

Multiscale Natural Fracture Dimensions in the Woodford Shale*

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Search and Discovery Article #51405 (2017)**

Posted August 7, 2017

*Adapted from oral presentation given at AAPG Southwest Section Meeting, Midland, Texas, April 29 - May 2, 2017

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Abstract

Understanding the natural fracture dimensions in ultra-low permeability shales is important because these parameters are related to the reservoir fluid flow capacity. There is a dearth of literature on the Woodford Shale fracture (primarily joints) dimensions, which include fracture apertures, heights, and lengths. Measurements from five outcrops in South-Central Oklahoma and derived thin sections were used to find the best-fit distributions and relationships between fracture apertures, heights, and lengths from outcrop to microscale.

Macrofracture (opening displacements > .05 mm) and microfracture (opening displacements < .05 mm) kinematic apertures were measured along scanlines oriented sub-perpendicular to the fracture traces on outcrops and under microscopes using thin sections, respectively. For large macrofractures (height > 1 m), height traces were measured on cliff faces. The cumulative frequency of the apertures and heights were plotted (separately) to find their best-fit distributions. Aperture vs. length measured along scanlines for some fractures were also plotted. In addition, macrofracture and microfracture spacings were recorded along scanlines.

Measured microfracture apertures range 0.001-0.05 mm. They primarily exhibit exponential, followed by lognormal distributions. Crack-seal textures are not evident in thin sections. Small macrofractures, i.e., the bed-bounded ones and those that transect a couple of beds (usually 1-10 cm in height) have apertures in the range of .05-1 mm and exhibit characteristic (exponential and lognormal) aperture distributions. Fracture aperture (mm) vs. length (m) plots exhibit power law (exponent range: 0.53-0.59) relationships. Microfractures show higher clustering ($\sigma_{\text{spacing}} \div \mu_{\text{spacing}} > 1$) compared to the small macrofractures ($\sigma_{\text{spacing}} \div \mu_{\text{spacing}} < 1$).

On the other hand, large macrofractures (i.e., height > 1 m), mostly striking in the E-W and NE-SW directions exhibit a power law and an exponential aperture distributions respectively. The apertures range 0.27-3.3 mm for the E-W and 0.27-10 mm for the NE-SW fractures. Both sets exhibit lognormal height distributions with maximum observed heights of 5 m (E-W set) and 1.8 m (NE-SW set). E-W set measured lengths range ~ 5-28 m and NE-SW set calculated lengths range ~ 5-10 m. Fracture length (m) vs. height (m) plots exhibit both a power law (exponent ~ 0.85) and a linear relationship (slope ~ 5.1) with similar R^2 values (~ 0.75). Large macrofractures are likely more efficient fluid

carriers compared to the microfractures and smaller macrofractures due to their wider opening displacements and transection of a larger number of beds.

References Cited

Ataman, O., 2008, Natural Fracture Systems in the Woodford Shale, Arbuckle Mountains, Oklahoma: Master's Thesis, Oklahoma State University, Stillwater, OK.

Gillespie, P.A., J.D. Johnston, M.A. Loriga, K.J.W. McCaffrey, J.J. Walsh, and J. Watterson, 1999, Influence of layering on vein systematics in line samples: in McCaffrey, K.J.W., Longeran, L., and J.J. Wilkinson (eds.), Fractures, Fluid Flow and Mineralization, Geological Society of London Special Publication 155, p. 601-611.

Hooker, J.N., S.E. Laubach, and R. Marrett, 2013, Fracture aperture size — frequency, spatial distribution, and growth processes in strata-bounded and non-strata-bounded fractures, Cambrian Mesón Group, NW Argentina: Journal of Structural Geology, v. 54, p. 54-71.

Northcutt, R.A., and J.A., Campbell, 1995, Geologic Provinces of Oklahoma: Web Accessed July 23, 2017, http://www.ogs.ou.edu/geolmapping/Geologic_Provinces_OF5-95.pdf

Portas, M., 2009, Characterization and Origin of Fracture Patterns in the Woodford Shale in Southeastern Oklahoma for Application to Woodford Shale in Southeastern Oklahoma for Application to Exploration and Development: Master's thesis, University of Oklahoma, Norman, OK

Vermilye, J.M., and C.H. Scholz, 1995, Relation between vein length and aperture: Journal of Structural Geology, v. 17/3, p. 423–434.

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Sayantan Ghosh (University of Oklahoma)

