500	Fold_Axis			30	S75E	Obf			(?) fold in Bigfork beds exposed on hillside
771	34.394842	-93.56948	Bedding	N86W	45SW			Obf			Bigfork Chert beds in Gap Creek
772	34.395381	-93.56737	Bedding	N90E	52S			unsure			black to gray thin bedded to laminated platy to blocky shale
773	34.395439	-93.56160	Bedding	N86E	49SE			Obf			(?) Bigfork Chert beds on south bank of Gap Creek - chaotic folding about 50 ft upstream
773	34.395439	-93.56160	Fault	N63W	70SW			Obf		unknown	(?) probably bedding plane fault that has cut up section
774	34.396447	-93.55638	Bedding	N83W	80NE			Obf			Bigfork Chert beds in Gap Creek
775	34.396560	-93.55448	Bedding	N79W	74NE			Obf			Bigfork Chert beds in Gap Creek
776	34.396891	-93.55244	verturned_Beddi	N88E	70SE			Obf			Bigfork Chert beds in Gap Creek - inferred to be overturned from overturned MDa on top of ridge to the north
777	34.396169	-93.55213	Bedding	N89E	75SE			Obf			Bigfork Chert beds on cutbank of Gap Creek
778	34.395267	-93.55169	Fold_Axial_Plane	N60E	88NW			Obf			cutbank exposure of broad open upright fold in Bigfork
778	34.395267	-93.55169	Fold_Axis			23	N60E	Obf			cutbank exposure of broad open upright fold in Bigfork
779	34.394152	-93.55154	Bedding	N87E	44SE			Obf			Bigfork Chert beds in stream
780	34.392934	-93.55218	Bedding	N76W	40SW			Obf			Bigfork Chert beds in stream
781	34.392378	-93.55196	Bedding	N79W	32SW			Opc			gray to dark gray thin bedded platy clay rich shale - Polk Creek?
782	34.391464	-93.55186	Bedding	N80W	37SW			MDa	Lower		base of Lower Novaculite
783	34.391042	-93.55204	Bedding	N79W	32SW			MDa	Lower		Lower Novaculite bedding on top of ridge
784	34.391018	-93.55479	Bedding	N84E	38SE			MDa	Lower		Lower Novaculite bedding on top of ridge
785	34.391573	-93.55474	Float					Smm			float of brown to tan weathered Missouri Mountain Shale
786	34.393235	-93.55471	Bedding	N83W	49SW			Obf			Bigfork Chert beds in stream
787	34.394719	-93.55457	Bedding	N90E	44S			Obf			Bigfork Chert beds in stream
788	34.395702	-93.55468	Bedding	N85E	76SE			Obf			Bigfork Chert beds in cutbank exposure
789	34.395081	-93.55732	Bedding	N78E	69SE			Obf			Bigfork Chert beds in stream
790	34.393752	-93.55680	Bedding	N90E	50S			Obf			Bigfork Chert beds in stream
791	34.394146	-93.55962	Bedding	N82E	57SE			Obf			Bigfork Chert beds in cutbank exposure
792	34.394556	-93.56057	Bedding	N81W	59SW			Obf			Bigfork Chert beds in stream
793	34.394888	-93.56376	Bedding	N87E	54SE			Obf			
794	34.393693	-93.56391	Bedding	N00E	24W			Obf			(?) folded Bigfork here?
