[PS]Rock and Fracture Characterization of the Woodford Shale along the I-35 Outcrop*

Henry Galvis-Portilla[1], Daniela Becerra-Rondon[1], David Duarte[1], and Roger Slatt[1]

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Abstract

Lately, the Upper Devonian-Lower Mississippian Woodford Shale is the most attractive unconventional resource play in Oklahoma. Particularly, in the southern flank of the Arbuckle uplift, the Woodford Shale crops out along a SE-NW belt that extends from Johnston County, through the type section in Carter and Murray counties. It thickens southward into the Ardmore Basin, where hundreds of wells have proved the oil/gas potential of this unit.

A road-cut exposure along the west side of Interstate-35 provides an excellent opportunity to examine in detail the lithological heterogeneities and the naturally fractured systems present in the uppermost 80 feet of the Woodford Shale. On this location, lithologies consist mostly of dark-colored, organic-rich and fine-grained rocks, stacked vertically in thin cycles (2-10 cm) of highly indurated cherty beds and fissile shales, along with few scattered dolomitic and silty beds. Very well-developed phosphate nodules and nodular beds are abundant throughout this section.

Detailed fracture analysis was conducted on every single bed (700 beds), recording its number of fractures (perfect bed-bounded), bed thickness, joint spacing, fracture filling material, and weathering response (hard or soft). Two well-defined and conjugate fracture sets were recognized. Fractures patterns are better developed in hard beds, they are abundant and perpendicular to the bedding, and scarce and irregular in soft beds. Many fractures die-out within the soft beds; however, few fractures go through both hard and soft beds. In addition, there is a direct correlation between fracture spacing and bedding thickness at least in the hard beds, thicker beds showed lesser number of fractures.

Comparisons between outcrop-based radioactivity profiles and subsurface Gamma Ray logs reveal many similarities, reflecting a relatively good lateral and vertical continuity, meaning low rock variability between outcrops and subsurface.

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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 GR, NW Argentina: Journal of Structural Geology, v. 54, p. 54–71.

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ABSTRACT

Lately, the Upper Devonian-Lower Mississippian Woodford Shale is the most attractive unconventional resource play in Oklahoma. Particularly, in the southern flank of the Arbuckle uplift, the Woodford Shale crops out along a SE-NW belt that extends from Johnston County, through the type section in Carter and Murray counties. It thickens southward into the Ardmore Basin, where hundreds of wells have proved the oil/gas potential of this unit.

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Detailed fracture analysis was conducted on every single bed (600 beds), recording its number of fractures (perfect bed-bounded), bed thickness, joint spacing, fracture filling material, and weathering response ('hard' or 'soft'). Two well defined and conjugate fracture sets were recognized. Fractures patterns are better developed in 'hard' beds, they are abundant and perpendicular to the bedding, and scarce and irregular in 'soft' beds. Many fractures die-out within the 'soft' beds, however few fractures go through both 'hard' and 'soft' beds. Also, there is a direct correlation between fracture spacing and bedding thickness at least in the 'hard' beds, thicker beds showed lesser number of fractures.

Comparisons between outcrop-based radioactivity profiles and subsurface Gamma Ray logs reveal many similarities, reflecting a relatively good lateral and vertical continuity, meaning low rock variability between outcrops and subsurface.

GEOLOGICAL SETTING

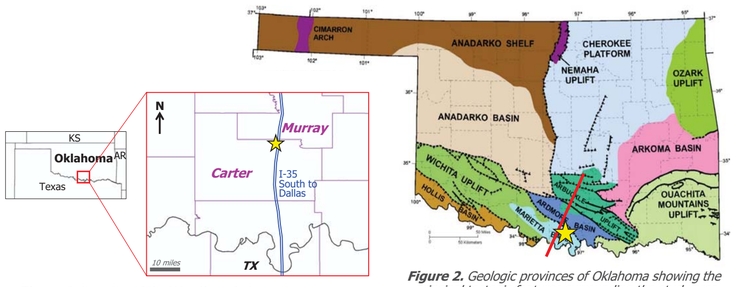


Figure 1. *Location of the Woodford shale road-cut outcrop in South Oklahoma (highlighted by the yellow star).*

Figure 2. *Geologic provinces of Oklahoma showing the principal tectonic features surrounding the study area. Cardott, 2012. Cross section is shown in Figure 3.*