May 2, 2017

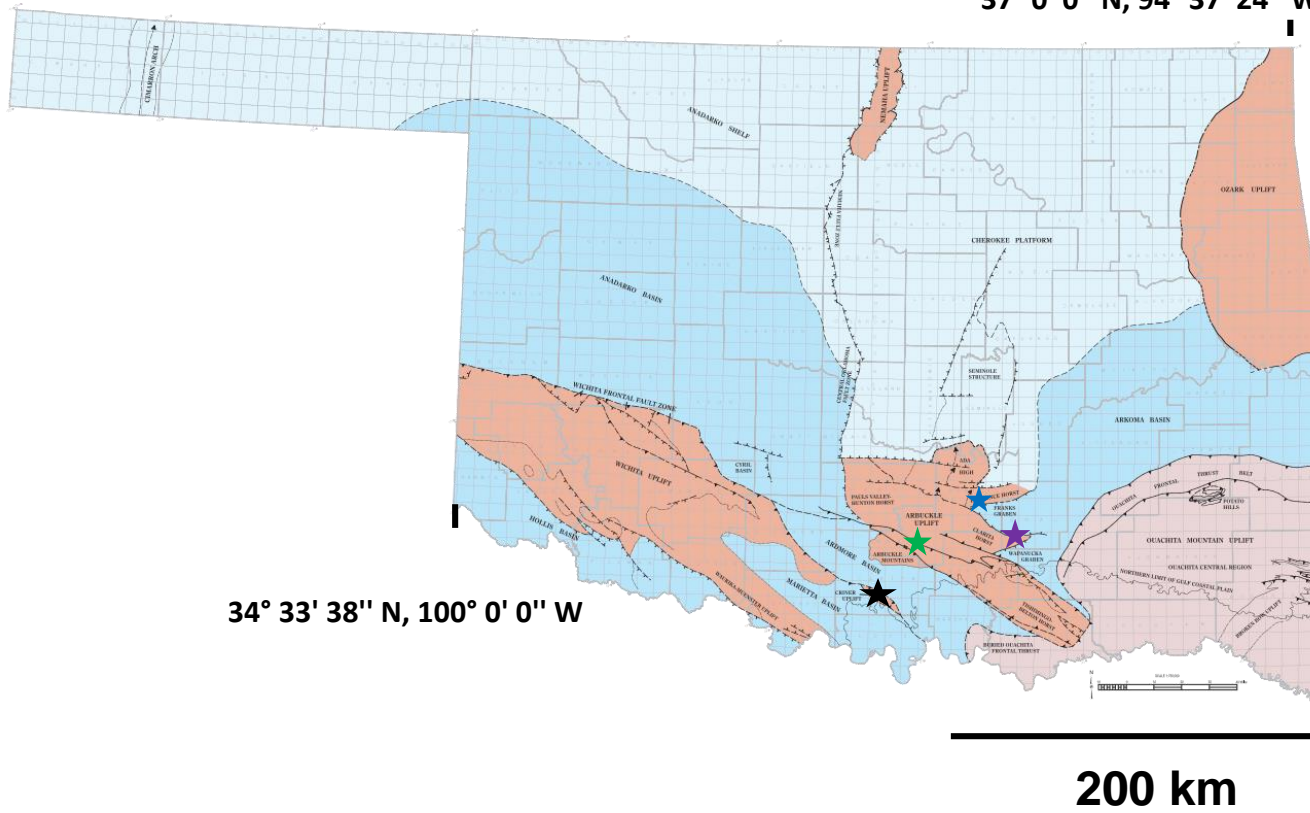
Locations (Southern Oklahoma)

37° 0' 0" N, 106° 0' 0" W

37° 0' 0" N, 94° 37' 24" W

34° 33' 38" N, 100° 0' 0" W

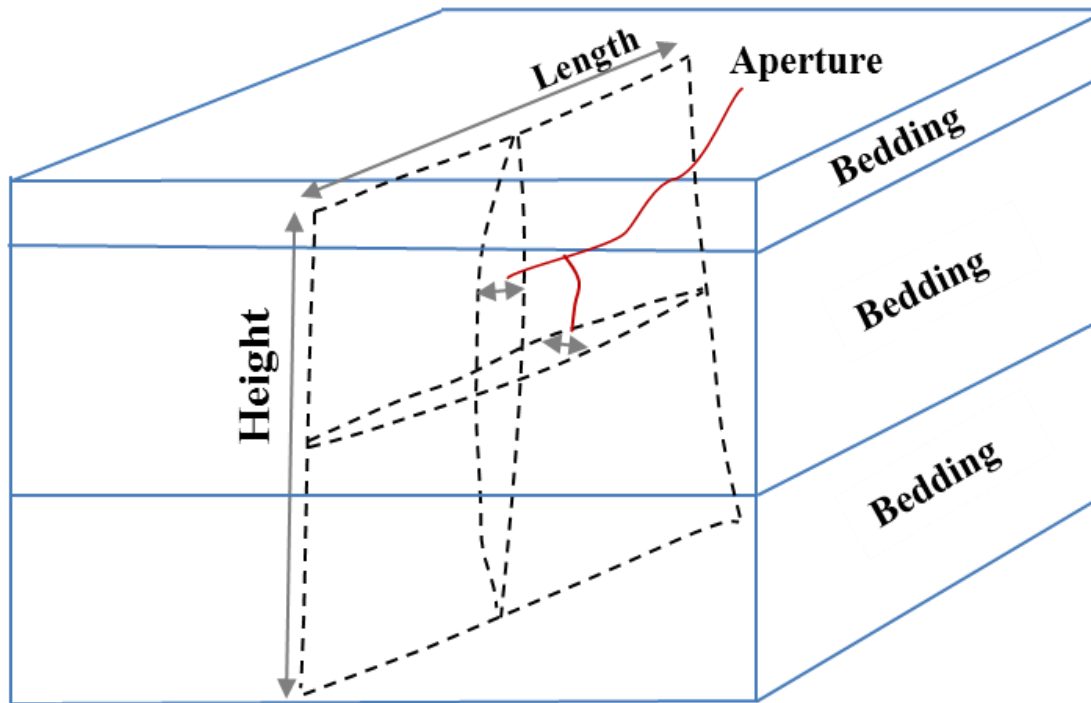
- ★ Wyche Shale Pit (Lawrence Uplift)
- ★ Clarita Shale Pit (Clarita Uplift)
- ★ US-77D and AWO (Arbuckle Mountains)
- ★ McAlister Cemetery Quarry (Criner Hills)



