[PS]Fracture and Stratigraphic Analysis of the Niobrara-Equivalent Cody Shale, Bighorn Basin, Wyoming*

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Search and Discovery Article #51625 (2019)**
Posted December 16, 2019

*Adapted from poster presentation given at 2019 AAPG Rocky Mountain Section Meeting, Cheyenne, Wyoming, September 15-18, 2019
 DOI:10.1306/51625Moots2019

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Abstract

Unconventional shale reservoirs have become a major focus of petroleum exploration and production in North America over the past 15 years. USGS assessments of unconventional targets include the Cody Shale of the Bighorn Basin, Wyoming. To further appraise the unconventional play potential of this unit, this study will characterize the lithology, fracture patterns, and stratigraphic patterns in the Cody. Deposited during the Late Cretaceous in anoxic conditions while this area was inundated by the Western Interior Seaway and composed of thousands of feet of grey to black shale and interbedded sandstone towards the top, this formation has potential to become highly productive in the near future. When drilling horizontal wells, the fractures within the formation must be understood to make the most out of each fracture job. To achieve this, over 350 feet of core will be examined from a range of depths as well as outcrop studies from multiple sites around the basin. Outcrop studies will occur in the summer and fall of 2019. When looking at core and outcrop, fracture characteristics and distribution in the Cody Shale will be analyzed to define dominant fracture orientations, size, and patterns. Lithologic characteristics and clay content in the interbedded sandstone of this formation will also be examined for effects on fracture patterns. The results from this research will aid in assessing the probability of unconventional petroleum resources of this untapped unit in the Bighorn Basin, WY.

Fracture and Stratigraphic Analysis of the Niobrara-Equivalent Cody Shale Bighorn Basin, Wyoming

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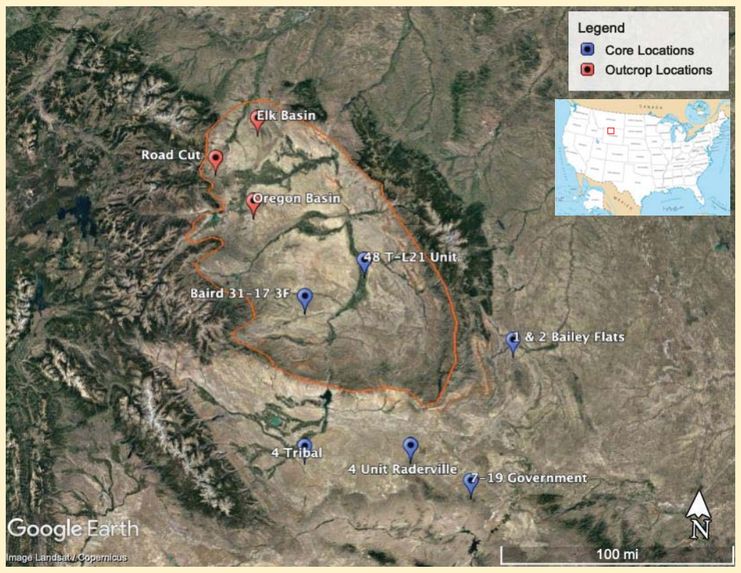
Abstract

Unconventional shale reservoirs have become a major focus of petroleum exploration and production in North America in recent history. USGS assessments of unconventional targets include the Cody Shale of the Bighorn Basin, Wyoming. To further appraise the unconventional play potential of this unit, this study will characterize the lithology, fracture patterns, and stratigraphic patterns in the Cody.

Deposited during the Late Cretaceous in anoxic conditions while this area was inundated by the Western Interior Seaway, and composed of thousands of feet of grey to black shale and interbedded sandstone towards the top, this formation has the potential to become highly productive in the near future. When drilling horizontal wells, natural fractures associated with this basin's compressional stress field must be understood in order to make the most out of each induced fracture job. In order to achieve this, over 153 feet of core was examined from a range of depths as well as outcrop studies from multiple sites around the basin. Further outcrop studies will occur in the fall of 2019.

When looking at core and outcrop, fracture characteristics and distribution in the Cody Shale will be analyzed in order to define dominant fracture orientations, size, and patterns. Lithologic characteristics and clay content in the interbedded sandstone of this formation will also be examined for effects on fracture patterns. The results from this research will aid in assessing the probability of unconventional petroleum resources of this untapped unit in the Bighorn Basin, Wyoming.

Study Locations



Core from 48 T-L21 Unit: 6480-6498

Black shale is present throughout this core, horizontal fractures were far too many to count reliably. Majority of fractures are horizontal with a vertical spacing of approximately 1.5 fractures per foot, but it is likely they are from coring process and there is no clear pattern to them. Roughly 50% of fractures pass all the way though the core, the other half are greater than 50% of the way through.