795	34.391270	-93.56402	Bedding	N85W	42SW			MDa	Lower		Lower Novaculite beds on top of ridge
796	34.391244	-93.56436	Bedding	N78W	63SW			MDa	Lower		Lower Novaculite beds on top of ridge
797	34.391250	-93.56631	Bedding	N87W	54SW			MDa	Lower		
798	34.391289	-93.56724	Bedding	N88W	52SW			MDa	Lower		

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
799	34.391216	-93.56873	Bedding	N68E	30SE			MDa	Lower		
800	34.390761	-93.56989	Bedding	N65E	35SE			MDa	Lower		
801	34.390500	-93.57023	Bedding	N46E	29SE			MDa	Lower		
802	34.390249	-93.57062	Bedding	N46E	41SE			MDa	Lower		
803	34.389553	-93.57082	Bedding	N20W	61NE			MDa	Lower		
804	34.389393	-93.57169	Bedding	N50W	74NE			MDa	Lower		near base of Lower Novaculite
805	34.391755	-93.57529	Bedding	N60W	68NE			Obf			Bigfork Chert beds in stream gully - agrees w/ STOP 804
806	34.393455	-93.59127	Bedding	N70W	84SW			Ow			wash-out exposure of black shale beds by private road crossing Gap Creek - Womble
807	34.393128	-93.59094	Bedding	N85W	75SW			Ow			(?) black to orange-brown, fractured to brecciated shale and minor chert - west beds; shale has "charcoal-like" texture
807	34.393128	-93.59094	Bedding	N76W	85NE			Ow			(?) black to orange-brown, fractured to brecciated shale and minor chert - east beds; shale has "charcoal-like" texture
807	34.393128	-93.59094	Fault	N65E	68NW			Ow		unknown	(?) west fault; sigmoidal features indicate both apparent thrust and normal faulting
807	34.393128	-93.59094	Fault	N31E	65NW			Ow		unknown	(?) east fault; sigmoidal features indicate both apparent thrust and normal faulting
807	34.393128	-93.59094	Bedding	N83W	77SW			Obf			(?) bedding about 100 ft upstream from STOP 807 GPS lat/long in Bigfork Chert; have crossed Ow-Obf contact
808	34.392614	-93.58854	Bedding	N70W	87SW			Obf			Bigfork Chert beds in Gap Creek
809	34.392524	-93.58788	Bedding	N54W	70NE			Obf			Bigfork Chert beds in Gap Creek
810	34.393104	-93.58414	Bedding	N88E	74SE			Ow?			black, charcoal-like shale beds along Gap Creek - Womble?
811	34.398629	-93.57354	Bedding	N88E	77SE			MDa	Lower		
812	34.397917	-93.57347	Bedding	N84W	74NE			MDa	Lower		Lower Novaculite beds near base of mbr
813	34.397679	-93.57359	Bedding	N85E	79NW			Smm			Missouri Mountain Shale beds in stream exposure
814	34.396308	-93.57427	Bedding	N90E	75S			Opc			brown to purple-gray, thin bedded, silty shale - Polk Creek?
815	34.395193	-93.57491	Bedding	N89E	78SE			Obf			Bigfork Chert beds in cut-bank exposure
816	34.394257	-93.57568	Bedding	N88E	72SE			Obf			Bigfork Chert beds in Gap Creek
817	34.392087	-93.58058	Bedding	N78E	52SE			Obf			Bigfork Chert beds in stream wash
818	34.391873	-93.58023	Bedding	N52W	84SW			Obf			rotated or folded Bigfork?
819	34.391313	-93.57953	Bedding	N83E	50SE			Obf			planar to consistent Bigfork Chert beds
820	34.390930	-93.58148	Bedding	N47E	04SE			Obf			hear-horizontal Bigfork Chert beds - folded?
821	34.391587	-93.58150	Bedding	N90E	43S			Obf			Bigfork Chert beds in stream gully
822	34.392374	-93.58210	Bedding	N76E	46SE			Obf			
823	34.393908	-93.59503	Bedding	N90E	65S			Ow?			black, thin bedded, fractured, blocky shale beds in Gap Creek - Womble?