Modified from Northcutt and Campbell (1995)

Objectives

Determination of Woodford Shale natural fracture lengths, apertures, heights, spacing, and their relationships at multiple scales



Aperture= opening displacement

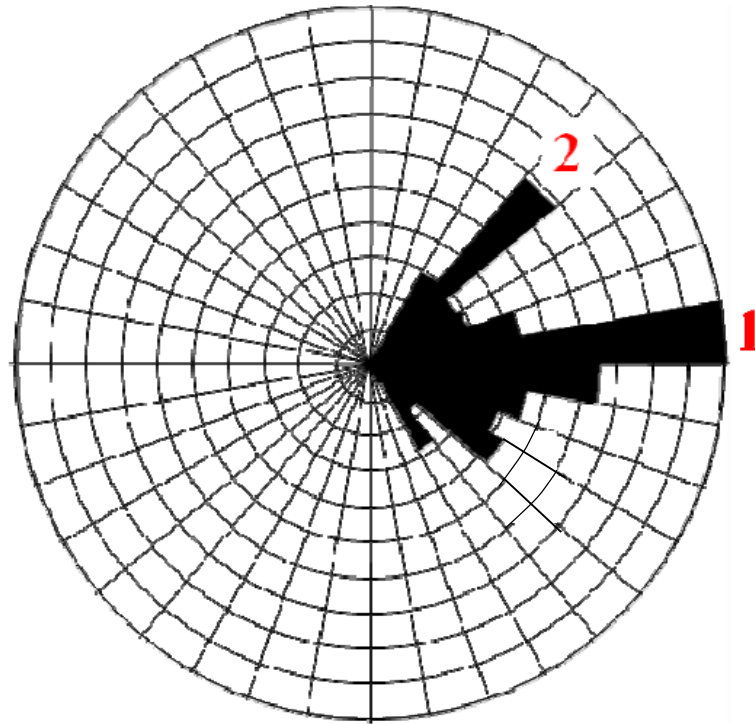
Fracture categories

1. **Microfractures** (Opening displacements: **0.001-.05** mm)
 - Cross a couple of laminations or stop within one thin lamination (**mm** scale height)

2. **Small macrofractures** (Opening displacements:**0.05-1** mm)
 - Transect a couple of beds (usually **1-10 cm** in height)

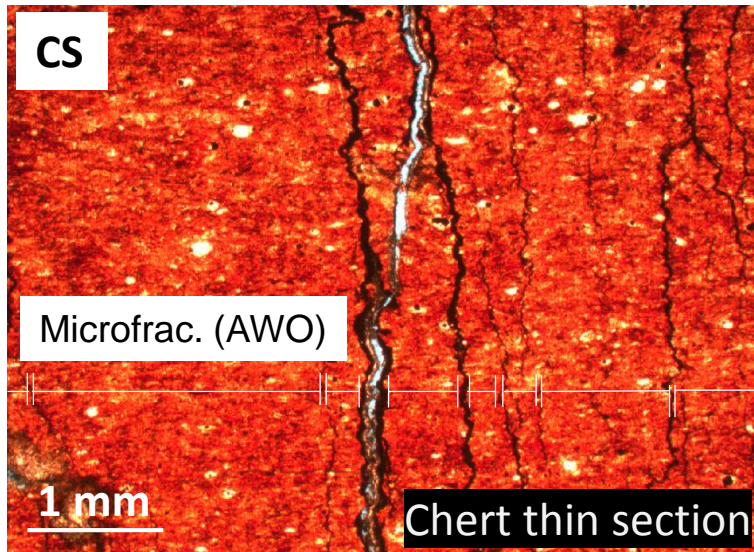
3. **Large macrofractures** (Opening displacements **>0.27** mm)
 - Height>1 m

Large macrofracture sets (Wyche)

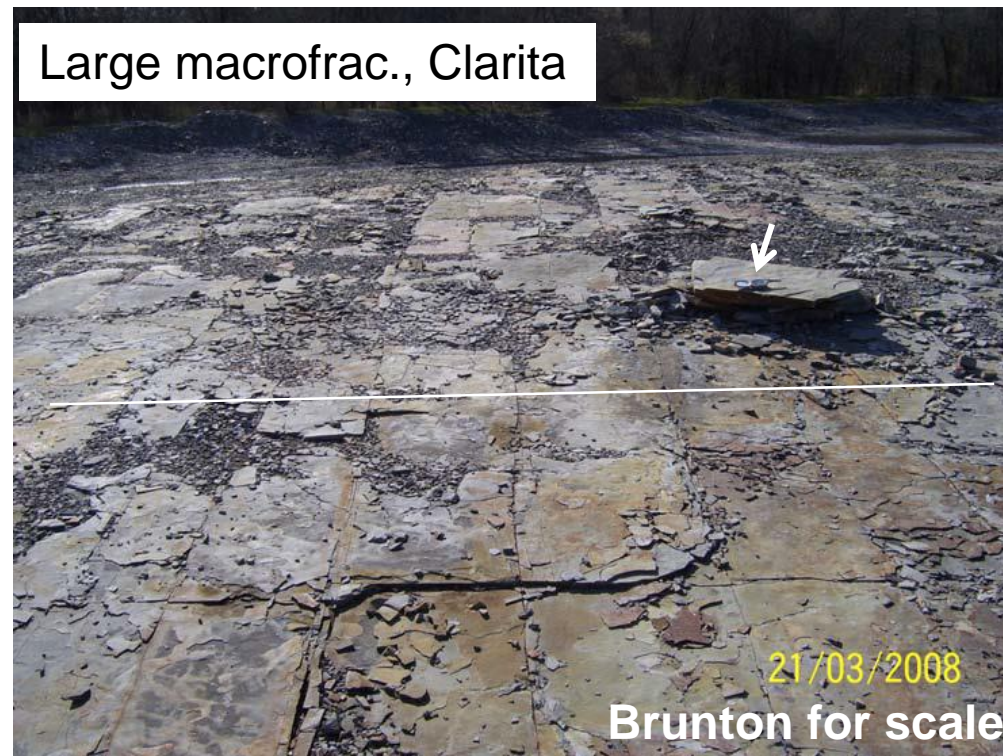


Modified from Portas (2009)

