[PS]Characterization and Origin of Fracture Patterns in a Woodford Shale Quarry in Southeastern Oklahoma for Application to Exploration and Development*

R.M. Portas[1] and R. Slatt[2]

Search and Discovery Article #50352 (2010)
Posted November 22, 2010

*Adapted from poster presentation at AAPG Annual Convention and Exhibition, New Orleans, Louisiana, April 11-14, 2010

[1]ConocoPhillips, Houston, TX (romi_217@hotmail.com)
[2]ConocoPhillips School of Geology and Geophysics, University of Oklahoma, Norman, OK (rslatt@ou.edu)

Abstract

The Woodford Shale is an important unconventional gas reservoir in Oklahoma. Production is by artificial fracturing of naturally fractured or unfractured rock. Therefore, understanding natural fracture networks may help in developing fracture stimulation procedures.

The main objective of this study was to document and understand the natural fracture patterns within the Woodford Shale by integrating and calibrating fractures and strata in the exposed vertical walls of a quarry using laser imaging detection and ranging (LIDAR) data, 2D seismic lines, and logs and core acquired in a well drilled behind a quarry wall.

Fracture measurements in the outcrop and LIDAR data revealed two extensional fracture sets with nearly vertical dip. Group 1 is a systematic fracture set with parallel orientations, regular spacing and mineral filling, having a median strike direction of N85°E. Group 2 is a nonsystematic fracture set, younger than Group 1, having a median strike direction of N45°E. There is no lateral lithology or bedding change; therefore the average fracture spacing is 1.2m (4ft). The present stress field in the area of study has an ENE-WSW direction that generated the fractures in Group 2, different from the paleostress that generated fractures in Group 1.

The Woodford Shale has three informal members and the Lower Woodford is not present in the area of study. There is a greater abundance of fractures in the Upper Woodford Shale than in the Middle Woodford Shale in the quarry, probably because of the former's higher content of quartz.

The 2D seismic lines imaged the Upper-Middle Woodford contact and the Woodford-Hunton unconformity surface. The faults interpreted on the seismic follow the same trend as the regional faults observed in the surrounding area.

Geologic history places regional and local structural events to have occurred after deposition of the Woodford Shale. Therefore, the Woodford Shale and the Hunton Group have the same fracture characteristics, and the fractures extend through both formations in the area of study. The information will be used as a baseline for improved understanding of fractures in the Woodford Shale to facilitate gas production by knowing fracture characteristics and in situ stress.

References

Northcutt, R.A., and J.A. Campbell (compilers), 1995, Geologic Provinces of Oklahoma: Oklahoma Geological Survey, Open-File Report OF5-95, Web accessed 5 November 2010, http://www.ogs.ou.edu/geolmapping/Geologic_Provinces_OF5-95.pdf

Perry, W.J., Jr., 1995, Arkoma Basin Province (062), *in* D.L. Gautier, G.L. Dolton, K.I. Takahashi, and K.L. Varnes, (editors) 1995 National assessment of United States oil and gas resources: Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series DDS-30, Release 2, one CD-Rom, Web accessed 5 November 2010, http://certmapper.cr.usgs.gov/data/noga95/prov62/text/prov62.pdf

Characterization and Origin of Fracture Patterns in a Woodford Shale Quarry in Southeastern Oklahoma for Application to Exploration and Development

R. M. Portas[1]; R. Slatt[2]

1. ConocoPhillips, Houston, TX, USA; 2. ConocoPhillips School of Geology and Geophysics, University of Oklahoma, Norman, OK, USA

ABSTRACT

The Woodford Shale is an important unconventional gas reservoir in Oklahoma. Production is by artificial fracturing of naturally fractured or unfractured rock. Therefore, understanding natural fracture networks may help in developing fracture stimulation procedures.

The main objective of this study was to document and understand the natural fracture patterns within the Woodford Shale by integrating and calibrating fractures and strata in the exposed vertical walls of a quarry using laser imaging detection and ranging (LIDAR) data, 2D seismic lines, and logs and core acquired in a well drilled behind a quarry wall.

Fracture measurements in the outcrop and LIDAR data revealed two extensional fracture sets with nearly vertical dip. Group 1 is a systematic fracture set with parallel orientations, regular spacing and mineral filling, having a median strike direction of N85°E. Group 2 is a nonsystematic fracture set, younger than Group 1, having a median strike direction of N45°E. There is no lateral lithology or bedding change; t herefore the average fracture spacing is 1.2m (4ft). The present stress field in the area of study has an ENE-WSW direction that generated the fractures in Group 2, different from the paleostress that generated fractures in Group 1.