824	34.394491	-93.59979	Bedding	N85E	51SE			Obf			Bigfork Chert beds in Gap Creek - eyeball measurement
825	34.394611	-93.60041	Bedding	N83W	68SW			Obf			Bigfork Chert beds in Gap Creek
826	34.394528	-93.60249	Bedding	N83W	60SW			Obf			large cut-bank exposure of planar to consistent Bigfork Chert beds in bend of Gap Creek
827	34.392347	-93.60962	Bedding	N75E	65SE			Obf			Bigfork Chert beds exposed in road cut by gate entrance to Bean Creek Cabins
828	34.384592	-93.61026	Bedding	N84E	52SE			MDa	Lower		top of Lower Novaculite
829	34.385988	-93.61104	Observation					Ms			exposures of brown to gray to rust-colored weathered platy to fissile shale - Stanley

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
830	34.386780	-93.61216	Bedding	N88W	47SW			Ms			pale green to gray to purple thin bedded weathered shale; black chert cgl bed 4-5 ft thick
831	34.387081	-93.61294	Bedding	N71E	55SE			MDa	Upper		poor exposures of Upper Novaculite along private driveway
832	34.387444	-93.61374	Bedding	N85E	53SE			MDa	Middle		brown to rust colored thin bedded blocky chert beds with thin green-gray shale interbeds
833	34.387780	-93.61140	Bedding	N76E	70SE			MDa	Middle		Middle Novaculite beds in streem gully
834	34.387780	-93.61087	Bedding	N88E	71SE			MDa	Middle		
835	34.387583	-93.61045	Bedding	N86W	73SW			MDa	Middle		bedding exposed at 5-6 ft tall adit opening
836	34.388395	-93.60942	Bedding	N90E	82S			MDa	Lower		top of Lower Novaculite
837	34.389104	-93.60964	Bedding	N80W	89NE			MDa	Lower		base of Lower Novaculite at bend in Caddo River
838	34.387328	-93.60955	Bedding	N86E	77SE			MDa	Upper		base of Upper Novaculite?
839	34.387010	-93.60934	Bedding	N85E	72SE			MDa	Upper		uppermost chert and shale beds of Upper Novaculite mbr
840	34.386142	-93.60879	Bedding	N85W	73SW			Ms			gray to brownish-gray, thin (4 inch to 2 ft thick) bedded, platy, laminated, clay-rich shale
841	34.385857	-93.60875	Fault	N80E	85SE			MDa	Lower	thrust	fractured to brecciated Lower Novaculite with curvi-planar surf - fault?
842	34.385840	-93.60891	Fault	N70E	60SE			MDa	Lower	thrust	tension fractures in HW suggest thrust faulting
842	34.385840	-93.60891	Slickenlines			41	S75E	MDa	Lower	thrust	tension fractures in HW suggest thrust faulting
842	34.385840	-93.60891	Tension_Joint	N82E	52SE			MDa	Lower		tension fracture measurement in HW (FW "missing")
843	34.385839	-93.61009	verturned_Beddi	N80W	85NE			MDa	Lower		
844	34.387762	-93.61479	Bedding	N67E	42SE			MDa	Middle		
845	34.388477	-93.61073	Bedding	N79W	67SW			MDa	Lower		top of Lower Novaculite mbr
846	34.388841	-93.61165	Bedding	N78E	67SE			MDa	Lower		
847	34.388863	-93.61353	Bedding	N87E	48SE			MDa	Lower		
847	34.388863	-93.61353	Joint	N12E	85NW			MDa	Lower		
848	34.388703	-93.61563	Bedding	N85E	50SE			MDa	Lower		
0849-1	34.388880	-93.61571	Bedding	N80E	50SE			MDa	Lower		base of Lower Novaculite mbr
0849-2	34.389465	-93.61575	Bedding	N60E	42SE			Smm			poor hillside outcrops of tan to brown, thin bedded, platy weathered Missouri Mountain Shale
850	34.388487	-93.61707	Bedding	N73E	42SE			MDa	Lower		
851	34.388101	-93.61841	Bedding	N62E	45SE			MDa	Lower		
852	34.387546	-93.61971	Bedding	N06W	54NE			MDa	Lower		GPS lat/long estimated from Google Earth profile
853	34.387352	-93.61983	Bedding	N18W	60NE			MDa	Lower		
854	34.386505	-93.61963	Bedding	N43W	68NE			MDa	Lower		
855	34.387478	-93.61861	Bedding	N42E	45SE			MDa	Lower		
0856-1	34.387506	-93.61651	Bedding	N52E	43SE			MDa	Middle		Middle Novaculite beds in stream gully
0856-2	34.387517	-93.61624	Bedding	N34E	45SE			MDa	Middle		Middle Novaculite beds in stream gully
857	34.387651	-93.61528	Bedding	N13E	57SE			MDa	Middle		folded Middle Novaculite beds? - does not agree with STOP 844 or topo trends
858	34.384498	-93.61535	Bedding	N74E	65SE			MDa	Lower		
859	34.383895	-93.61565	Bedding	N73E	75SE			MDa	Lower		near top of Lower Novaculite
860	34.383867	-93.61632	Bedding	N70E	68SE			MDa	Lower		
861	34.384268	-93.61710	Bedding	N72E	72SE			MDa	Lower		
861	34.384268	-93.61710	Joint	N15W	89SW			MDa	Lower		
0861-2	34.384357	-93.61828	Bedding	N87E	70SE			MDa	Lower		

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
862	34.384155	-93.61887	Bedding	N85W	73SW			MDa	Lower		
863	34.383866	-93.61988	Bedding	N88W	60SW			MDa	Lower		
864	34.383311	-93.62005	Float					MDa	Middle		float of Middle Novaculite on hillside
865	34.383362	-93.62177	Bedding	N88W	66SW			MDa	Lower		near top of Lower Novaculite mbr
866	34.384101	-93.62285	Bedding	N82E	67SE			MDa	Lower		
867	34.384619	-93.62234	Float					Smm			float of tan colored Missouri Mountain Shale in ovtrned tree stump
868	34.386427	-93.62316	Bedding	N52E	65SE			Opc?			(?) black, thin bedded, platy to blocky to laminated shale in deeply-incised gully - Polk Creek? Sample w/ double slicks!