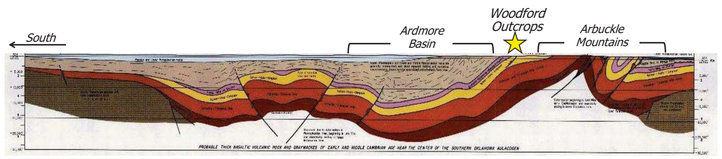


Figure 3. *Geologic cross section from the Arbuckle Mountains, through the Ardmore Basin showing the relative location of the Woodford outcrops in southern Oklahoma. GSA, 1982*

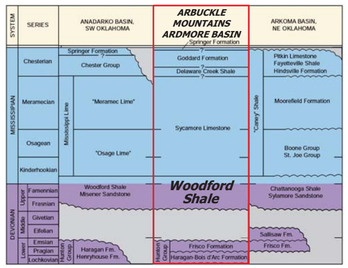


Figure 4. *Generalized chronostratigraphy of Late Devonian-Early Mississippian strata of the Arbuckle Mountains and Anadarko Basin. Comer, 2008*

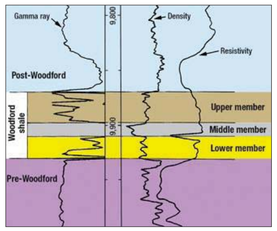
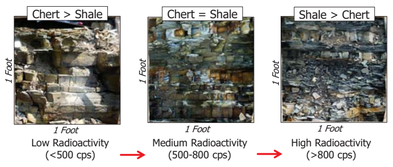


Figure 5. *Informal stratigraphic sudivison of the Woodford Shale in Oklahoma. Typically exhibiting high radioactivity on the gamma-ray log. After Hester et al., 1990.*

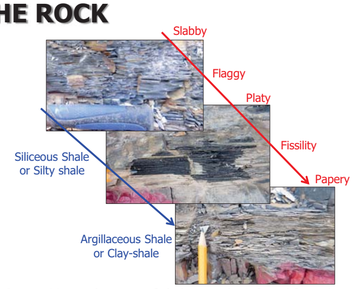
I-35 ROADCUT OUTCROP

Exposure of the Woodford shale along the interstate-35. Illustrating the thin-bedded character and the radioactivity variations from base towards the top. Beds are dipping 240/45°SW. Measured stratigraphic thickness is 80 feet.

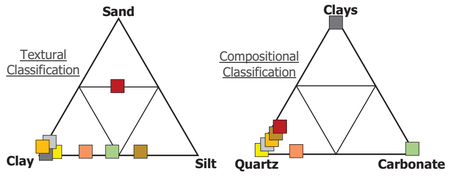
DESCRIBING THE ROCK



Chert/shale ratio per foot are depicting the radioactivity readings.



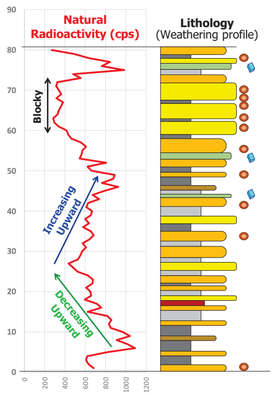
Composition and texture of shales may be inferred from the parting and stratification response (Potter, 1980)



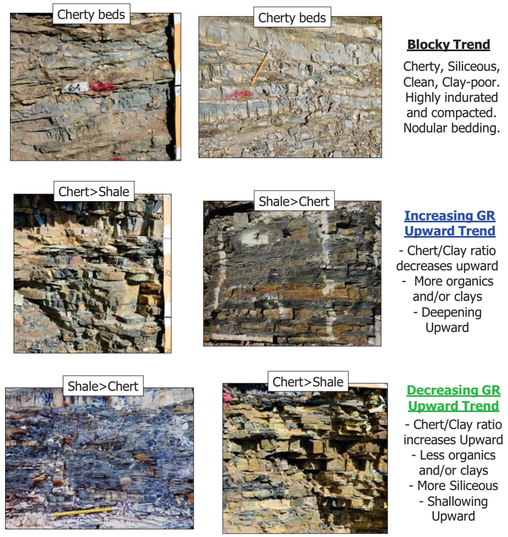
- Argillaceous Shale
- Siliceous Mudstone
- Siliceous Shale
- Chert
- Silty Mudstone
- Phosphatic Mudstone
- Sandy Mudstone
- Dolomitic Mudstone

8 Lithofacies recognized at hand-specimen scale

STRATIGRAPHY



- Argillaceous Shale
- Siliceous Shale
- Silty Mudstone
- Sandy Mudstone
- Siliceous Mudstone
- Chert
- Phosphatic Mudstone
- Dolomitic Mudstone
- Phosphate Nodules
- Dolomite



Blocky Trend

Cherty, Siliceous, Clean, Clay-poor. Highly indurated and compacted. Nodular bedding.

