[PS]A Fault Kinematic Analysis with Observations Pertaining to Fault Trends within the Core of the Arbuckle Anticline, Southern Oklahoma, USA*

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Search and Discovery Article #51255 (2016)**
Posted May 9, 2016

*Adopted from poster presentation given at AAPG Southwest Section meeting in Abilene, Texas, April 9-12, 2016

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Abstract

The Arbuckle Mountains, located within south-central Oklahoma, have been the focus of numerous studies concentrating on the structural evolution of the North American Continent. The Arbuckle Anticline, located in the western area of the Arbuckle Mountains, is well recognized as an uplift from the Ouachita Orogen (Dott 1933; Ham 1951; Ham 1973; Tanner 1967). Efforts were made (Brewer et al. 1983; Ham 1951; Ham 1969; Granath 1989; Tanner 1967) to document the major structural features in an attempt to summarize the deformation history of the Arbuckle Mountains. However, the smaller-scale structural features along Interstate 35 have mostly been overlooked in these studies. There has been no notable attempt to give a complete kinematic analysis of the Arbuckle Anticline or to determine what type of strain has affected the region on an outcrop scale. Numerous faults and other features are undocumented, and displacement directions have been inconclusively assessed (as determined by recent gathering of slickenline data).

The focus of this study is on the core of the Arbuckle Anticline along Interstate 35 at Mile Marker 48. The outcrop has exposures of the Ft. Sill Limestone and Royer Dolomite. The methods to analyze this outcrop include geologic mapping, panoramic annotations, kinematic analysis, and fracture analysis along the outcrop. These methods were used to determine the dip-slip versus strike slip motion at the core of the anticline, temporal relationships between the fractures sets and the deformation, and if the structures found within the core are kinematically compatible with the rest of the Arbuckle Anticline. Data from a Master's student's project (Hessert 2016) were used in conjunction with the data presented here to allow for compatibility comparisons between the core of the anticline and the limbs.

The results are as follows: (1) Kinematic analysis from fault striae within the anticline core show a greater occurrence of strike slip movement to dip slip movement consistent with reverse and oblique left-lateral strike slip motion and displacement; (2) The Arbuckle Anticline core contains the Ft. Sill Limestone interleaved with the Royer Dolomite in a previously unrecognized imbricate; (3) Shallowly plunging fold hinges throughout the core are parasitic, indicate left-lateral rotation, and define the hinge of the Arbuckle Anticline as NW-SE; (4) Both pre-folding

and post-folding fracture sets can be differentiated and indicate a maximum principle stress direction of N41E; (5) Structures along Mile Marker 48 are found to be kinematically compatible on an outcrop scale as well as throughout the rest of the anticline.

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A Fault Kinematic Analysis with Observations Pertaining to Fault Trends Within the Core of the Arbuckle Anticline, Southern Oklahoma, USA

Katrina Soundy, Jenna Hessert, Aaron Yoshinobu

Texas Tech University, Department of Geosciences, Spring 2016

Abstract

Withhin in the core of the Arbuckle Anticline there is signficiant strike slip to dip slip offset, contrary to what previous surveys have indicated (they indicated dominately dipslip offset). An oblique, strike slip dominated offset occured along MM48 causing an older unit (Ft. Sill Limestone) to rest adjacent to a younger unit (Royer Dolomite). A fault and fold kinematic analysis of the core also demonstrates a dominate strike-slip offset. Fracture analysis of the core demonstrates that the core is kinematically compatible with the rest of the anticline and demonstrates which fault sets occured pre-folding, and which occured post folding.

Introduction

The Arbuckle Mountains, located within south-central Oklahoma, have been the focus of numerous studies concentrating on the structural evolution of the North American Continent. The Arbuckle Anticline, located in the western area of the Arbuckle Mountains, is well recognized as an uplift from the Ouachita Orogen (Dott 1933; Ham 1951; Ham 1973; Tanner 1967). Efforts were made (Brewer et al. 1983;Ham 1951; Ham 1969; Granath 1989; Tanner 1967) to document the major structural features in an attempt to summarize the deformation history of the Arbuckle Mountains. However, the smaller-scale structural features along Interstate 35 have mostly been overlooked in these studies. There has been no notable attempt to give a complete kinematic analysis of the Arbuckle Anticline or to determine what type of strain has affected the region on an outcrop scale. Numerous faults and other features are undocumented, and displacement directions have been inconclusively assessed (as determined by recent gathering of slickenlinedata).
The focus of this study is on the core of the Arbuckle Anticline along interstate-35 at Mile Marker 48. The outcrop has exposures of the Ft. Sill Limestone and Royer Dolomite.

