Subsidence and Burial Histories of the Fort Worth Basin Reflect Prolonged Ouachita Orogeny during the Mississippian-Permian

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EXTENDED ABSTRACT

The Fort Worth Basin in north-central Texas, U.S.A., is one of the major hydrocarbon production systems of the Marathon-Ouachita-Appalachian Orogeny, which was formed due to the collision between Laurentia and Gondwana during the Paleozoic (Walper, 1982; Thompson, 1988; Erlich and Coleman, 2005; Elebiju et al., 2010) (Fig. 1). The basin is bounded by the Red River and Muenster arches to the north, the Ouachita fold-and-thrust belt to the east, the Llano Uplift to the south, and the Bend Arch parallel to the Ouachita structural front to the west (Fig. 1). Current studies to the Fort Worth Basin mainly focus on hydrocarbon exploration and production (Pollastro, 2003; Thomas, 2003; Jarvie et al., 2005), and the subsidence history of the basin and its dynamic relationship to the Ouachita thrust belt remain controversial. Previous studies suggested that the Ouachita fold-and-thrust belt to the east of the Fort Worth Basin was the main sediment source during the Late Mississippian–Late Pennsylvanian (e.g., Walper, 1982; Grayson et al., 1991; Noble, 1993; Pollastro, 2003). However, others suggested that the Muenster Arch to the north of the Fort Worth Basin was the primary sediment source during the Early Pennsylvanian (Lovick et al., 1982; Thomas, 2003), and the Arch caused subsidence of the basin as early as the Mississippian (Loucks and Stephen, 2007). The post-Pennsylvanian strata are poorly preserved in the Fort Worth Basin, limiting our understanding to the post-Pennsylvanian subsidence history of the basin. Current understanding to the post-Pennsylvanian burial and exhumation history of the basin can be classified into two schools of thought: (1) Grayson et al. (1991) and Montgomery et al. (2005) suggested that sediment accumulation lasted into the Permian, and no additional sedimentation occurred until the Early Cretaceous; and (2) Jarvie et al. (2005) and Ewing (2006) argued that the basin experienced exhumation during the Late Triassic-Jurassic as a result of rift-shoulder uplift during the opening of the Gulf of Mexico. Erlich and Coleman (2005) have reconstructed the subsidence history of the basin and their work suggested that the Late Mississippian-Pennsylvanian subsidence rate in the north-

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ern part of the basin was two times higher than the southwestern part of the basin. Because the work did not correct for sediment compaction and loading, the tectonic subsidence rates were overestimated.

In this study, we examine the late Paleozoic evolution of sedimentation patterns in the basin by correlating well logs and reconstructing isopach and structure maps. Our results show that the tectonic uplift of the Muenster Arch to the northeast and the Ouachita thrust belt to the east of the basin started to influence the subsidence of the basin as early as the middle-late Mississippian, and the Ouachita Thrust Belt became the primary tectonic load by the late-middle Pennsylvanian when the depocenter shifted to the eastern part of basin. In addition, we model the 1D and 2D subsidence histories of the basin during the Paleozoic, and constrain its dynamic relationship to the Ouachita Thrust Belt. Because the post-Paleozoic strata were largely eroded in the region, which adds uncertainty to the subsidence reconstruction, we used Petromod 1D software to conduct thermal maturation modeling in order to constrain the post-Paleozoic burial and exhumation histories by matching the modeled vitrinite reflectance with measured vitrinite reflectance along several depth profiles in the basin (Table 1). Our results show that the Fort Worth Basin experienced an average of 7.0 km of subsidence during the Pennsylvanian and Permian in order to reach the gas maturation (Fig. 2), suggesting flexural subsidence of the basin continued to the Permian in response to the continued propagation of the Ouachita thrust belt during the Ouachita Orogeny. This is also consistent with the 2D flexural modeling, which suggests that the size of the Ouachita Thrust Belt was relatively small by the end of the Early Pennsylvanian, and continuous development of the belt caused additional flexural subsidence of the basin during the Permian. This study explains the subsidence history of the Fort Worth Basin during the late Paleozoic, and sheds insights on regional tectonics and hydrocarbon maturation within the basin.

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SUBSIDENCE AND BURIAL HISTORIES OF THE FORT WORTH BASIN REFLECT PROLONGED OUACHITA OROGENY DURING THE MISSISSIPPIAN-PENNSYLVANIAN

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September 2016

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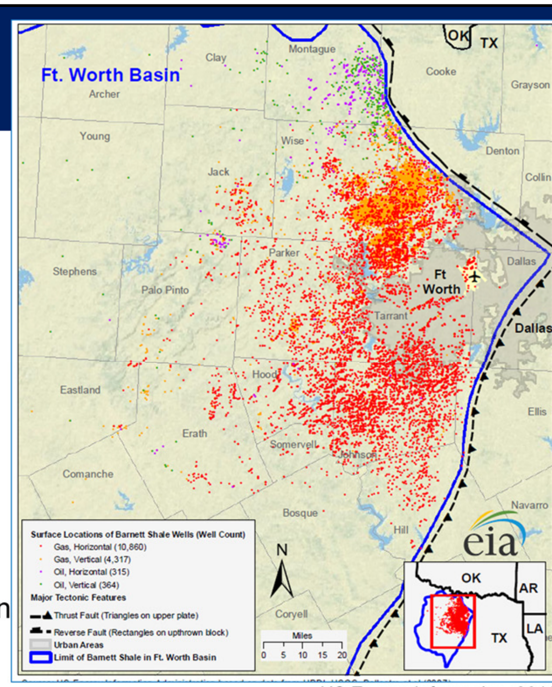
Introduction:

- Hydrocarbons have been discovered and produced from:
  - Ellenburger carbonate
  - Marble Falls carbonate
  - Atoka conglomerate and sandstone
  - Strawn conglomerate and sandstone
- Lots of research focusing on hydrocarbons, but subsidence history and relationship to Ouachita Fold-and-Thrust Belt and influences on hydrocarbon maturation have not been well understood

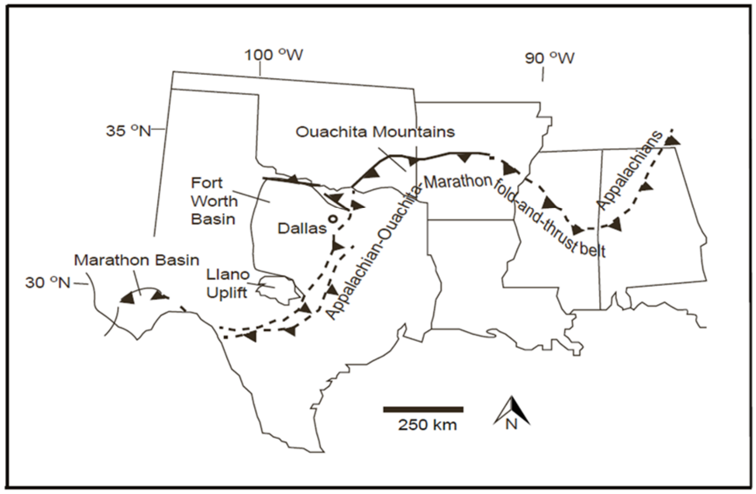


US Energy information, 2011

- The FWB in north-central Texas is a major petroleum producing system in North America.
- On this map we are looking to the distribution of the wells that producing from the Mississippian Barnett Shale.
- The Barnett is one of the several reservoirs in the basin. And the other reservoirs include the Ellenburger, Marble Falls, Atoka, and Strawn.