869	34.389187	-93.62182	Bedding	N39E	42SE			Ow?			on south bank of Caddo River: dark gray to black, thin bedded to finely laminated to blocky, graptolitic shale - Polk Creek or Womble?
870	34.387866	-93.62288	Bedding	N48W	45NE			Opc?			stream channel exposure of gray to black, thin bedded, blocky, fractured shale w/ minor vf grained sandstone laminae
871	34.387222	-93.62298	Bedding	N63E	44SE			Obf			(?) folded Bigfork Chert just a few ft downstream from here; see notebook
872	34.386958	-93.62279	Bedding	N70E	70SE			Opc?			black to dark gray blocky siliceous shale - Polk Creek?
873	34.385731	-93.62079	Float					MDa	Lower		loose cobble of angular, poorly sorted, matrix-supported, fine to coarse pebble novaculite breccia - fault breccia?
874	34.385357	-93.62000	Bedding	N70W	86SW			MDa	Lower		Lower Novaculite beds trend NW here and terminated along strike towards NW
874	34.385357	-93.62000	Joint	N21E	66SE			MDa	Lower		
875	34.385265	-93.61965	Fault	N74E	69NW			MDa	Lower	left-lateral strike-slip	4 ft x 4 ft slickensided surface in Lower Novaculite
875	34.385265	-93.61965	Slickenlines			20	S70W	MDa	Lower	left-lateral strike-slip	tension fractures and chatter marks suggest left-lateral shear
876	34.385194	-93.61906	Bedding	N48W	49NW			MDa	Lower		intensely fractured Lower Novaculite; some dark mineral staining
877	34.384744	-93.61915	Bedding	N80W	61SW			MDa	Lower		
878	34.385113	-93.61809	Bedding	N90E	47S			MDa	Lower		planar surface at east end of outcrop
879	34.385033	-93.61692	Bedding	N40E	52SE			MDa	Lower		(?)
880	34.384842	-93.61595	Bedding	N71E	67SE			MDa	Lower		
881	34.385002	-93.61140	Bedding	N65E	66SE			MDa	Lower		unsure if this is good bedding surface
882	34.388004	-93.61360	Fold_Axial_Plane	N80W	50NE			MDa	Middle		fold in Middle Novaculite exposed on private road
882	34.388004	-93.61360	Fold_Axis			04	N89E	MDa	Middle		fold in Middle Novaculite exposed on private road
882	34.388004	-93.61360	Bedding	N84W	64SW			MDa	Middle		undeformed bedding to the east of folding
883	34.388088	-93.61294	Bedding	N87E	68SE			MDa	Middle		Middle Novaculite beds on private road cut
884	34.388334	-93.61204	Bedding	N83E	67SE			MDa	Lower		top of Lower Novaculite exposed on private road cut
885	34.382812	-93.61193	Bedding	N75E	75SE			MDa	Upper		1-2 ft thick Upper Novaculite beds exposed on private driveway
886	34.381812	-93.61073	Bedding	N67E	16NW			Ms			Stanley shale beds exposed on private driveway
887	34.381128	-93.61481	Bedding	N85E	85NW			Ms			Stanley Shale beds exposed on old logging road
888	34.384165	-93.61093	Bedding	N83E	75SE			MDa	Middle		Middle Novaculite beds on private drive road cut
889	34.381000	-93.61030	Bedding	N83E	77SE			Ms			blue-gray very hard vf grained sandstone in Stanley exposed in stream bed of private drive
890	34.382112	-93.60905	Bedding	N76E	75SE			Ms			
numbering error - 891-900 inadvertantly skipped											
901	34.38523241	-93.57030430	Bedding	N55W	74SW			MDa	Upper		top of Upper Novaculite mbr
902	34.38534364	-93.57085861	Bedding	N62W	72SW			MDa	Upper		top of Upper Novaculite mbr
903	34.38639090	-93.57115439	Bedding	N82W	66SW			MDa	Middle		Middle Novaculite beds in stream gully; undisturbed beds