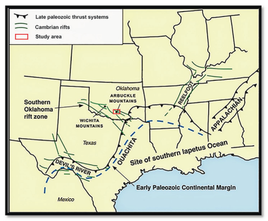


Fig. 1 The location of the study site is within the Arbuckle Mountains which formed within the Souther Oklahoma rift zone. (Modified Hansen et al., 2013)

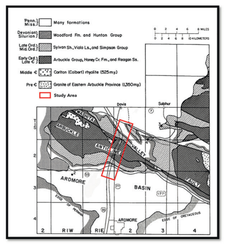


Fig. 2 The study area was along I-35, this is a general geologic map of the Arbuckle Anticline. (Modified Ham, 1969)

Methods

The methods to analyze this outcrop include geologic mapping, panoramic annotations, kinematic analysis, and fracture analysis along the outcrop. These methods were used to determine the dip-slip versus strike slip motion at the core of the anticline,temporal relationships between the fractures sets and the deformation, and if the structures found within the core are kinematically compatible with the rest of the Arbuckle Anticline. Data from a Masters student's project (Hessert 2016) were used in conjunction with the data presented here to allow for compatibility comparisons between the core of the anticline and the limbs.

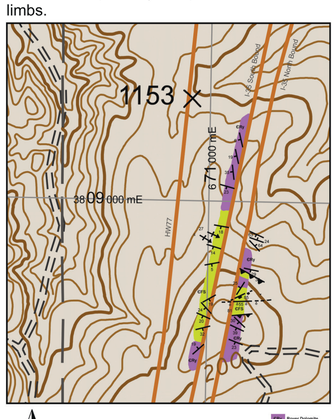


Fig. 3 A topographic map view of MM48 along I-35. Both the East and West outcrops are illustrated here demonstrating the contacts between the Ft. Sill Limestone and the Royer Dolomite. Other structural geatures were noted and annotated here as well using conventional symbols. (Soundy 2016)

West Side of Mile Marker 48

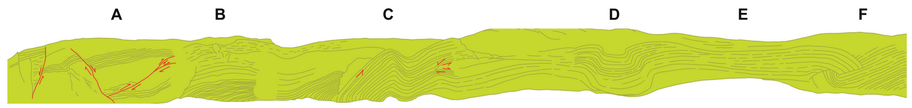


*Fig. 4 A complete illustration of the outcrop along the west wide of Mile Marker 48 which is predominately composed of Ft. Sill Limestone (denoted in green). The Primary structures are: **A.** A Horst with a normal fault which displaced the beds ~1 meter, referred to as the Ft. Sill Horst. **B.** A series of beds that have an average orientation of N59W/17SW and display several prominent fracture sets, referred to as the Ft. Sill Teeth. **C.** An asymmetric z-fold, referred to as Wave A. **D.** A box fold, referred to as Ft. Sill Box Fold. **E.** A series of beds with a mostly horizontal orientation, referred to as True Bedding. **F.** A faul propogation fold, referred to as Wave. B*

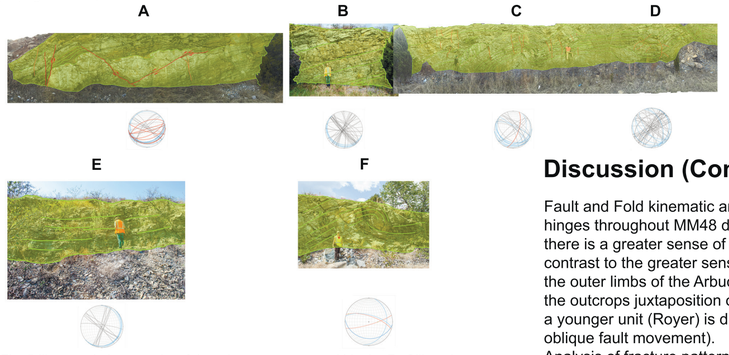


Fig. 5 Illustrated photographs of the primary structures within the Ft. Sill on the west side of MM48. Faults are denoted in red, beds in green, and fractures in orange.The labeled structures are the same as they are in Fig. 4.