Introduction:

- Foreland basin of Ouachita-Marathon Fold-and-Thrust Belt
- During the Early Ordovician Laurentia subducted underneath Gondwana
- Followed by oblique collision of Laurentia and Gondwana plates
- Exposed only in Marathon and Solitario uplifts in West Texas, and in Ouachita Mountains in Arkansas and Oklahoma



Loomis et al.,1994

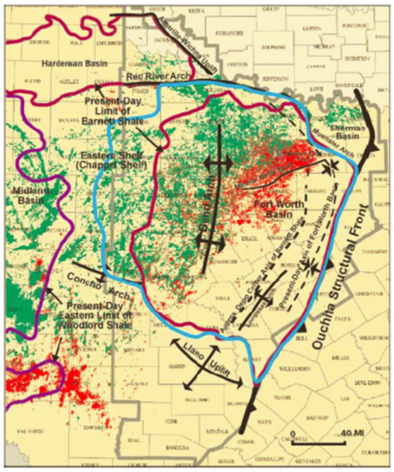
- The Fort Worth Basin classified as one of several foreland basins of the Ouachita-Marathon Fold-and-Thrust Belt.
- In the vicinity of the FWB, Ouachita-Marathon Fold-and-Thrust Belt is mostly buried underneath the Mesozoic and Cenozoic strata of the Gulf Coastal Plain, and exposed only in the Marathon and Solitario uplifts in West Texas and in the Ouachita Mountains in Arkansas and Oklahoma.
- In the last few decades, all studies were focusing on the hydrocarbon explorations and production in the fort worth basin, but limited studies focused on the tectonic history in which the basin has experienced.

- Controversial, why? Because some studies suggest Ouachita thrust belt was the primary sediments source during the late Mississippian to early Pennsylvanian.

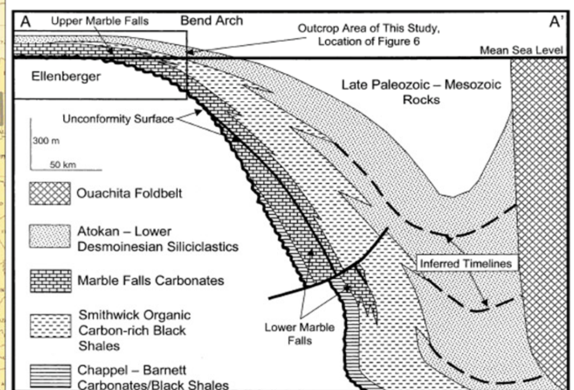
Research Background

1- Ouachita Thrust Belt was the main source of sediments during Late Mississippian–Late Pennsylvanian (Grayson et al., 1991; Pollastro, 2003)

2- Muenster Uplift was the primary source of sediments during Early Pennsylvanian (Lovick et al.., 1982; Thomas, 2003)



Pollastro et al., 2003

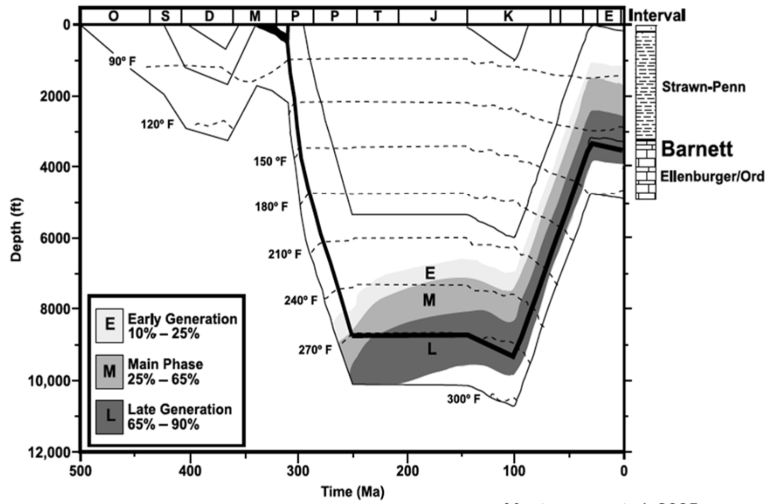


Erlich and Coleman; 2005, after Grayson et al.,1989

- Previous studies suggest that the Ouachita to the east of the basin…
- Others suggest that the Muenster Uplift to the north of the basin…
- Moreover, fault styles and orientations within the basin are variable reflecting a complex stress field that may not be explained by a single structure element.
- Or both.

Introduction:

- **Post-Pennsylvanian burial history, scenario 1**
- Deposition ended in Permian, and resumed in Early Cretaceous (Grayson et al.,1991; Montgomery et al., 2005)

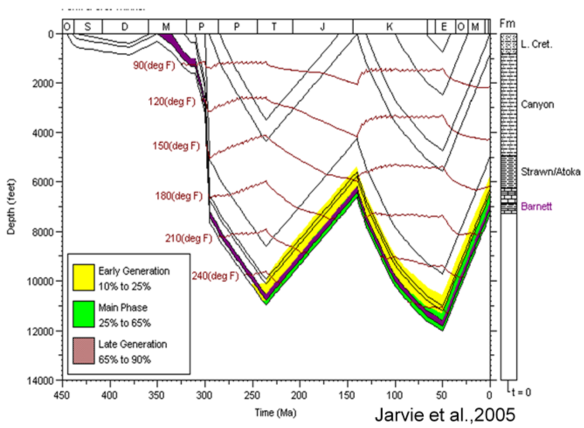


Montgomery et al.,2005

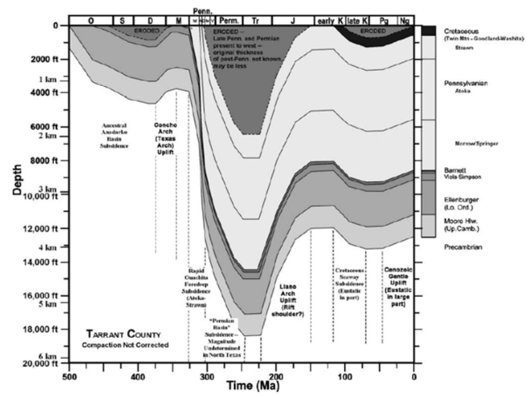
- Stratigraphy is a reflection of the interplay between sediments and accommodation; therefore, it can be used to understand the subsidence and thermal history of the basin.
- Because the post-Pennsylvanian strata are mostly eroded in the Fort Worth Basin, understanding the post-Middle Pennsylvanian depositional burial and exhumation has not well constrained.
- Current understanding of post Pennsylvanian burial and exhumation history includes 2 school of thoughts.

Introduction:

- **Post-Pennsylvanian, scenario 2**
- Exhumation during Triassic and Jurassic as a result of rift-shoulder uplift during the opening of Gulf of Mexico (Jarvie et al., 2001, 2004, 2005; Ewing, 2006)