Aperture, intensity (P10), and spacing measurements



- CS= Bed cross section view
- Aperture, intensity, and spacing measured along scanlines (scanline example shown in each photograph)



Modified from Ataman (2008)

Height (Wyche)

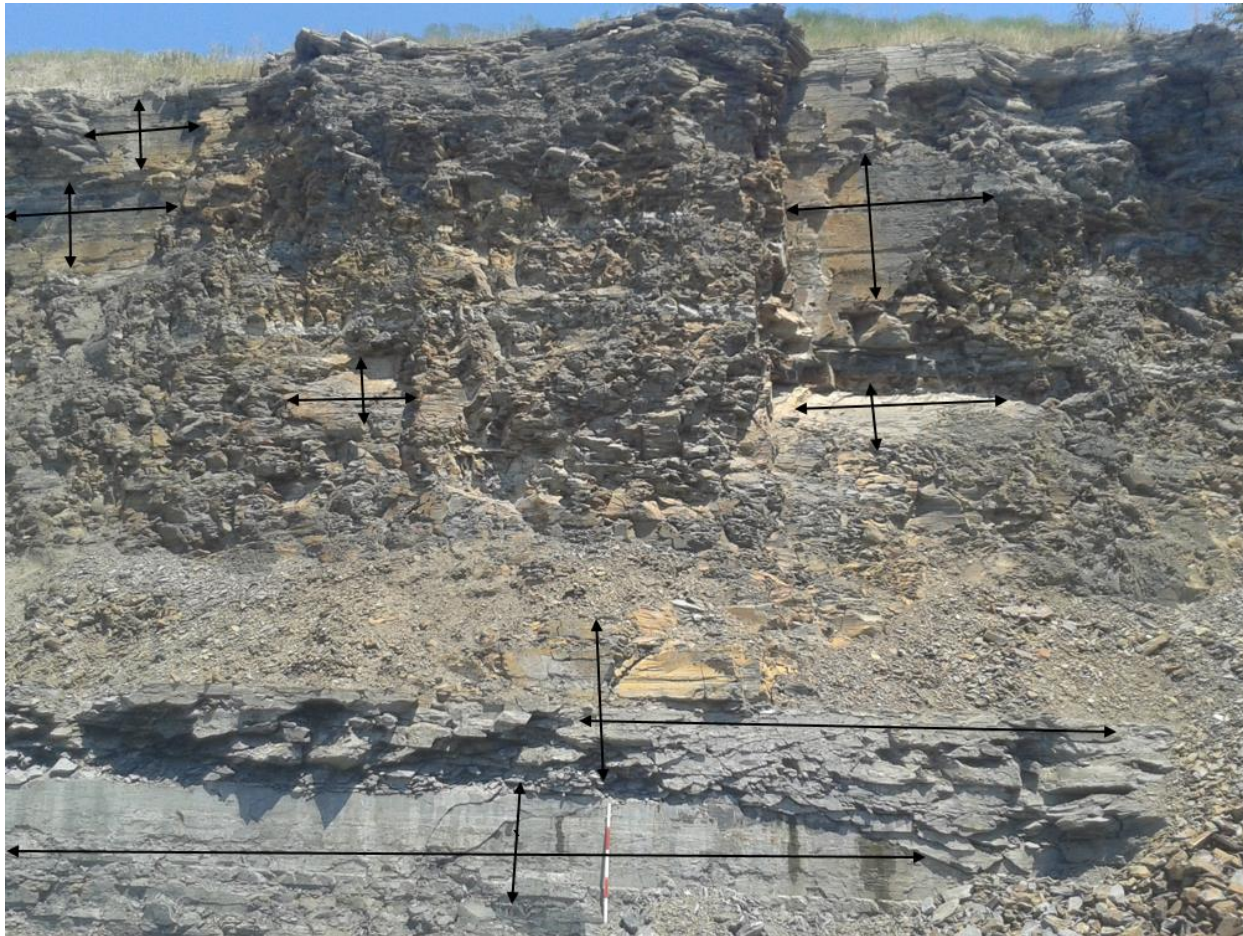
E-W frac traces



E-W frac traces



Length vs. height (Wyche)