The Woodford Shale has three informal members and the Lower Woodford is not present in the area of study. There is a greater abundance of fractures in the Upper Woodford Shale than in the Middle Woodford Shale in the quarry, probably because of the former's higher content of quartz.

The 2D seismic lines imaged the Upper-Middle Woodford contact and the Woodford-Hunton unconformity surface. The faults interpreted on the seismic follow the same trend as the regional faults observed in the surrounding area.

Geologic history places regional and local structural events to have occurred after deposition of the Woodford Shale. Therefore, the Woodford Shale and the Hunton Group have the same fracture characteristics, and the fractures extend through both formations in the area of study. The information will be used as a baseline for improved understanding of fractures in the Woodford Shale to facilitate gas production by knowing fracture characteristics and in situ stress.

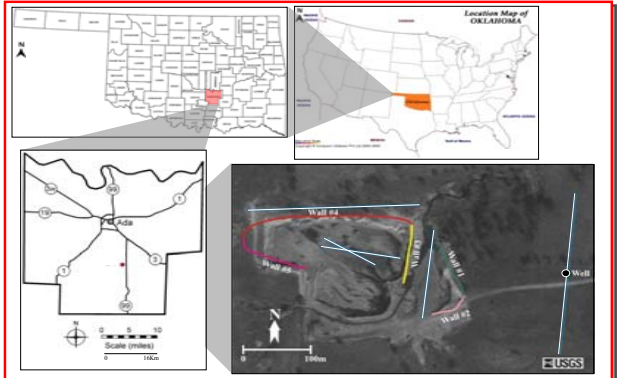
OBJECTIVES

Understand the fracture patterns within the Woodford Shale by integrating and calibrating fractures and strata in exposed quarry walls using laser imaging detection and ranging (LIDAR) data, 2D seismic lines, and the logs and core acquired in a well drilled behind a quarry wall.

Specific goals are to determine if fractures:

- Align with the general strike of faulting in the study area.
- Distribution is somehow affected by paleotopography on the underlying Hunton Group unconformity surface.
- Sets are confined to the Woodford Shale or extend into the Hunton Group.
- Have an uniform spacing or if they occur in swarms.

AREA OF STUDY

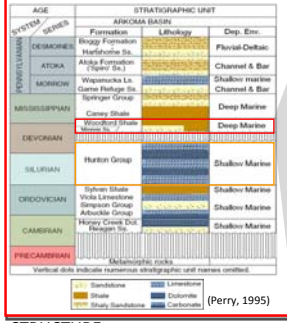


The area of study is located in SE Pontotoc County, Oklahoma, where the Woodford Shale is exposed on vertical walls as high as 50ft and three-dimensionally- positioned, providing the sense as if one is standing on a fluid contact in the middle of a Woodford reservoir.

GEOLOGICAL SETTING

STRATIGRAPHY

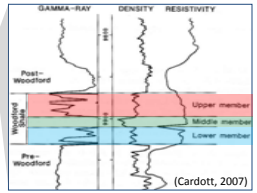
The Woodford Shale is a Upper Devonian to Lower Mississippian Formation, composed of black shale facies, chert, siltstone, sandstone, dolostone, pyrite, and lighter facies.



(Perry, 1995)

Lower Woodford Shale

- Deposited close to shore during transgression
- Smallest areal extent



(Cardott, 2007)

Middle Woodford Shale

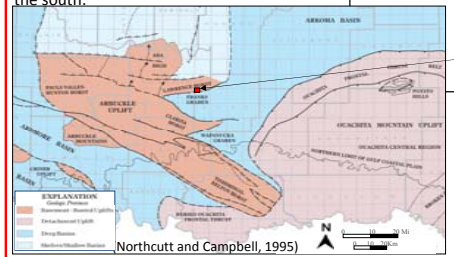
- Highest TOC
- Greatest areal extent
- Kerogen Type I and II
- Deposited farther from shore during sea level rise

Upper Woodford Shale

- Lowest TOC
- Kerogen Type II and phosphate nodules.
- Deposited closer to shore during a sea level fall

STRUCTURE

Area of interest is located east of the Arbuckle Mountains and west of the Arkoma Basin in the Lawrence Uplift, bounded by the Ahloso Fault to the north and the Stonewall Fault to the south.