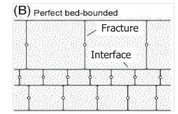
Increasing GR Upward Trend

- Chert/Clay ratio decreases upward
- More organics and/or clays
- Deepening Upward

Decreasing GR Upward Trend

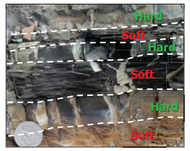
- Chert/Clay ratio increases Upward
- Less organics and/or clays
- More Siliceous
- Shallowing Upward

FRACTURE ANALYSIS: METHODS



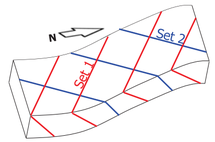
Perfect bed-bounded: all fractures in a specific bed that span vertically from upper to lower bed interfaces. Hooker, 2013.

Layered units provide competence contrasts ('Hard' - 'Soft') that determine the natural fracture development

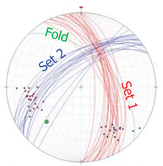


- Counting fractures every single bed contained in an area of 1x3 feet.
- Were recorded the following data per bed (About 600 beds):
  - * Is it 'Hard' or 'Soft' (fissil)?
  - * Bed thickness
  - * Number of fractures
  - * Fracture-Filling Material (veins)
  - * Fractures orientation (when clear)
  - * Fracture Spacing

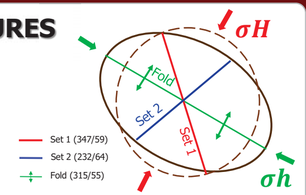
FOLD-RELATED FRACTURES



Fractures are organized in two conjugate sets. the angle between the two families is 60°.

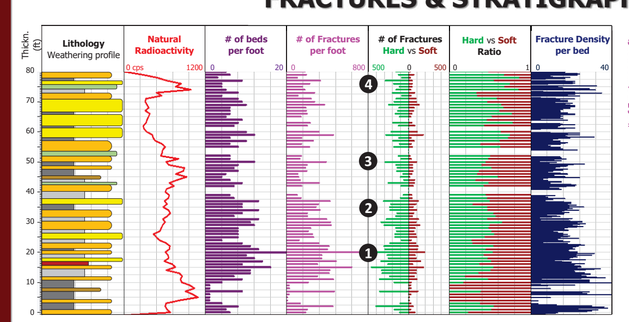


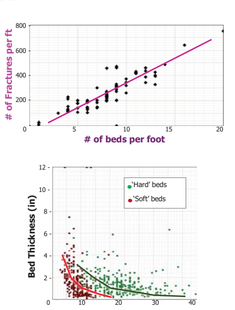
Stereographic projections reveals the two well defined families of fractures, which are conjugated and between them and oblique to the fold.

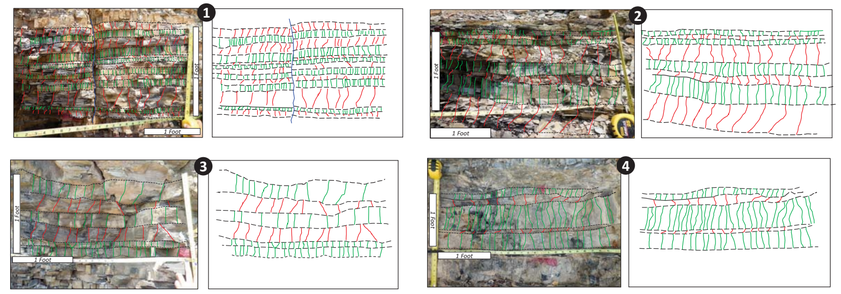


Fractures and fold orientations are in accordance with the regional paleo-stress (σH=N45°E) then suggesting syn-folding fractures

FRACTURES & STRATIGRAPHY







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