Jarvie et al.,2005

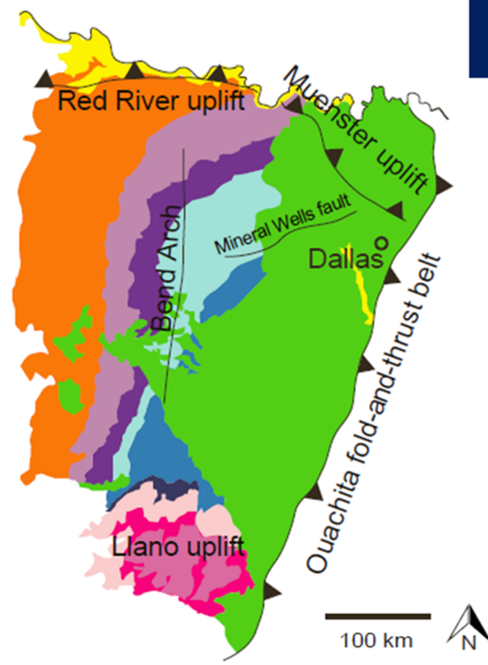


Ewing, 2006

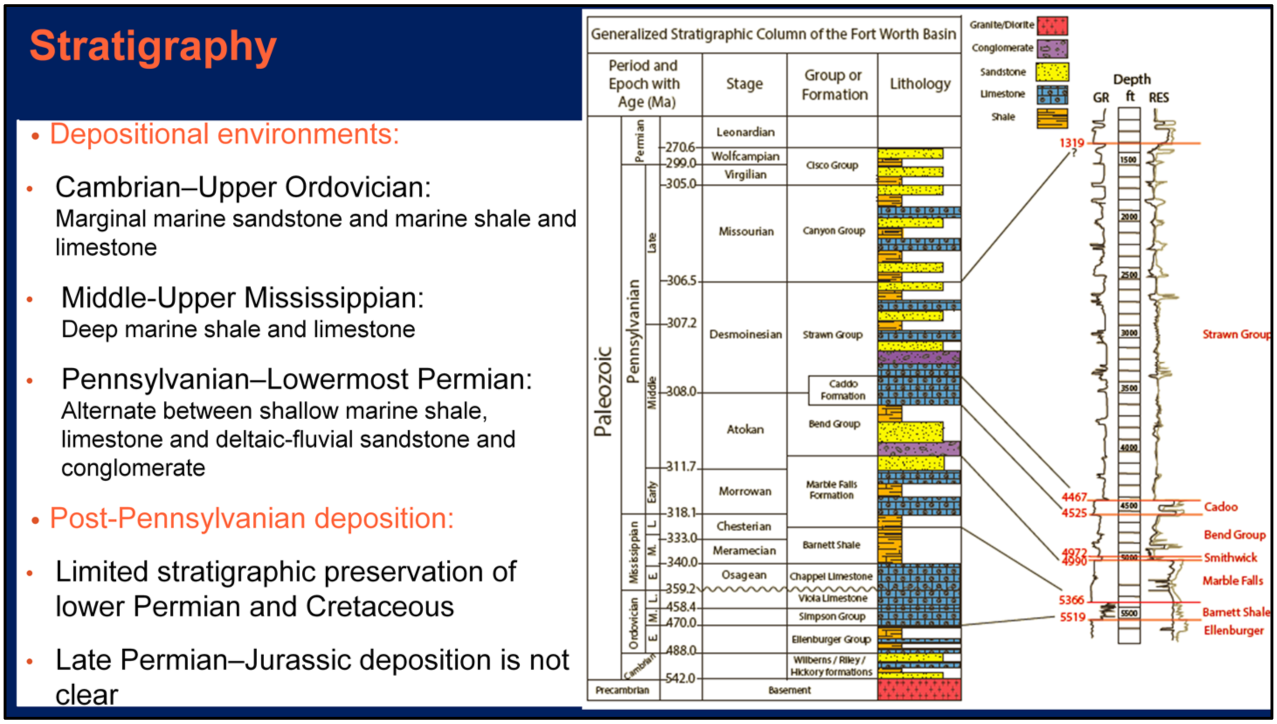
Therefore, the post-Middle Pennsylvanian burial and exhumation history should be constrained in order to understand the subsidence history and maturation of source rocks in the Fort Worth Basin.

Geological Setting

- Pennsylvanian and lowermost Permian strata overlain by Lower Cretaceous
- Basin bounded by:
  - Red River Uplift
  - Muenster Uplift
  - Ouachita Fold-and-Thrust Belt
  - Llano Uplift
  - Bend Arch
- Reactivation of deep normal faults during Late Paleozoic



- This is a geological map of the Fort Worth Basin, the Pennsylvanian strata are in blue and is change from E to W to the younger strata of Permian age in orange, and both are unconformably overlain by the Lower Cretaceous deposits.
- The Fort Worth Basin is a shallow, asymmetrical basin with length of 320 km and width varies from 16 to 160 km.
- The basin bounded by: Red River and Muenster arches to the north…OFTB to the east, Llano Uplift to the south, and Bend Arch to the west.
- The northwest striking Red River and Muenster uplifts were formed due to the reactivation of the rift related faults of the southern Oklahoma aulacogen and also responsible for the initial rise of Llano Uplift.



- Let me introduce the stratigraphy:
- The Cambrian-Ordovician: Wilberns-Riley – Hickory formations, Ellenburger, Viola, and Simpson groups.

Followed by regional unconformity, thus there are no Silurian and/or Devonian strata preserved.

- Middle-upper Mississippian: Chapel, Barnett and lower Marble Falls units.
- Pennsylvanian: upper Marble Falls, Atoka, Strawn, Canyon, and Cisco units.
- Post Pennsylvanian deposition: Only 300 m of Permian strata preserved and 400 m of the lower Cretaceous preserved in the basin.

Therefore…The understanding of the post Pennsylvanian deposition is very limited.

Research Objectives

1- Construct structure and isopach maps during several time slices of Paleozoic

- To document changes of sedimentation pattern though time

2- Model thermal maturation of hydrocarbon

- To constrain post-Middle Pennsylvanian burial and exhumation history

3- Reconstruct 1D tectonic subsidence curve

4- Reconstruct 2D flexure subsidence profile

- To constrain tectonic and flexural subsidence history and mechanism

Size and geometry of the basin.

Method 1:
Construct structure and isopach maps

- 92 well logs were loaded into Petra software for stratigraphic correlation
- Based on previous studies of cores and well log cross-sections (Hackley et al., 2008; Hentz et al., 2012), strata were divided into four units including:

  1- Mississippian Barnett Shale

  2- Pennsylvanian Marble Falls Formation

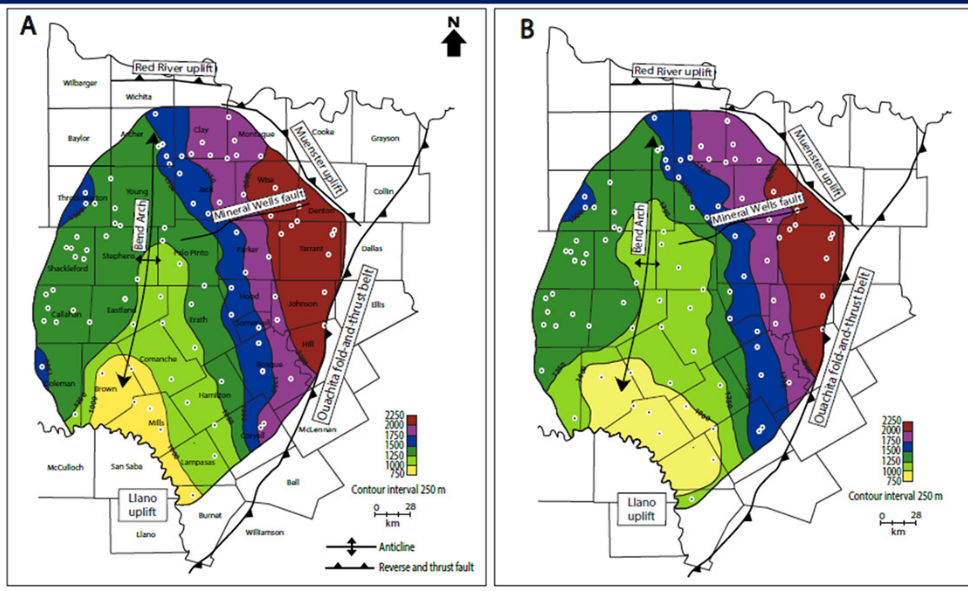
  3- Pennsylvanian Bend Group

  4- Pennsylvanian Strawn Group

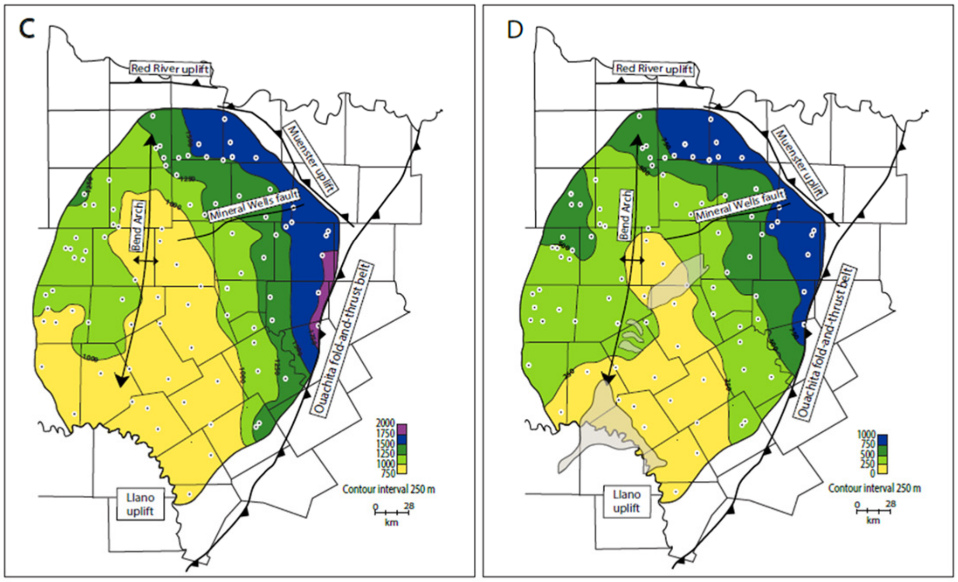
In this study:

- We used 92 well logs for stratigraphic correlation through the basin in order to construct structure and isopach maps.
- These well logs are loaded into Petra software for correlation based on previous studies of well-core comparison and well log cross-sections (Hackley et al., 2008; Hentz et al., 2012).
- I divided the strata into four units:

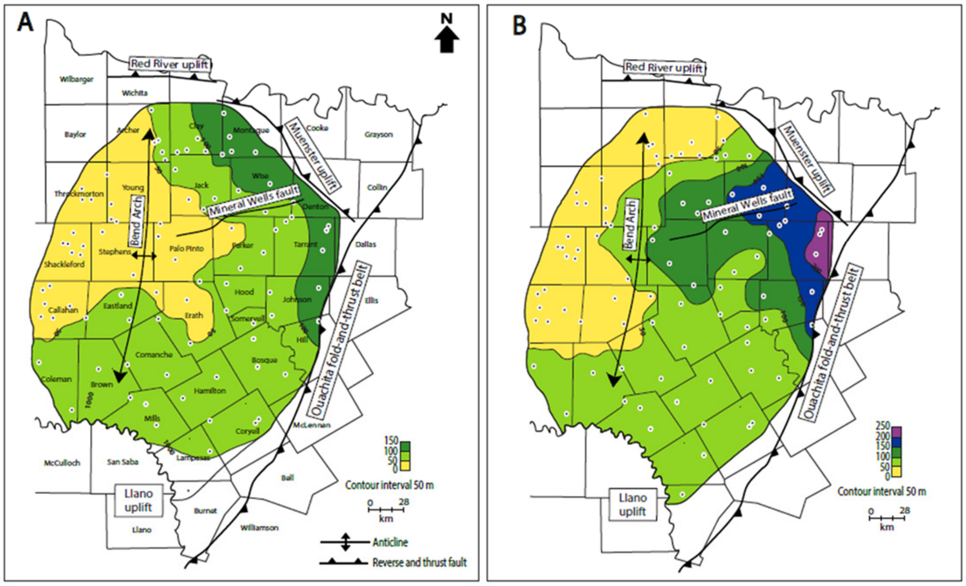
Result 1: Structure Maps



Result 1: Structure Maps

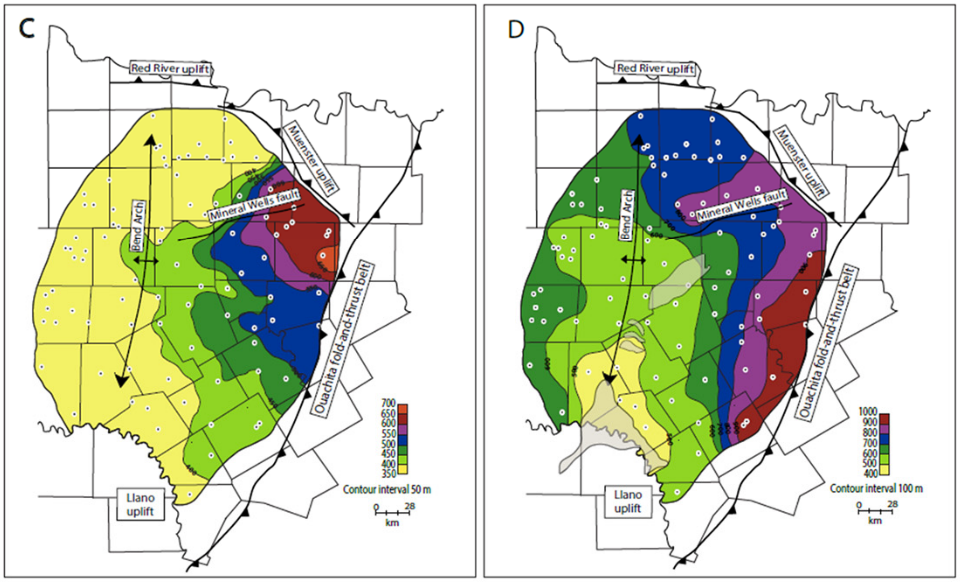


Result 1: Isopach Maps

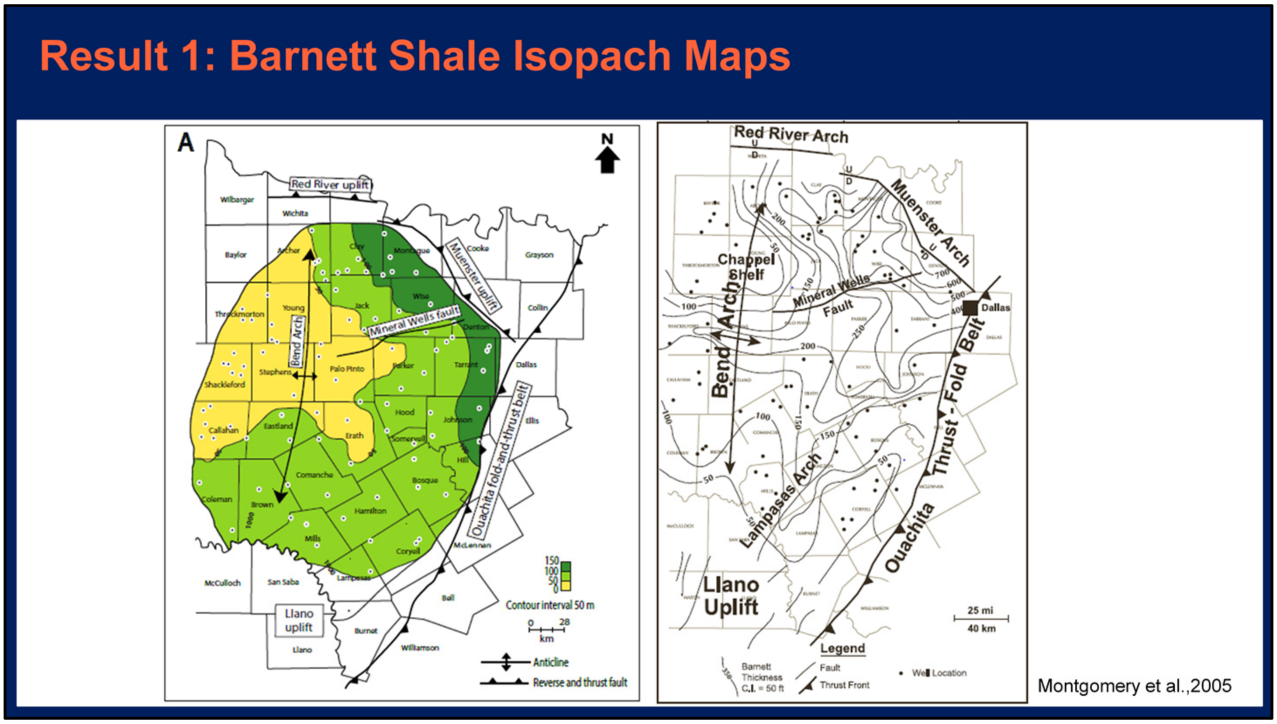


- Generally they thicken toward east and northeast, and thins to the west. The thickness of the Barnett Shale varies between 5 m and 150 m with the maximum in the northeast corner of the basin.
- The thickness of the Marble Falls varies between 10 m and 250 m. and the pattern is similar to the Barnett Shale, showing thickening toward the east and northeast of the basin.