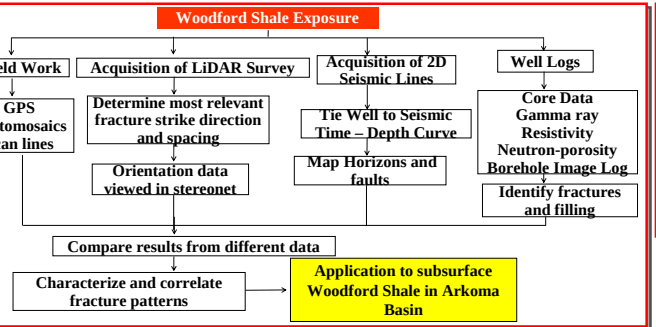


Northcutt and Campbell, 1995)

The Lawrence Uplift was formed during the Pennsylvanian. Its western end was uplifted more than its eastern end, exposing older rocks to the west.

The Franks Graben is open to the east, merging with the Arkoma Basin and exposing older rocks are to the east.

WORKFLOW

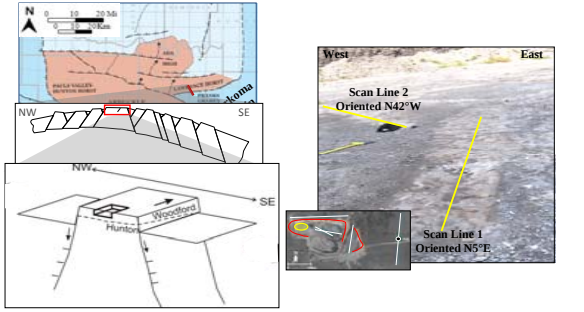


METHODOLOGY – OUTCROP STUDY

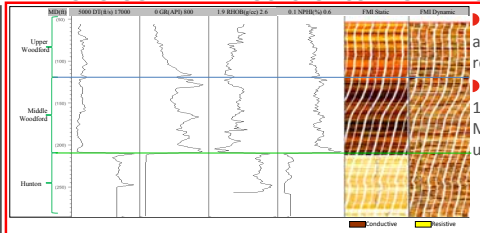
The area of study is located on a horst structure bounded by two southwest-northeast- striking normal faults located north and south of the study area. Outcrop has exposures only of the Woodford Shale, as laminated shale, with color variations from black to light gray. It is not possible to observe Hunton Group exposures or the unconformity surface that separates it from the Woodford.

The first step in this research was to create a detailed map of the area of study using a metric tape and a hand-held GPS receptor.

Then, photomosaics and scan lines to measure fracture orientations in quarry floor.



METHODOLOGY - BEHIND-OUTCROP CORING AND LOGGING



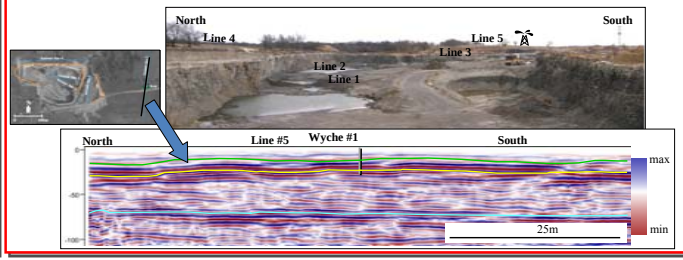
- Logs penetrated to a depth of 250ft (3'' res, FMI 0.5'' res)
- Core deepens from 10ft to 210ft. Missing the unconformity by 2ft.

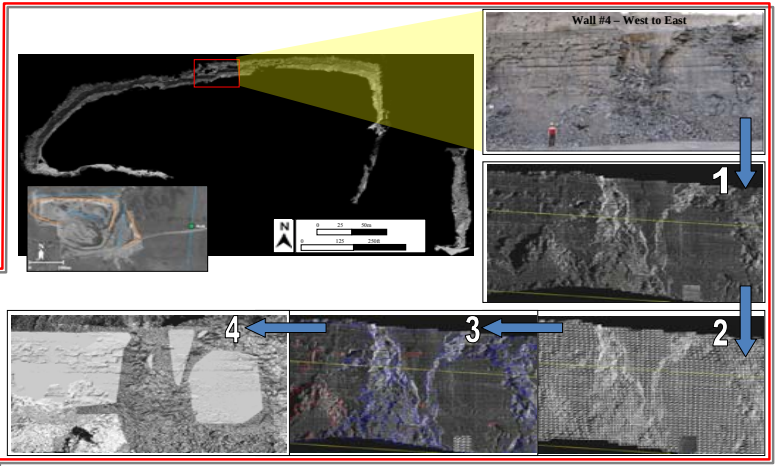
METHODOLOGY - LASER IMAGING DETECTION AND RANGING (LIDAR)