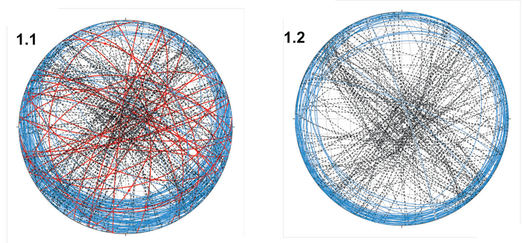


*Fig. 6 Are stereonets for the outcrop along the west side of MM48. **Stereonet 1.1** includes all of the data gathered throughout the outcrop. The bolded red lines represent faults, the red points on those lines represent slickenlines, the dashed black lines represent fractures, and the bluelines reprsent bedding. **Stereonet 1.2** Display the fractures taken across the outcrop rotated to their respective beds. The faults and bedding were both unfolded.*

Discussion

From field observations gathered, a previously unnoted Royer-Sill Imbricate was recorded on the east side of the outcrop as well as several smaller scale structural features on the west side of the outcrop. The features on the west side of the outcrop were initially studied independently, and orientation data was recorded with respect to each feature. The Royer-Sill Imbricate was studied as a whole, with fracture sets taken at key locations throughout the outcrop.
From field observations alone, the Royer-Sill Imbricate on the east side demonstrates an up-thrust of Ft. Sill on top of the Royer (an older unit on top of a younger unit). On the west side several fold hinges demonstrate a left lateral movement, with the down plunge of hinges along the numerous folds dipping towards the south east. The juxtaposition of the Ft. Sill outcrop directly across from the Royer Exposure suggest either, a fault parallel to the interstate, or some sort of left lateral up-thrust that placed the Fort Sill at the same elevation as the Royer Dolomite from across the interstate.

Discussion (Cont.)

Fault and Fold kinematic analysis from fault straie and fold hinges throughout MM48 demonstrate that along this outcrop there is a greater sense of left lateral motion. This is in contrast to the greater sense of dip-slip motion observed on the outer limbs of the Arbuckle Anticline. This suggests that the outcrops juxtaposition of an older unit (Ft. Sill) adjacent to a younger unit (Royer) is due to a left-lateral up-thrust (an oblique fault movement).
Analysis of fracture patterns within the core was performed to determine the relationship of fracture sets within the core versus the outer limbs of the anticline. Fracture data was gathered for a Master's project along the two outer limbs of the anticline at outcrops at MM44 and MM50. Fracture data was also gathered within the core along MM48 on both the east and west side. Fracture sets were gathered with respect to bedding. Other data gathered was their adjacency to faults and other structures, the thickness of the bedding they occurred in, and the how far spaced apart the fractures were. The beds were then unfolded, and the degree to which those beds were unfolded was noted. The fracture sets were then also rotated to the same degree that the beds were unfolded to. This resulted in a method of "normalizing," fracture sets to bedding which allows for a more direct comparison between fracture sets at different outcrops. The unfolding of fracture sets also allowed for determining which fracture sets occurred before folding, and post folding of the anticline.
There are three dominating fracture sets at MM44 and MM50 that stand out when the fractures are rotated with respect to folded bedding. At MM44 there is a fracture set with an average orientation of 246.2/88.3 designated fracture set A1, a fracture set with the average orientation 021/84.8 designated fracture set A2, and a fracture set with an average orientation of 121.3/52 designated fracture set B. Fracture sets A1 and A2 cross cut each other, and occurred nearly simultaneously, but fracture set B crosses sets A1 and A2 demonstrating fracture set B is the youngest of these sets.
These three sets are also noted in MM50, their orientations are as follows: A1 is oriented 77.7/88.7, A2 is oriented 180.3/86.2, and B is oriented 130.5/85.2. The difference in orientation between MM44 and MM50 are minor, with the least noted variation in fracture set B, likely due to it being the youngest set. The overturning of the Northern limb (Hessert 2016) could have caused fracture sets A1 and A2 to have the fracture planes reactivate leading to new fracture sets forming oblique to the original sets seen in MM44. Fracture sets A1 and A2 retain the same angular relationship as with the southern limb.
These three fracture sets are seen throughout the outcrop. Focusing on the core, sometimes only one or two sets are present when unfolded. Also noted in the core, new fracture sets with different orientations are present, indicating these likely occurred post-folding (Fig. 6 and 10).