Result 1: Isopach Maps



- And these are the isopach maps of the Pennsylvanian Bend Group and Strawn groups.
- Also they thicken toward east and northeast, and thins to the west.
- The thickness of the Bend Group varies between 150 m and 650 m. The isopach patterns of this group is similar to the Barnett Shale, showing thickening toward the east and northeast of the basin.
- The thickness of the Strawn Group varies between 400 m and 1000 m with the thickest strata in front of the Ouachita Fold-and-Thrust Belt, and the thinnest strata distributed in the southern end of the Bend Arch.



- For comparison, this is a higher resolution isopach map of the Mississippian Barnett shale from Montgomery et al., 2005. Our map shows similar thickness distribution, and both shows that the formation thickens toward the northeast of the basin and shallow toward the west.

Method 2:
Post-Middle Pennsylvanian Exhumation and Burial History

- Used Schlumberger PetroMod 1D
- Best fit is generated by matching modeled $\%R_o$ with measured $\%R_o$
- Modeled data from five counties

County	Formation / Group	Vitrinite Reflectance (%Ro)	References
Archir	Cisco	0.49 - 0.67	Hackely at al., 2009
Archir	Canyon	0.51	Hackely at al., 2009
Archir	Strawn	0.77	Hackely at al., 2009
Archir	Barnett	0.50 - 0.70	Pollastro et al., 2007
Young	Cisco	0.58 - 0.77	Hackely at al., 2009
Young	Canyon	0.53 - 0.88	Hackely at al., 2009
Young	Strawn	0.71 - 0.86	Hackely at al., 2009
Young	Barnett	0.68 - 0.90	Pollastro et al., 2007
Wise	Strawn	0.80 - 0.85	Hill et al., 2007
Wise	Smithwick	0.65 - 1.15	Hill et al., 2007
Wise	Barnett	0.98 - 1.21	Pollastro et al., 2007
Erath	Smithwick	0.64 - 1.02	This study
Erath	Barnett	0.80 - 0.90	Pollastro et al., 2007
Hill	Strawn	0.82 - 0.85	This study
Hill	Barnett	1.35 - 1.90	Pollastro et al., 2007

- Used the Schlumberger Petromod software to model the burial and exhumation history and hydrocarbon maturation in the basin.
- By varying the post-Pennsylvanian strata thickness and exhumation history and match the modeled %Ro to the measured %Ro, the best-fit scenario gives the burial and exhumation history of the basin.
- These are the Ro data were used for this study.

Method 2:
Post-middle Pennsylvanian Exhumation and Burial History

- Model assumptions:
  - Heat flow: 60 mW/m^2
  - Most of sedimentation occurred during Pennsylvanian
  - Less sedimentation occurred during Early Permian
  - Another episode of sedimentation occurred during Cretaceous
  - Two exhumations:

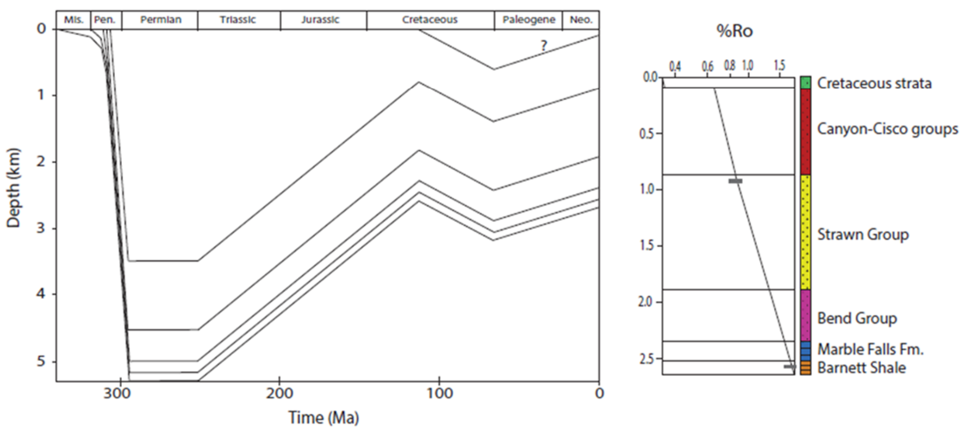
    1- During Triassic–Early Cretaceous

    2- After Cretaceous

- The estimated heat flow of 60 is constant with the estimated heat flow in the Appalachians and the global average for continental lithosphere.

Results 2:
Post-Middle Pennsylvanian Exhumation and Burial History

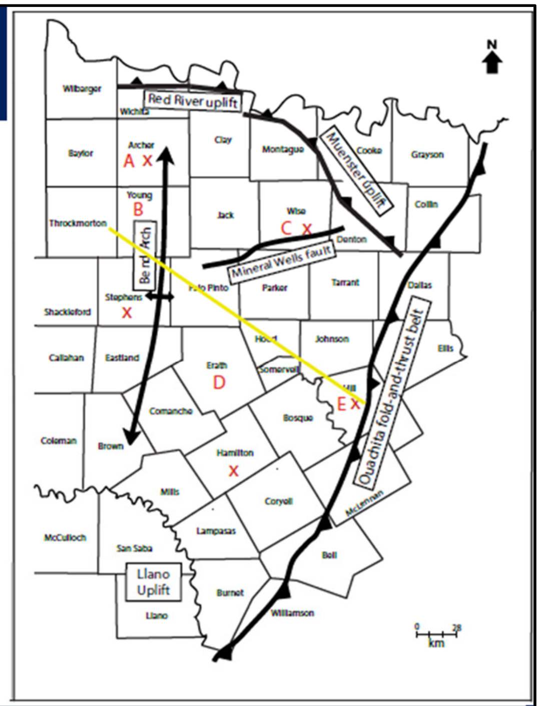
- Required burial thickness of Pennsylvanian and any possible Permian strata was 3.7–5.2 km
- Decreases ~10% if the depositional hiatus or low-rate deposition lasted until Late Triassic



- In order to bury the Mississippian and Pennsylvanian source rocks to elevated temperature to reach the maturation window, the thermal model requires 3.7–5.2 km of Pennsylvanian and any possible Permian in the five counties and the strata thicken toward the east.
- The required thickness decrease…

Method 3:
1D Tectonic Subsidence

- Stratigraphic thickness data from 5 wells
- Thickness were backstripped
- Sediment load were removed
- Data were corrected for paleo-water depth and sea level change

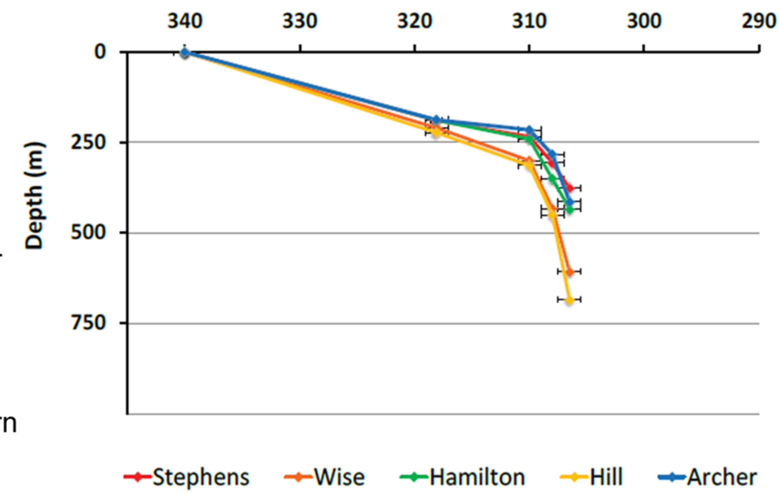


Result 3:
1D Tectonic Subsidence

- Rapid tectonic subsidence during 310.0–306.5 Ma
- Subsidence rate:

  from 8 m/Myr to 91 m/Myr

- Similar to foreland basin subsidence of convex-up pattern



Method 4:
2D Flexural Subsidence Modeling

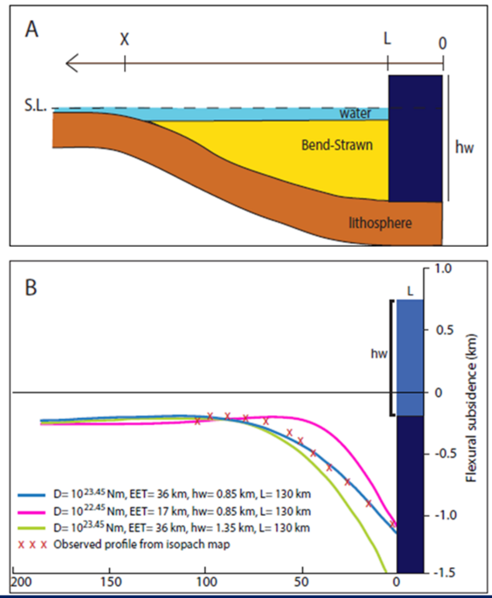
- To determine if the shape of Fort Worth Basin can be explained by flexural subsidence
  - Assume Ouachita Fold-and-Thrust Belt as a rectangular load
  - Assume elastic deformation of the lithosphere
  - Remove the influence of compaction
  - $W= (\rho_L h_L/2(\rho_m-\rho_s))*[2- \exp(- x+L/\alpha) \cos(x+L/\alpha)- \exp(- L-x/\alpha) \cos(L-x/\alpha)]$ by (Angevine et al.,1993)
  - Conduct to the Pennsylvanian Bend and Strawn groups (310–308 Ma)
  - Vary the height and width of Ouachita, and the flexural rigidity of lithosphere to match the reconstructed subsidence profile with observed subsidence
- 2 Scenarios

  based on the location of Ouachita Fold-and-Thrust Belt

- Finally, we modeled the 2D flexural subsidence to determine if the shape of the basin can be explained by flexural subsidence…we assumed that the OFTB is rectangular load and the lithosphere experience elastic deformation and we applied this flexure subsidence equation from Angevine et al to model the flexure subsidence…
- This is a long equation but what it really says is the subsidence amount at certain distance away from the mountain is controlled by the height, width, and density of the mountain. So we read the subsidence profile from the isopach map, and we assign the mountain height and width to see if I can model this observed subsidence profile.
- This is conducted to the Pennsylvanian Bend and Strawn groups.
- We combined the groups together because they were deposited when the basin experienced accelerated subsidence (result of 1D tectonic subsidence).
- By varying the height and width of the Ouachita Fold-and-Thrust Belt and the lithosphere flexural rigidity, we model the 2D flexural subsidence profile in order to match the observed 2D flexural subsidence profile.
- Because it is not clear if the front of the Ouachita Fold-and-Thrust Belt was in its modern location, therefore we gave 2 scenarios

Result 4:
2D Flexural Subsidence Modeling, Scenario 1

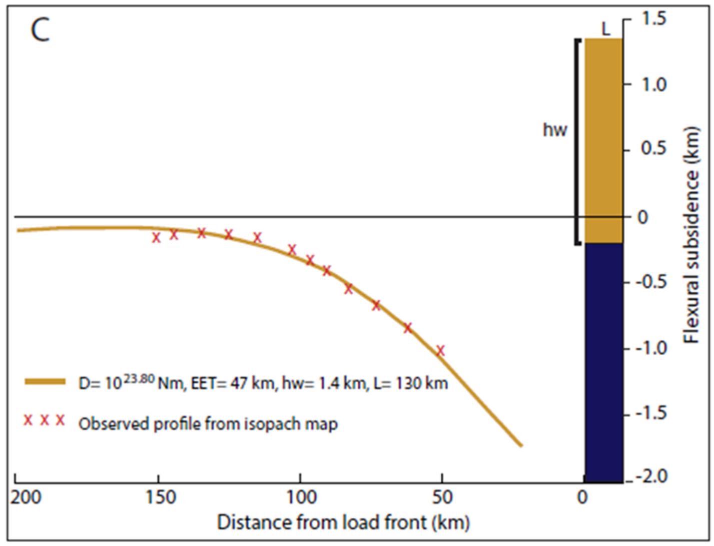
- Ouachita front was in modern location
  - Load density of 2650 kg/m^3
  - Basin-fill density of 2000 kg/m^3
  - Flexural rigidity of $10^{23.45}$ Nm
  - EET: 36 km
  - Load size: height 0.85 km, width 130 km



- In this scenario, I assumed the front of the Ouachita Fold-and-Thrust Belt was in its modern location, when the modeled flexural subsidence profile matches the observed profile, the yielded lithosphere flexural rigidity and load size are the minima.
- Here I'm showing the best fit ... The red crosses are the decompacted thickness from isopach map. The blue curve is the modeled basin profile.
- This scenario gives lithosphere flexural rigidity of $10^{23.45}$ Nm, which is equivalent to an effective elastic thickness of 36 km, and the height and half width of the mountain of 0.85 km and 130 km, respectively.

Result 4:
2D Flexural Subsidence Modeling, Scenario 2

- Ouachita front was 50 km to the east
  - Load density of 2650 kg/m^3
  - Basin-fill density of 2000 kg/m^3
  - Flexural rigidity of $10^{23.80}$ Nm
  - EET: 47 km
  - Load size: height 1.4 km, width 130 km

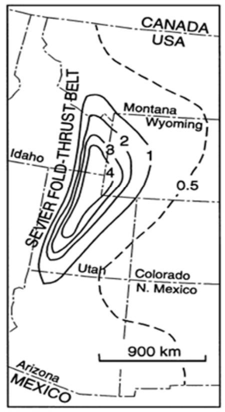


- In Scenario 2, we assume the front of the Ouachita Fold-and-Thrust Belt was 50 km to the east of its modern location.
- We used 50 km because it yielded a lithosphere flexure rigidity that is similar to present lithosphere flexure rigidity in south-central USA.
- This scenario increases the basin width and lithosphere flexural rigidity as well as the load size.
- The best-fit of lithosphere flexural rigidity is $10^{23.80}$ Nm, which is equivalent to an effective elastic thickness of 47 km and a mountain height of 1.4 km.
- An effective elastic thickness of 47 km is high compared to the effective elastic thickness of a region that has experienced flexural weakening; for example, the Himalayan foreland basin. It is also high compared to the modern effective elastic thickness in south-central U.S.A. Therefore, the yielded lithosphere flexural rigidity and load size of Scenario 2 are the maximum.

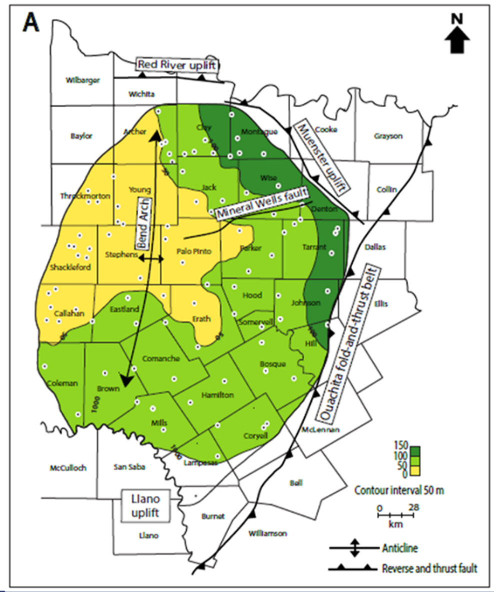
Discussion:
Interpretation of Basin Evolution

- **Middle-late Mississippian:**

- Basin fill thickened toward northeastern corner of the basin
- Initial foreland basin stage in response to mountain loading
- Fort Worth basin was at its initial foreland basin stage in response to tectonic loading of Muenster uplift