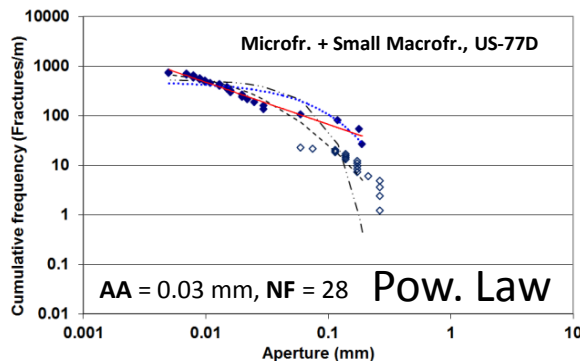
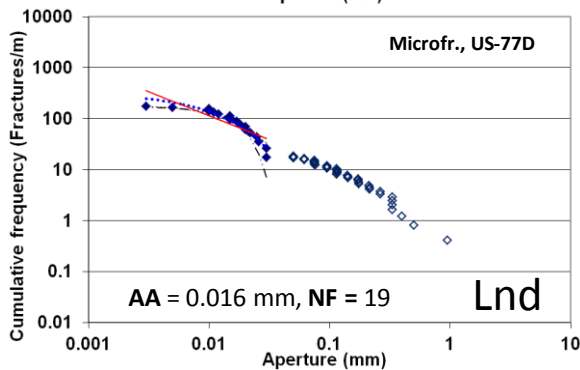
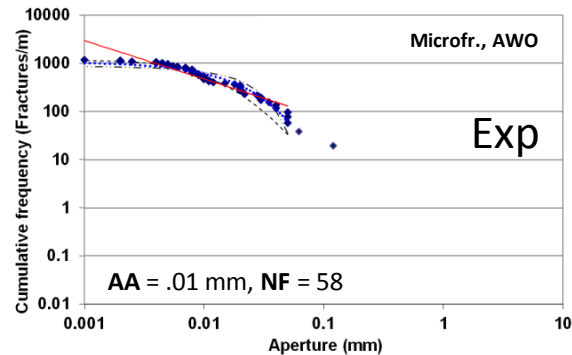


Main problem in determining length-height relationship is obscurity of the fracture face due to rock matrix or fracture truncation. Lengths need more corrections (compared to heights) by making observations from the quarry floor, where the fracture traces are less obscure.

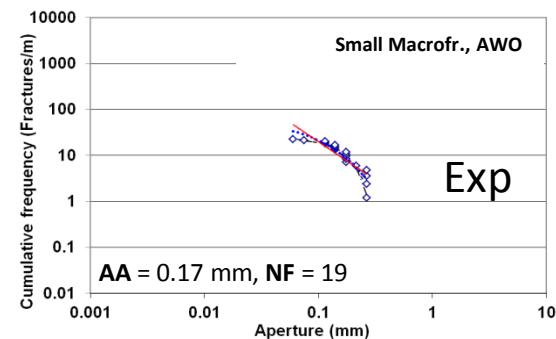
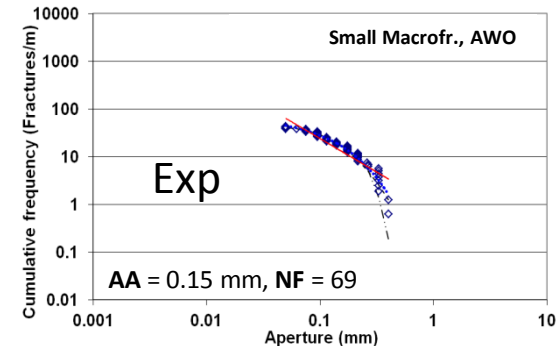
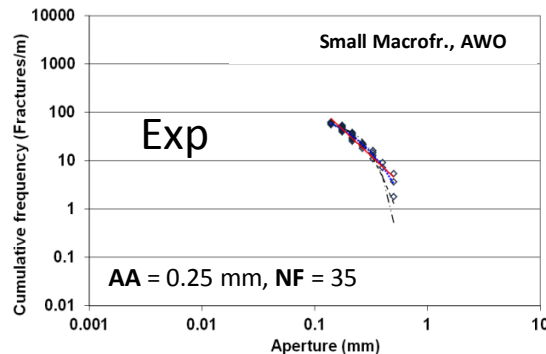
Results

Aperture distribution

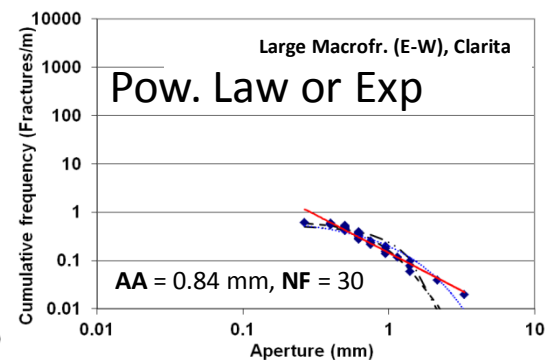
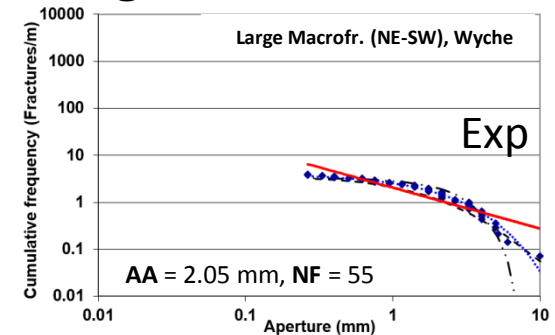
Microfractures