- Determines the distance to an object using laser pulses.
- Measuring the time it takes for a pulse to reach an object and return as a reflected signal.
- Scan large areas, recording many distance points in 3D (x,y,z)
- Rock characterizations in areas difficult to access by hand.
- Accuracy of 4mm and recording up to 2000 points per sec
- Capability to scan large areas in a short time.

METHODOLOGY – 2D SEISMIC LINES

Five 2D seismic lines were shot. The acquisition was conducted with a 48 channel seismograph, P-wave geophones, and an automatic sledge hammer striking an aluminum plate as the source.

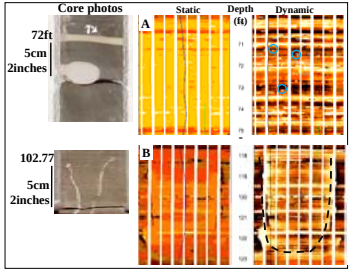


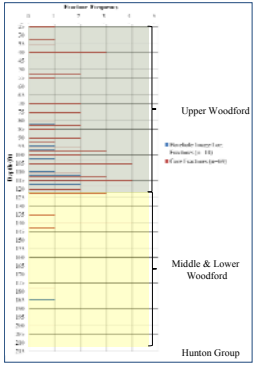


RESULTS

BEHIND-OUTCROP CORING AND LOGGING

- 14 fractures interpreted on the borehole image log. Mean strike orientation of 50°
- 69 fractures identified in core
- Most fractures are in the Upper Woodford Shale Member, higher quartz and lower clay content.

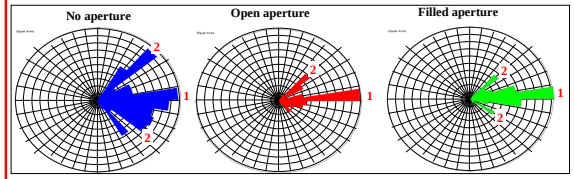




RESULTS

FRACTURE MEASUREMENTS ON QUARRY FLOOR

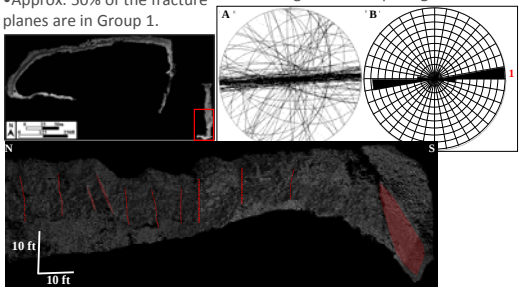
- Group 1: 75-105º (W-E)
- Group 2: 30-45º (NE-SW) 105-120º (NW-SE)
- Measure size of fracture apertures and filling material.
- Most of the fractures with filled aperture are in Group 1



LIDAR DATA

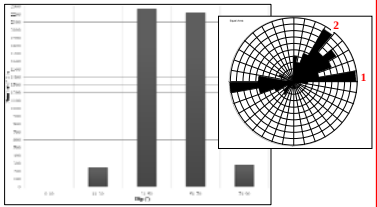
Fracture planes manually picked:

- 131 planes
- Approx. 50% of the fracture planes are in Group 1.
- 80% of planes have dip magnitudes between 76-90º
- Average fracture spacing of 4ft



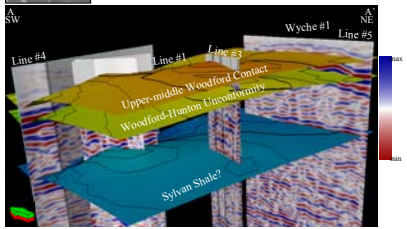
Fracture planes automatically interpreted:

- 5008 fracture planes.
- Only planes with high dips were considered (n=280).
- Most of the fracture planes are in Group 1, followed by Group 2.

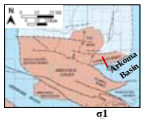


2D SEISMIC LINES

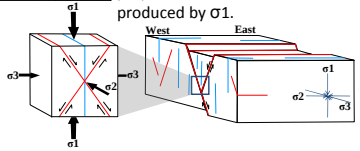
Surfaces have a NW dip with no apparent sign of predominant topography on the Hunton Group.