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
904	34.38691841	-93.57089810	Bedding	N64W	68SW			MDa	Lower		top of Lower Novaculite mbr
905	34.38715139	-93.57044414	Bedding	N42W	77SW			MDa	Lower		
906	34.38720131	-93.57000913	Fault	N58W	85NE			MDa	Lower	right-lateral strike-slip	probable small scale right-lateral strike slip fault in Lower Novaculite; no slickenlines
906	34.38720131	-93.57000913	Tension_Joint	N75E	71NW			MDa	Lower		tension fracture measurement on SW block; NE block is missing
906	34.38720131	-93.57000913	Tension_Joint	N78E	46NW			MDa	Lower		tension fracture measurement on SW block; NE block is missing
907	34.38725571	-93.56989886	Bedding	N64W	64SW			MDa	Lower		
908	34.38772451	-93.57051360	Bedding	N65W	71SW			MDa	Lower		
909	34.38764407	-93.57109739	Bedding	N61W	69SW			MDa	Lower		
910	34.38753314	-93.57105020	Bedding	N45W	69SW			MDa	Lower		bedding measurement about 40 ft west of STOP 111
911	34.38728029	-93.57099900	Bedding	N55W	67SW			MDa	Lower		
912	34.38758025	-93.57128748	Bedding	N58W	57SW			MDa	Lower		
913	34.38770828	-93.57143079	Breccia					MDa	Lower		very large outcrop of massive brecciated Lower Novaculite - bedding obliterated
914	34.38766862	-93.57178573	Fault	N73E	81SE			MDa	Lower	left-lateral strike-slip	faint slickenlines on planar surface in Lower Novaculite; tension joints and chatter marks suggest left-lateral shear
914	34.38766862	-93.57178573	Slickenlines			21	N77E	MDa	Lower	left-lateral strike-slip	faint slickenlines on planar surface in Lower Novaculite; tension joints and chatter marks suggest left-lateral shear
914	34.38766862	-93.57178573	Tension_Joint	N24E	85NW			MDa	Lower		tension joints suggest left-lateral shear
914	34.38766862	-93.57178573	Tension_Joint	N25E	80NW			MDa	Lower		tension joints suggest left-lateral shear
914	34.38766862	-93.57178573	Tension_Joint	N24E	87NW			MDa	Lower		tension joints suggest left-lateral shear
915	34.38766301	-93.57189213	Breccia					MDa	Lower		large outcrop of massive brecciated Lower Novaculite; no bedding preserved
916	34.38734590	-93.57204084	Bedding	N55W	55SW			MDa	Lower		
917	34.38712345	-93.57213650	Fault	N36E	87SE			MDa	Lower	right-lateral strike-slip	(?) VERY planar surface in Lower Novaculite; no slickenlines; tension joints suggest right-lateral shear
917	34.38712345	-93.57213650	Tension_Joint	N77W	84SW			MDa	Lower		(?) VERY planar surface in Lower Novaculite; no slickenlines; tension joints suggest right-lateral shear
917	34.38712345	-93.57213650	Tension_Joint	N72W	87NE			MDa	Lower		(?) VERY planar surface in Lower Novaculite; no slickenlines; tension joints suggest right-lateral shear
918	34.38708919	-93.57197876	Fault	N72E	80SE			MDa	Lower	right-lateral strike-slip	fault surface extends laterally for at least 20 ft, probably extends uphill at least another 100 ft; tension joints suggest right-lateral shear
918	34.38708919	-93.57197876	Tension_Joint	N51W	53SW			MDa	Lower		tension joint measured in SW block
918	34.38708919	-93.57197876	Tension_Joint	N60W	77SW			MDa	Lower		tension joint measured in NE block
919	34.38692570	-93.57227277	Fault	N39E	83SE			MDa	Lower	left-lateral strike-slip	(?) planar fault surface with slickenlines; Middle Novaculite mbr on east side of fault juxtaposed against Lower mbr on west side