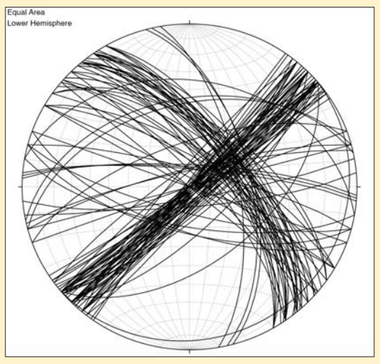
Core from 1 & 2 Bailey Flats: 10-106, 183-193

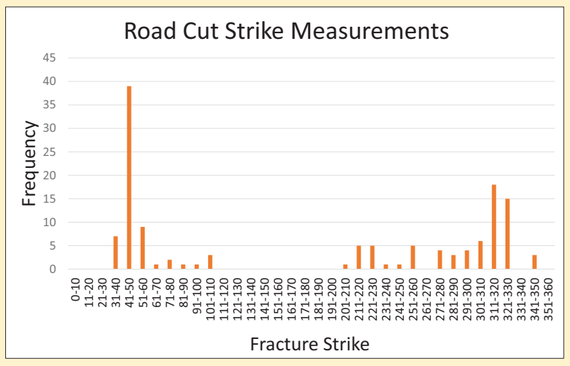
All fractures present are horizontal to sub-horizontal within the Cody shale. This section consists of grey shale with various sandy inclusions with the largest being 1 cm in thickness. Horizontal fractures in this section averages 19 per foot with at least 90% of them fracturing through the core, and there is indication of preferential fracture along interbedded sandstone-shale interfaces.

Core from 4 Unit Raderville: 2178-2193

Grey shale with horizontal fractures likely caused by coring that are too numerous to count, but vertical fractures occur at roughly 1.3 fractures per foot with no common direction or pattern. Interbedded sandstone can be found up to two inches thick at 2185, oil staining of this interbedded sandstone and shale begins at 2183 and continues through 2190.

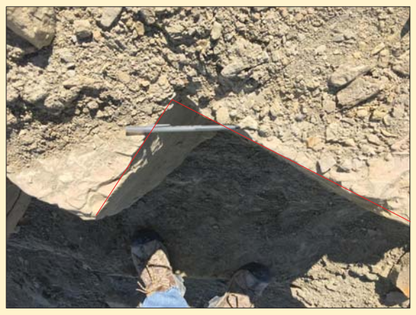
Road Cut at the Junction of Wyoming Highways 120 and 296





Two dominant strike directions are clear, 41-50 and 311-330

Jacob's staff is 1.5 meters tall with decimeter increments



Typical fracture pattern from outcrops at the road cut location, right fracture strike is 45 and left fracture strike is 325

Core from Baird 31-17 3F: 4739-4768, 5004-5016

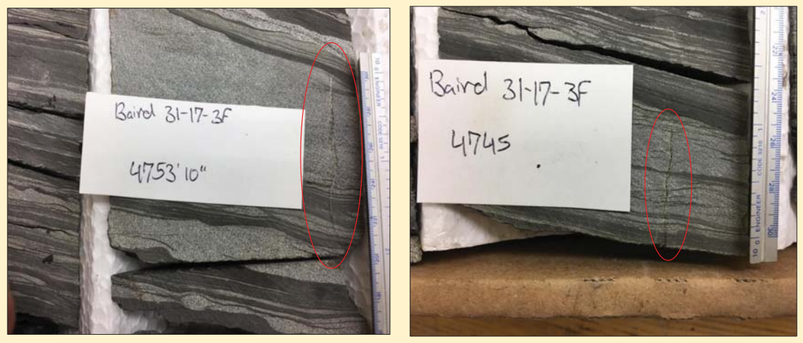
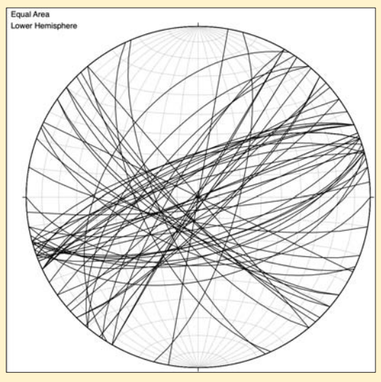
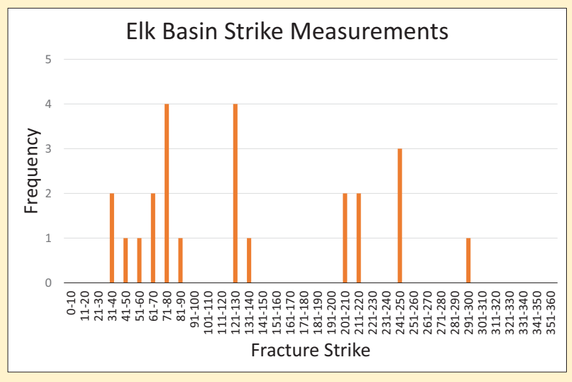