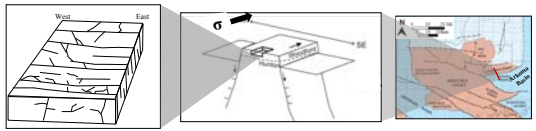
DISCUSSION



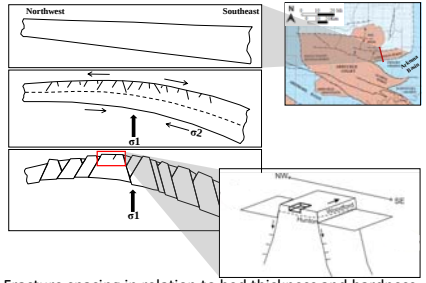
The Wyche Shale Pit is in the Lawrence Horst, contained between normal faults. There is a close relation between the orientation of fractures and the orientation of the stress field. The plane of an extensional fracture is perpendicular to σ3, created by failure produced by σ1.



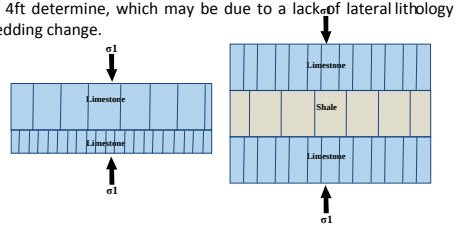
Outcrop, LIDAR, and well data showed two groups of fractures. Group 1 is a systematic fracture set due to the similar geometry, regular parallel orientations and regular spacing of the fractures. Group 2 is a nonsystematic fracture set, having irregular geometry. Nonsystematic fractures terminate when they intersect the primary set of fractures. Therefore, Group 2 is younger than Group 1.



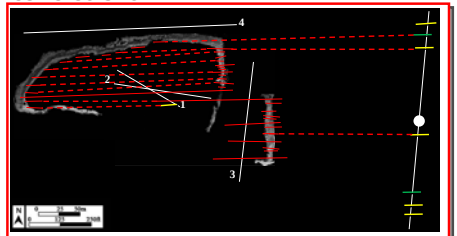
The normal faulting in the Lawrence Uplift-Franks Graben area was generated by tensional collapse created during the orogeny.
Vertical principal stress overcame in magnitude the other two horizontal principal stresses.
Geologic history places regional and local structural events to have occurred after the deposition of the Woodford Shale formation.



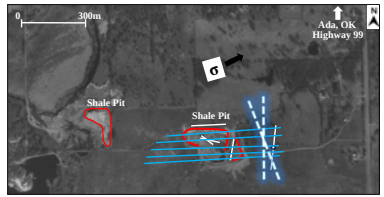
Fracture spacing in relation to bed thickness and hardness.
It was hard to see any bedding on the Upper Woodford Shale exposed on the outcrop walls.
Lithology seems to be the factor affecting fracture spacing.
The core contains more fractures in the Upper Woodford Shale due to the higher quartz content that makes it more rigid.
There was no core data for the Hunton to compare, but on seismic the interval below the Woodford-Hunton contact is more fractured that the interval above.
On the quarry walls, there visually seemed to be fracture swarms, but after the LIDAR data was characterized, an average fracture spacing of 4ft determine, which may be due to a lack of lateral lithology or bedding change.



CONCLUSIONS



- LIDAR, borehole image log and seismic are great tools to interpret fractures and fracture orientations on shale plays.
- The study area has a normal-faulting stress regime.
- Two fractures sets were interpreted with nearly vertical dip.
- The faults interpreted on seismic follow the same trend as regional faults and coincide with fracture orientations. On seismic, the interval below the Woodford-Hunton contact contains more fractures than the interval above.
- There are no lateral lithology or bedding changes; therefore fractures are regularly spaced 1.2m (4ft).



ACKNOWLEDGMENTS

ConocoPhillips / Devon Energy / Pit owners / Dr. Tim Wawrzyniec from UNM / Erik Kitt and the company 3D Geophysics / Dr. Bob Davis and Schlumberger / Nichole Bucker / Ashley Merritt / Stereonet v1.2.0 Cornell University / Split-FX v2.0 / Polyworks by Innovmetric Software / OU School of Geology and Geophysics / Dr. Roger Slatt / Dr. Kurt Marfurt / Dr. Jim Forgotson / Dr. John D. Pigott.