919	34.38692570	-93.57227277	Slickenlines			08	S36W	MDa	Lower	left-lateral strike-slip	(?) planar fault surface with slickenlines; Middle Novaculite mbr on east side of fault juxtaposed against Lower mbr on west side
919	34.38692570	-93.57227277	Bedding	N30W	64SW			MDa	Lower		(?) bedding measurement in Lower Novaculite west of fault
919	34.38692570	-93.57227277	Bedding	N60E	44SE			MDa	Middle		(?) bedding measurement in Middle Novaculite east of fault
920	34.38683473	-93.57180673	Bedding	N76W	50NE			MDa	Middle		
921	34.38603775	-93.57228625	Bedding	N70W	61SW			MDa	Upper		white (fresh) to brown (weathered) hard medium bedded (1 - 2 ft thick) Upper Novaculite
922	34.38587292	-93.57248943	Bedding	N48W	43SW			MDa	Upper		2 ft thick Upper Novaculite beds in stream channel

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
923	34.38565435	-93.57268112	Float					Ms			conglomerate
924	34.38292254	-93.57996681	Bedding	N75E	34NW			Ms			Stanley shale beds exposed in ditch along Forest Service Road
925	34.37867608	-93.59445405	Bedding	N83W	82NE			Ms			Stanley shale beds exposed in ditch along Forest Service Road
926	34.38441045	-93.60285894	Bedding	N47E	57SE			Ms			Stanley shale beds expsoed in ditech on north side of Adams Lane
927	34.38584304	-93.59781181	Bedding	N78W	85NE			Ms			Stanley shale beds on north roadside of Adams Lane
928	34.38568841	-93.60164223	Bedding	N50E	84SE			Ms			Stanley shale beds on north roadside of Adams Lane
929	34.38609288	-93.60287380	Vertical_Bedding	N81E	90			Ms			Stanley shale beds exposed in ditch on west side of Warrior Lane
930	34.37596277	-93.59469643	Bedding	N65W	86NE			Ms			on east side of Highway 8; gray (fresh), hard to well-indurated, vf grained quartzitic sandstone in Stanley
931	34.38077896	-93.52858432	Bedding	N76E	85SE			Ms			on driveway entrance to Nicholson Cemetary; red to brown, chaotically deformed Stanley shale beds; some competent beds at entrance
932	34.38539411	-93.52733402	Bedding	N68E	54SE			Ms			Stanley shale beds in ditch on west side of Mountain Home Road
932	34.38539411	-93.52733402	Bedding	N08E	38SE			Ms			Stanley Shale beds in ditch on west side of Mountain Home Road
933	34.38908215	-93.52648075	Bedding	N63E	65SE			Ms			Stanley shale beds in ditch on west side of Mountain Home Road
934	34.39203162	-93.52546543	Bedding	N08W	51NE			Ms			Stanley Shale beds in ditch on west side of Mountain Home Road
935	34.40086711	-93.52059217	Bedding	N52W	70NE			Ms			Stanley Shale beds in creek just SE of Mountain Home Cemetery; lots of folding and faulting here
936	34.40428304	-93.51557437	Bedding	N83E	73SE			Ms			Stanley Shale beds on north side of Mountain Home Road
937	34.39285047	-93.50665242	Bedding	N35E	45SE			Ms			Stanley Shale beds on north side of Old Caddo Gap Road
938	34.37939064	-93.52262803	Bedding	N74E	30SE			Ms			Stanley Shale beds in ditch on east side of North Bumblebee Road
939	34.37534978	-93.50773265	Bedding	N45E	61SE			IPjv			brown (weathered) to dark gray (fresh), v. hard to well indurated, moderately sorted, fine to vf grained quartzitic sandstone - Pennsylvanian Johns Valley?