Image on the left shows core with a vertical fracture at 4752'10" in a section of interbedded sandstone, with secondary mineralization

Elk Basin Outcrops





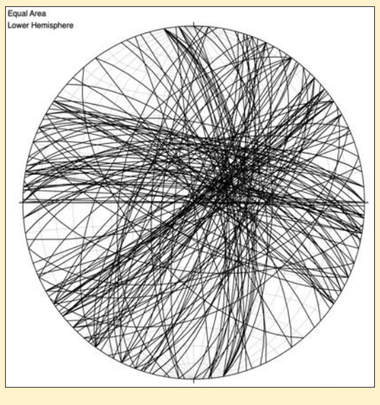
Dominant strike directions much less defined, 71-80 and 121-130

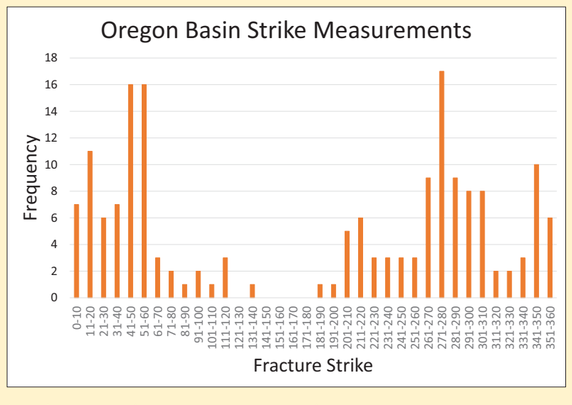
Fracture with a strike of 75 at an Elk Basin outcrop

Core from 4 Tribal: 4850-4864

This core consists of sandstone very similar to that found from 1191-1193 in Bailey Flats #2. Fractures present are parallel to sub parallel, but sections of core were missing so a fracture spacing could not be recorded. There were only two fractures present, and they did not pass all the way through the core

Oregon Basin Outcrops



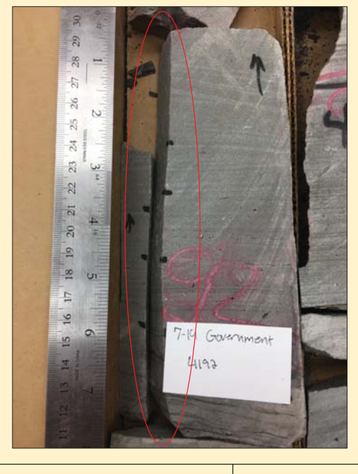


Least defined strike direction of the three study areas, 41-60 and 271-280

Jacob's staff is 5 feet tall with six inch increments

Fracture at an Oregon Basin outcrop with a strike of 50

Core from 7-19 Government: 4142-4197



The average horizontal fracture spacing in this core is three per vertical foot with a vertical fracture spacing that varies depending on the core lithology. Fracture frequency was found to be higher in intervals containing less quartz content. The image to the left shows a vertical fracture that is almost 8" long

Conclusions to Date

Based off the 368 strike measurements at three different locations and 153 feet of core analysis, the data suggests there is a dominant strike orientation in the range of 41-50 degrees. There is also suggestion of a secondary, less defined, strike direction in the range of 250-300 degrees. This points to the dominant stress direction to be out of the South to Southwest. Based off the paper by R.R. Gries (1990), this is within the constraints of the Laramide Orogeny as NW-SE trending structures are dominant in Northern Wyoming, and are associated with Paleocene compression from the Southwest. Following this conference, further outcrop studies will be conducted along the Southern and Eastern margins of the Bighorn Basin to further refine these conclusions. These locations will be distant from localized structures such as the anticlines that the Elk and Oregon Basin fields sit on in order to avoid fractures that do not represent the regional picture of the Bighorn Basin.

Sources

Gries, R.R. 1990. Rocky Mountain Foreland structures: Changes in Compression Direction Through Time. Petroleum and Tectonics in Mobile Belts. Editions and Technip, 129-146.

Map of United States: https://nationalmap.gov/small_scale/printable/reference.html#list

Aerial image made using Google Earth