East Side of Mile Marker 48

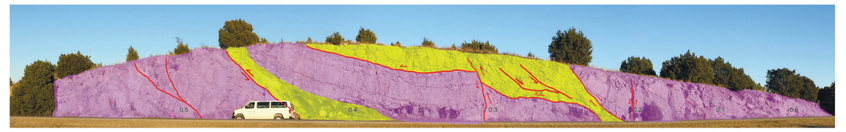
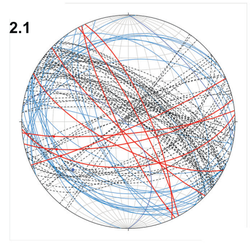


Fig. 7 A panoramic photograph of the east side of Mile Marker 48 along I-35. The Royer Dolomite is denoted in purple and the Ft. Sill Limestone in green. The faults are notted in red with arrows to demonstrate directin of displacement. The Royer Dolomite has massive bedding while the Ft. Sill Limestone is thinly beddeed and has undulating strata. Panoramic photograph taken by Dr. Aaron Yoshinobu.



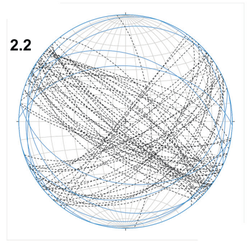


*Fig 10 Are stereonets for the outcrop along the east side of MM48. **Stereonet 2.1** includes all of the data gathered throughout the outcrop. The bolded red lines represent faults, the red points on those lines represent slickenlines, the dashed black lines represent fractures, and the bluelines reprsent bedding. **Stereonet 2.2** Display the fractures taken across the outcrop rotated to their respective beds. The faults and bedding were both unfolded.*

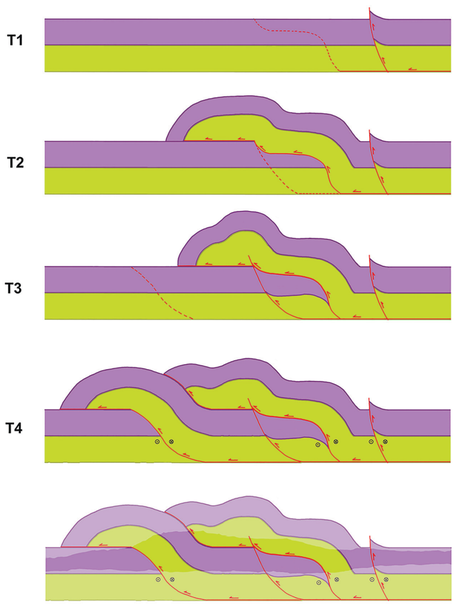


Fig. 8 Interpretation of the Royer-Sill Imbricatae.Slickenlines gathered at the outcrop demonstrated shallow thrust faulting as well as left lateral movement. The illustration shows the evolution of the structure over time. The Ft. Sill was thrust over the Royer. In the final image the darker areas represent what units and structures are exposed in the outcrop

Results

The results are as follows: (1) Kinematic analysis from fault striae within the anticline core show a greater occurrence of strike slip movement to dip slip movement consistent with reverse and oblique left-lateral strike slip motion and displacement; (2) The Arbuckle Anticline core contains the Ft. Sill Limestone interleaved with the Royer Dolomite in a previously unrecognized imbricate; (3) Shallowly plunging fold hinges throughout the core are parasitic, indicate left-lateral rotation, and define the hinge of the Arbuckle Anticline as NW-SE; (4) both pre-folding and post-folding fracture sets can be differentiated and indicate a maximum principle stress direction of N41E; (5) structures along Mile Marker 48 are found to be kinematically compatible on an outcrop scale as well as throughout the rest of the anticline.

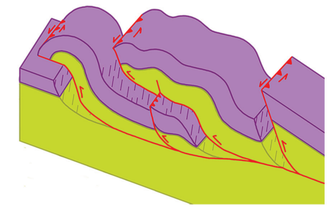


Fig. 9 The Royer Sill Imbricate has both thrusting and left lateral offset. In this illustration the outcrop is drawn in three deminsions to demonstrate the net direction of movement in his outcrop.

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