940	34.37550226	-93.50748519	Bedding	N38E	43SE			IPjv			brown (weathered) to gray (fresh), v. hard, quartzitic, vf grained sandstone; quartz veins (no HCl fizz)
941	34.38571466	-93.50110830	Bedding	N06W	41NE			Ms			Stanley Shale beds?
942	34.38537341	-93.50045020	Bedding	N28E	38SE			Ms			gray to dark gray shale in road cut - Stanley?
943	34.38326634	-93.60624150	Bedding	N87E	55SE			Ms			Stanley Shale beds on west bank of Caddo River at Arrowhead Campground
944	34.38541784	-93.60767329	Bedding	N70E	47SE			MDa	Lower		large outcrop of Lower Novaculite on west bank of Caddo River
944	34.38541784	-93.60767329	Joint	N05W	77SW			MDa	Lower		large outcrop of Lower Novaculite on west bank of Caddo River
944	34.38541784	-93.60767329	Fault	N67E	43SE			MDa	Lower	oblique right-lateral normal	probable bedding plane fault w/ slickenlines; chatter marks suggest normal faulting
944	34.38541784	-93.60767329	Slickenlines			27	S39W	MDa	Lower	oblique right-lateral normal	probable bedding plane fault w/ slickenlines; chatter marks suggest normal faulting
945	34.38073596	-93.60637060	Bedding	N66E	85SE			Ms			Stanley Shale beds on Stonegate Drive
946	34.38361951	-93.60473567	Bedding	N63E	40SE			Ms			gray (fresh), hard, well-indurated, vf grained graywacke beds on east bank of Caddo River
947	34.38504050	-93.60621335	Fold_Axial_Plane	N01E	62SE			MDa	Middle		fold in Middle Novaculite along old railroad grade
947	34.38504050	-93.60621335	Fold_Axis			48	S50E	MDa	Middle		fold in Middle Novaculite along old railroad grade
947	34.38504050	-93.60621335	Fold_Axial_Plane	N09E	49SE			MDa	Middle		fold in Middle Novaculite along old railroad grade
947	34.38504050	-93.60621335	Fold_Axis			36	S45E	MDa	Middle		fold in Middle Novaculite along old railroad grade
948	34.38526475	-93.60639971	Bedding	N88E	60SE			MDa	Middle		
949	34.38532575	-93.60412226	Bedding	N75E	88NW			MDa	Lower		possible Lower Novaculite bedding exposed on water tower access road

(?) -Possible erroneous or suspect data

STOP	Latitude	Longitude	Feature	Strike	Dip	Plunge	Bearing	Fm	MDa_Mbr	Apparent Fault Sense	Comments
950	34.38583158	-93.60445010	Bedding	N40E	74SE			MDa	Upper		poorly exposed Upper Novaculite beds on water tower access road

(?) -Possible erroneous or suspect data

Vita

The author, Martin Lee Messmer, grew up in rural Savanna, Illinois and attended Luther Preparatory School in Watertown, Wisconsin. After graduating in 2003, the author attended Northern Illinois University in DeKalb, Illinois. While at Northern Illinois, the author conducted independent research entitled “Hydroseismicity and Northern Illinois Earthquakes” with Dr. Philip Carpenter. In Summer 2007, the author interned with the Earthquake Hazards Team, U.S. Geological Survey in Golden, Colorado, and researched seismic methods to evaluate urban earthquake hazards of the St. Louis, Missouri, metropolitan area, while also working on seismic survey teams in San Jose, California, Portland, Oregon, and Seattle, Washington. The author received the 2007 NIU Internship/Co-op Student of the Year Gold Award for his work with the U.S. Geological Survey. In December 2007, the author graduated Cum Laude and received a Bachelor of Science in Geology from Northern Illinois University and after graduation returned to work with the U.S. Geological Survey in Golden, Colorado until November 2009. The author has since worked as a geologist with the Division of Minerals Evaluation, Office of the Secretary, U.S. Department of Interior based in Denver, Colorado. In August 2014, the author began graduate studies at Stephen F. Austin State University in Nacogdoches, Texas. His thesis research focused on the structural geology of the Caddo Gap area in the Ouachita Mountains of Arkansas. The author received his Master of Science degree from Stephen F. Austin State University in May 2018.