Small macrofractures



Large macrofractures



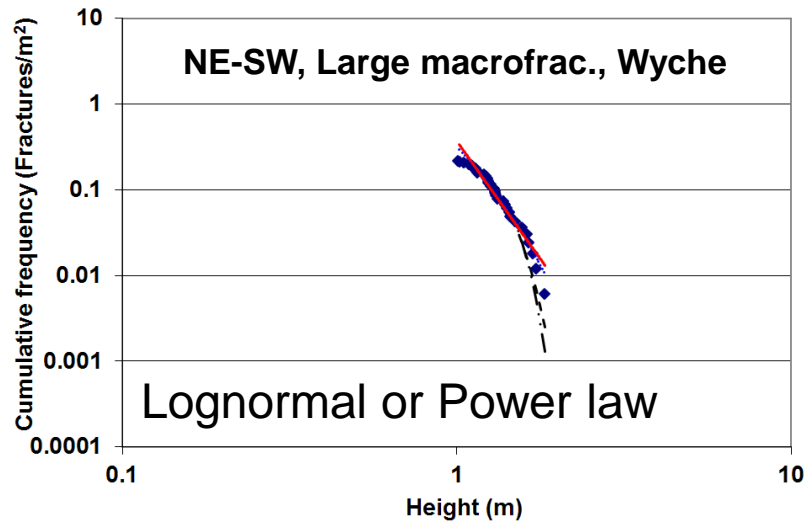
PL slope range: -0.33 to -2

- · — · — · — · — Normal distribution
- - - - - Lognormal distribution
- Power law distribution
- · · · · Exponential distribution

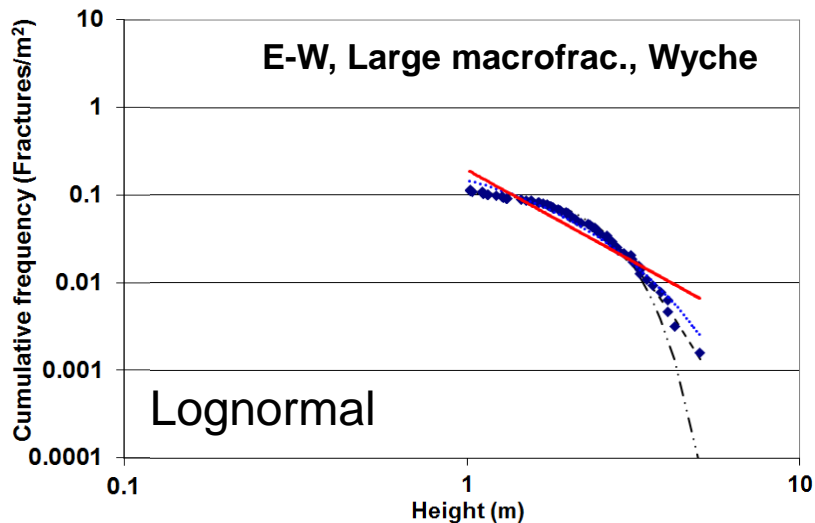
AA=Average aperture; NF=Number of fractures for calculation

Method by Hooker et al. (2013)

Height distribution



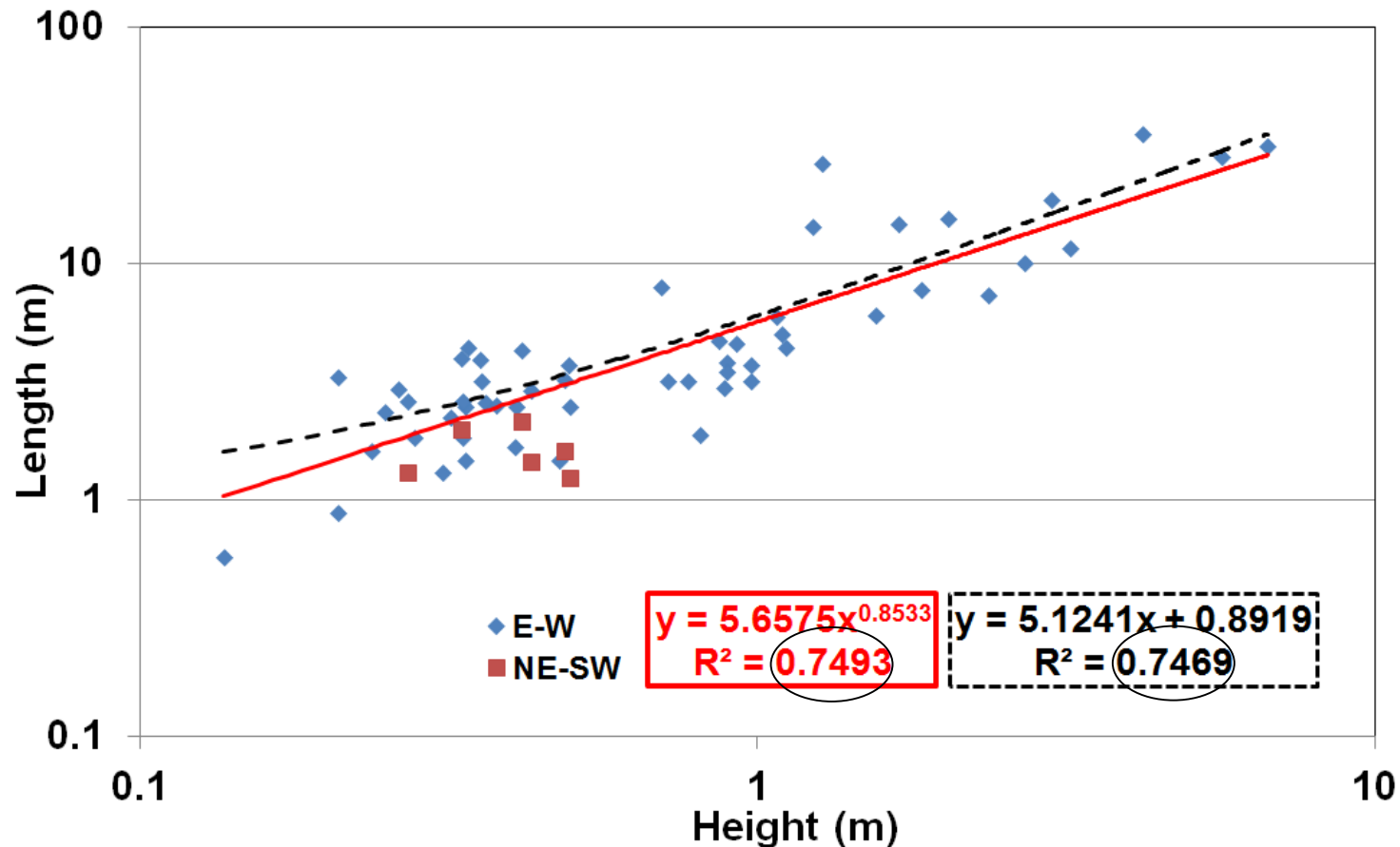
Height range: 1 to **1.8** m (Avg.: 1.3 m)