Isopach map of Sevier foreland basin (Cross, 1986)

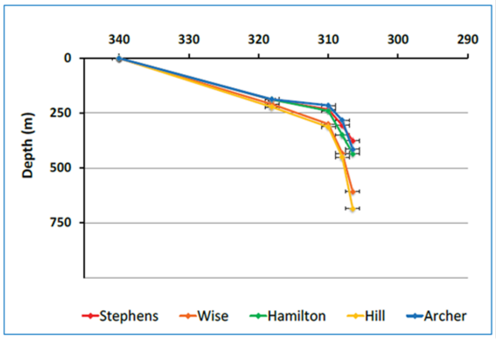


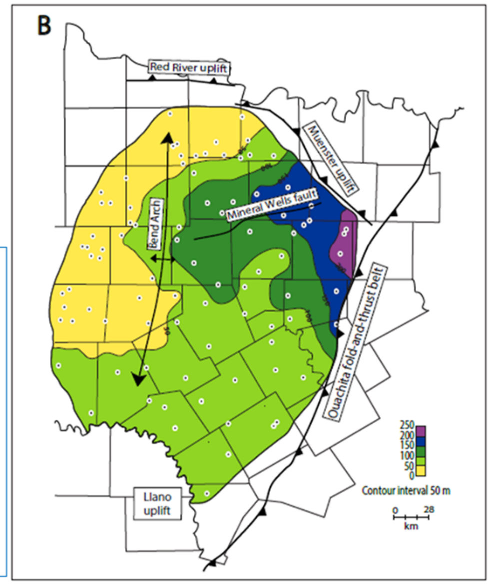
- Talk about the color. This is the isopach map of the Mississippian Barnett Shale which shows that it is thickens toward the Ouachita Fold-and-Thrust Belt.
- For comparison I show the isopach map of the foreland basin of another large FTB ... the Cretaceous Sevier FTB in western US … the isopach map of the FWB display the same pattern as the Sevier foreland basin as the strata thickens toward the thrust belt.
- This suggests that the FWB was at its initial foreland basin stage in response to mountain loading to the north and east of the basin as early as the Middle-Late Mississippian.
- In addition, the result shows that the Muenster Uplift to the north of the basin also played a major role in the basin subsidence.

Discussion:
Interpretation of Basin Evolution

- **Early Pennsylvanian (Morrowan):**

- Depocenter shifted eastward
- The northern segment of Ouachita Orogeny contributed as an additional load
- Subsidence rate was relatively low

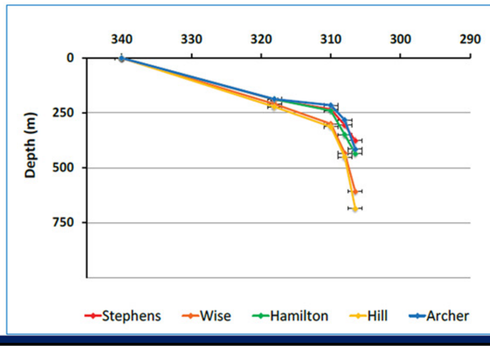


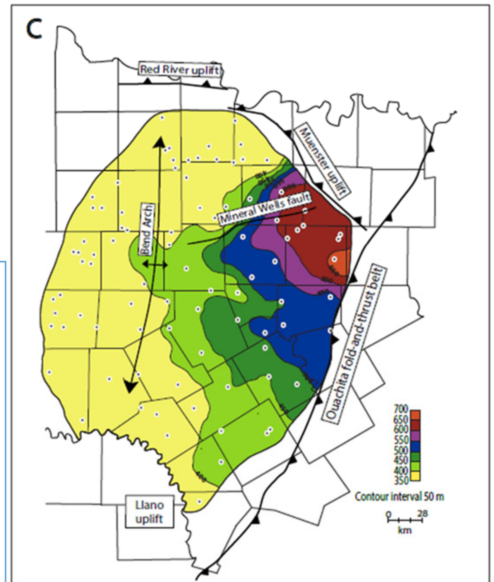


Started in the Early-Middle Pennsylvanian (Atokan), the depocenter of the Fort Worth Basin remained in the northeast, with accelerated basin subsidence initiated in response to the propagation of the Ouachita Fold-and-Thrust Belt.

Discussion:
Development of a Peripheral Foreland Basin

- **Early-Middle Pennsylvanian (Atokan):**
- Depocenter of the basin continued to shift eastward with basin subsidence acceleration
- Consistent with thick, synorogenic deposits of the Bend Conglomerate in the northeastern part of the basin (Lovick et al., 1982)

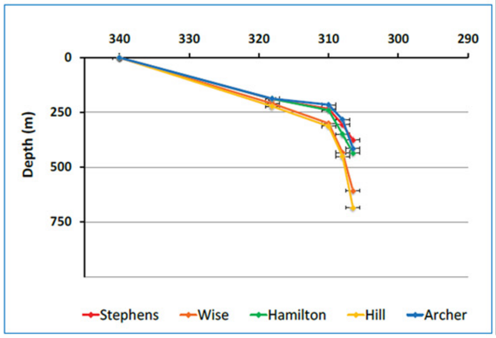


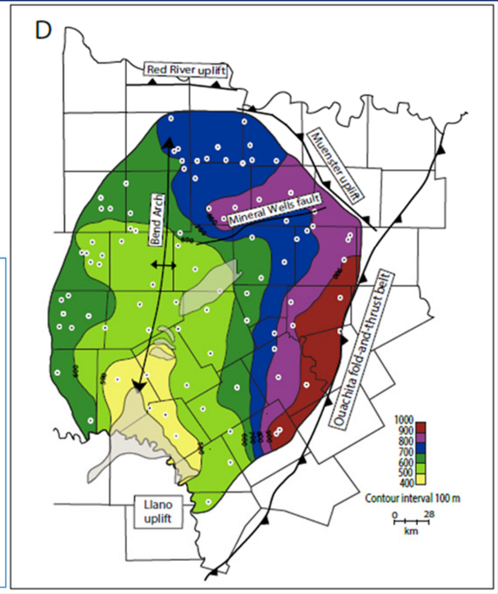


Due to the westward propagation of Ouachita Fold-and-Thrust Belt and the southwestward suturing of Laurentia and Gondwana.

Discussion:
Development of a Peripheral Foreland Basin

- **Late-Middle Pennsylvanian (Desmoinesian):**
- Depocenter of the basin completely shifted to east, parallel to Ouachita Fold-and-Thrust Belt
- Basin-fill pattern suggests Ouachita Fold-and-Thrust Belt was dominant tectonic load controlling the subsidence of the basin
- Muenster Uplift influencing only the northeastern corner of the basin

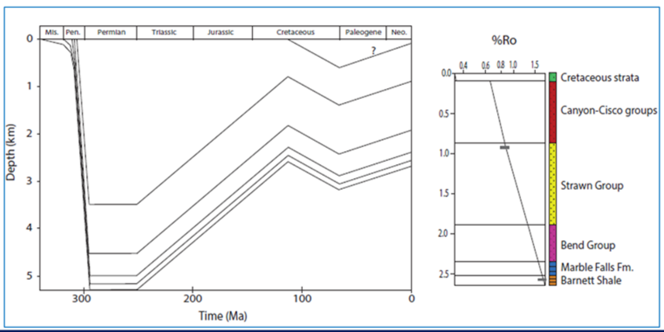


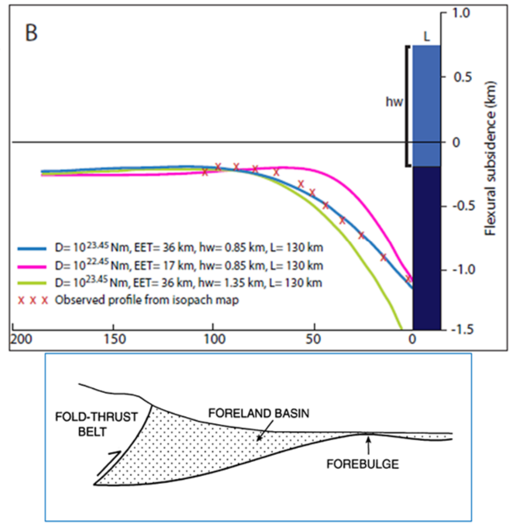


- The Ouachita Fold-and-Thrust Belt became the only tectonic load of the Fort Worth Basin during the Desmoinesian. Starting in the Early-Middle Pennsylvanian (Atokan), the depocenter of the Fort Worth Basin remained in the northeast, with accelerated basin subsidence initiated in response to the propagation of the Ouachita Fold-and-Thrust Belt. Thick, synorogenic molasse deposits of the Bend Conglomerate occurred in the northeast part of the basin and extended toward the Bend Arch (Lovick et al., 1982).
- During the Late-Middle Pennsylvanian (Desmoinesian), the depocenter of the basin completely shifted to the east, parallel to the Ouachita Fold-and-Thrust Belt, and the forebulge depozone occurred as the Bend Arch. The basin-fill pattern suggests the Ouachita Fold-and-Thrust Belt was the only tectonic load controlling the subsidence of the basin