Height range: 1 to **5** m (Avg.: 2.2 m)

Note: These distributions are influenced by height of the fracture trace visible.

Length-height relationship (Wyche)



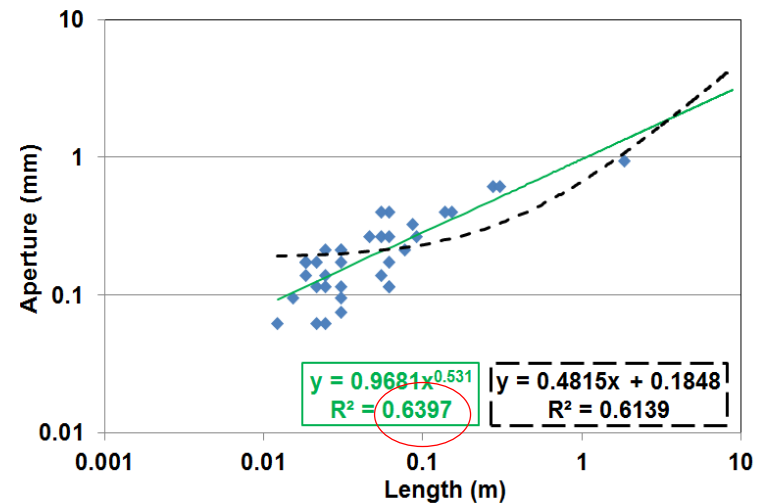
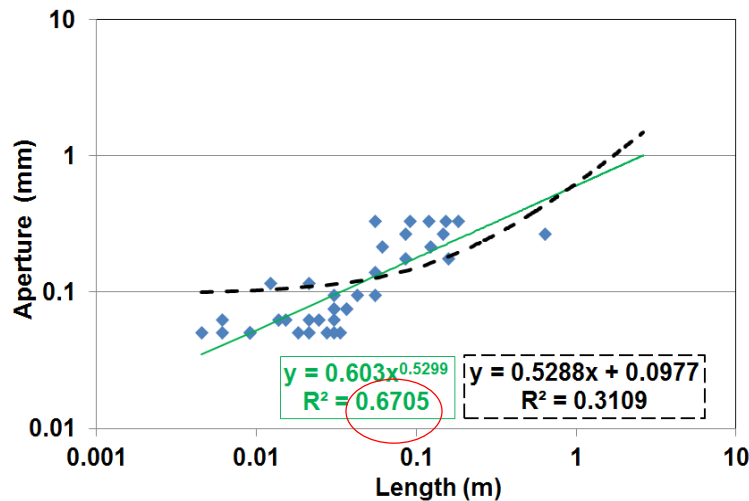
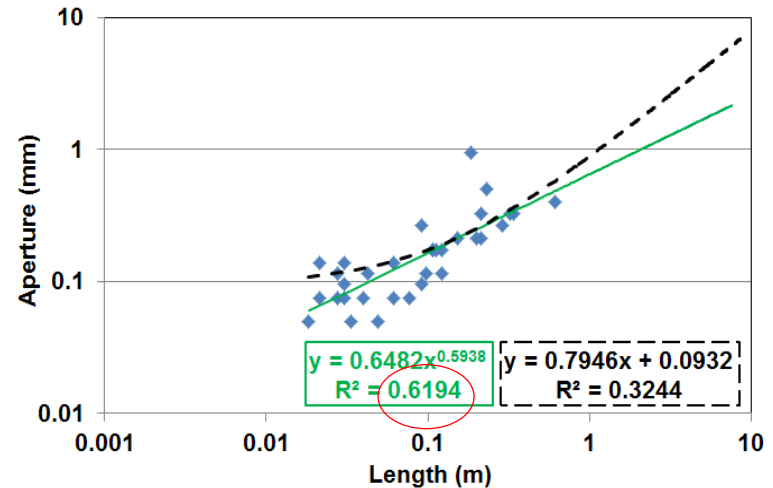
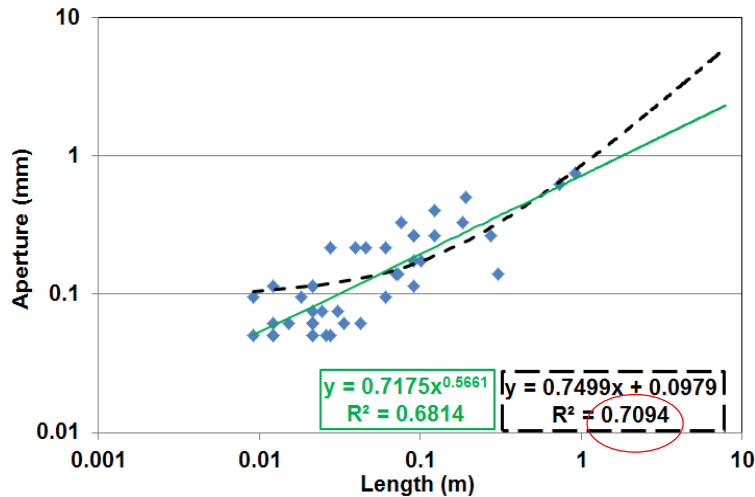
Max E-W fracture length ~**28** m (90 ft)

Max NE-SW fracture length ~**10** m (33 ft)

Both linear and power-law produce good fits.

Note: Equations after adjusting for truncation of fracture lengths.

Aperture-length relationship (US-77D)



Power law (green line) with a slope of 0.53-0.59 gives better fits (compared to a linear fit) in three out of four measurements. These graphs can serve as a guideline for estimating one variable if the other is known. Vermilye and Scholz (1995) obtained similar slope values from non-shale lithologies in their study areas.

Clustering tendencies

Large Macrofractures (measured at Clarita)

Chert beds ($C_v = \sigma_{\text{spacing}} / \mu_{\text{spacing}} = 0.53, 0.74$)

C_v method by Gillespie et al. (1999)



Small macrofractures and microfractures

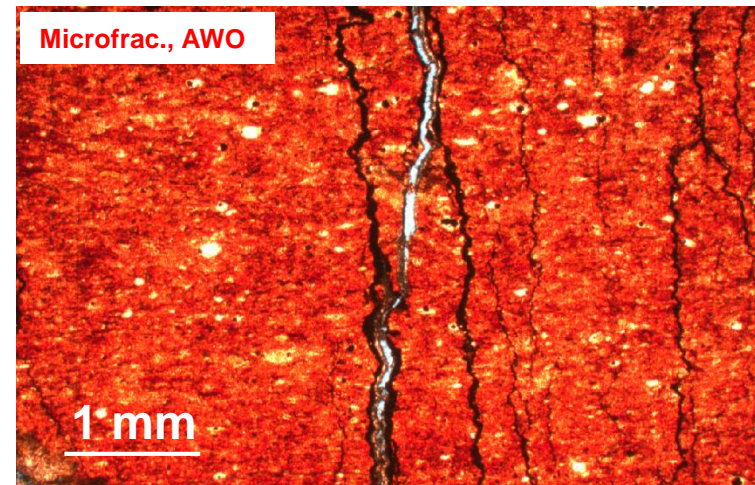
Chert beds (measured at AWO)

$C_v = 0.49$ (1.48), 0.85 (1.1), 0.41 , 0.44 (1.6),
 0.79 , 0.47 (0.85), 0.58 (1.3), 0.63 , 0.51 , 0.73



Non-chert beds (measured at McAlister)

$C_v = 0.83$ (1.2), 0.43 (.64), 0.58 ,
 0.82 (.68), 0.52 , 0.77 , 0.63 (.78),
 0.48 , 0.62 , 0.6



Microfractures generally show more clustering (higher C_v) compared to macrofractures.

Conclusions

In the studied areas:

- Characteristic kinematic aperture-size distributions were observed.
- Mostly lognormal height distributions were observed.
- Power law or linear length-height relations were observed.
- Power law aperture-length relations were observed.
- E-W natural fractures are substantially longer compared to the NE-SW fractures.
- E-W natural fractures have twice the average height of NE-SW fractures in height > 1 m range.
- E-W natural fractures are substantially narrower compared to the NE-SW fractures.
- Microfractures are more clustered compared to macrofractures.

References

- Ataman, O. 2008. Natural Fracture Systems in the Woodford Shale, Arbuckle Mountains, Oklahoma. Master's Thesis, Oklahoma State University, Stillwater, OK.
- Gillespie, P.A., J.D. Johnston, M.A. Loriga, K.J.W. McCaffrey, J.J. Walsh, and J. Watterson, 1999. Influence of layering on vein systematics in line samples, in Mc-Caffrey, K.J.W., Longeran, L., and J.J., Wilkinson, eds. Fractures, Fluid Flow and Mineralization: Geological Society [London] Special Publication 155, p. 35–56.
- Hooker, J.N., S.E. Laubach, and R. Marrett, 2013. Fracture-aperture size—Frequency, spatial distribution, and growth processes in strata-bounded and nonstrata-bounded fractures, Cambrian Mesón Group, NW Argentina.
- Northcutt, R.A., and J.A., Campbell, 1995.
http://www.ogs.ou.edu/geolmapping/Geologic_Provinces_OF5-95.pdf
- Portas, R.M., 2009. Characterization and Origin of Fracture Patterns in the Woodford Shale in Southeastern Oklahoma for Application to Woodford Shale in Southeastern Oklahoma for Application to Exploration and Development. Master's thesis, University of Oklahoma, Norman OK.
- Vermilye, J.M., and C.H. Scholz, 1995. Relation between vein length and aperture, J. Struct. Geol., 970 17(3), 423– 434.