Discussion:
Development of a Peripheral Foreland Basin

- During Desmoinesian, the height of Ouachita Thrust Belt was between 0.85 km and 1.4 km
- Ouachita Belt must had not been fully developed
- Ouachita Fold-and-Thrust Belt must had experienced additional vertical growth during Late Pennsylvanian and Permian



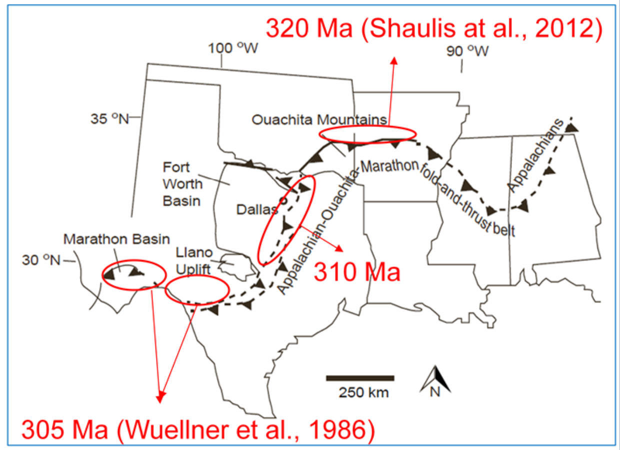


DeCelles and Giles,1996

- Our interpretations that the Fort Worth Basin was mainly influenced by the tectonic loading of the Muenster Uplift during the Middle-Late Mississippian and Ouachita Orogeny during and after Middle Pennsylvanian.

Discussion:
Significance for Regional Tectonics

- Period of rapid flexural subsidence became younger southwestward due to closure of Rheic Ocean and diachronous suturing of Laurentia and Gondwana
- Basement-involved Amarillo-Wichita-Muenster Uplift System was reactivated before forming entire segment of Ouachita Thrust Belt



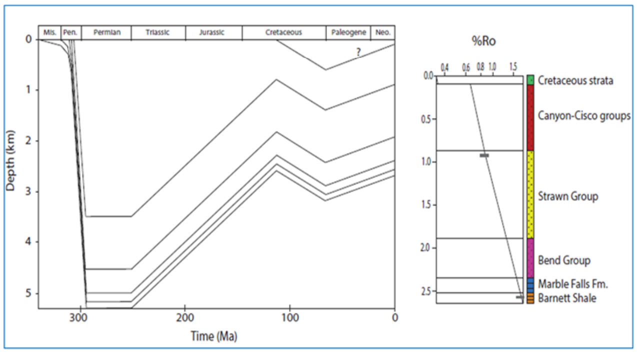
Loomis et al.,1994

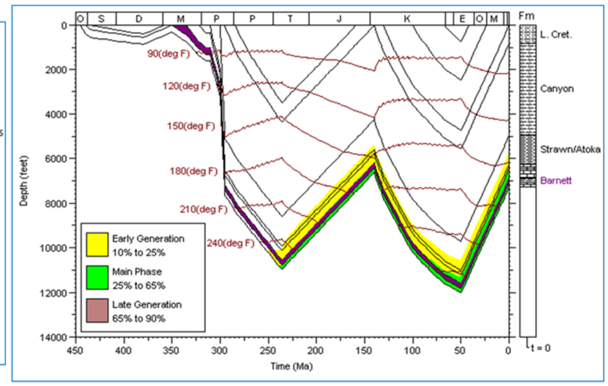
- Other peripheral foreland basins of the Ouachita-Marathon Orogeny in the vicinity of the Fort Worth Basin include the Arkoma Basin in Oklahoma, and the Marathon and Val Verde basins in West Texas (Dickinson and Lawton, 2003).
- The rapid flexural subsidence of the Fort Worth Basin began during the Atokan when the Ouachita Orogen became the predominant load, which was ~10 Myr younger than the timing of the increased deposition associated with rapid subsidence in the Arkoma basin during the Late Mississippian (Shaulis et al., 2012), and ~5 Myr older than the documented initial foredeep development in the Marathon and Val Verde basins during the Desmoinesian (Wuellner et al., 1986).
- This trend has been explained as the southwestward closure of the Rheic Ocean and diachronous suturing of Laurentia and Gondwana (Dickinson and Lawton, 2003).
- The gradual eastward shift of depocenter in the Fort Worth Basin during the Early-Middle Pennsylvanian fits in this geologic framework, suggesting that the Ouachita Orogen gradually developed southwestward in East Texas, and became part of the Ouachita-Marathon Orogen System during the Permian.
- The switch of dominant tectonic load from the Muenster Uplift to the Ouachita Orogen during the Early Pennsylvanian also bears significance for Ancestral Rocky Mountain Orogeny.
- The basement-involved Amarillo-Wichita-Muenster Uplift System was part of the Ancestral Rocky Mountain Orogeny.

- The dominant tectonic loading of the Muenster Uplift during the Late Mississippian suggests that the basement-involved Muenster Uplift developed before forming the entire segment of the Ouachita Fold-and-Thrust Belt in East Texas.

Discussion: Significance for Petroleum Generation

- Barnett Shale reached gas maturation window due to an average of 4.5 km of burial during Pennsylvanian and possibly Permian
- Cretaceous burial and exhumation doesn't influence Barnett Shale maturation





Jarvie et al.,2005

- The burial and exhumation history and heat flow of a basin influence the thermal maturation and hydrocarbon generation of source rocks
- Because our burial and exhumation history modeling suggests a continued foreland basin subsidence during the Late Pennsylvanian, and possibly Early Permian, the Mississippian and Lower Pennsylvanian source rocks were thermally matured during the Late Pennsylvanian when the accommodation space caused by the flexural loading of the Ouachita Orogen was quickly filled by denudation of the orogen.
- Our modeling results show that the maturation of the Barnett Shale was caused by an average of ~4.5 km of burial during the Pennsylvanian and possibly Permian, and the accommodation for burial was very likely produced by the continued flexural subsidence.
- Although the Cenozoic exhumation or burial history is uncertain, a small amount of burial or exhumation less than 0.5 km does not influence the maturation of the Barnett Shale. Therefore, the Barnett Shale reached gas maturation window during the Middle-Late Permian. An average of ~4.5 km of Pennsylvanian-Permian burial is comparable to the previous results of thermal maturation modeling.

Summary

- Tectonic uplift of the Muenster Uplift to the northeast of the Fort Worth Basin influenced as early as Middle Mississippian
- Basin experienced 3.7-5.2 km of burial during Pennsylvanian, and burial depth deepens toward east
- Flexure subsidence continued into Pennsylvanian in response to the growth of the Ouachita Orogeny and southeastward suturing of Laurentia and Gondwana
- The Mississippian Barnett Shale reached the gas maturation window during the Middle-Late Permian

Thank you

(questions!)

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