Preliminary Facies Analysis, Regional Sequence Stratigraphy and Distribution of Stratigraphically Controlled Mechanical Units of the Middle and Upper Williams Fork Formation, Piceance Basin, Colorado

Michele Wiechman1 and Jennifer L. Aschoff1

Search and Discovery Article #50619 (2012)**
Posted June 25, 2012

*Adapted from poster presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012
**AAPG©2012 Serial rights given by author. For all other rights contact author directly.

1Department of Geology and Geological Engineering, Colorado School of Mines, Golden, CO (mwiechma@mymail.mines.edu)

Abstract

The Piceance Basin, northwest Colorado, is home to one of the most important basin-centered tight-gas accumulations in North American. A wide range of geologic controls is responsible for the variation in gas production from the heterogeneous, low permeability reservoirs here, but these controls are not well understood. Outcrop-to-subsurface stratigraphic correlation and detailed analysis of facies can elucidate potential stratigraphic controls on geographic and stratigraphic zones with better gas production. The objectives of this project are to: (1) characterize the specific types of fluvial and marine facies in the middle and upper Williams Fork Formation, (2) delineate the regional distribution of, and transitions between these depositional facies, (3) determine mechanical properties in these facies that affect fractures and (4) disentangle potential relationship between depositional and mechanical properties of the facies that may control gas production. Here, we present the first phase of the project including preliminary regional sequence-stratigraphic framework for the middle and upper Williams Fork Formation. The database focuses on outcrop data and consists of eight new detailed (10cm scale) measured sections, five published sections, six outcrop gamma-ray profiles, detailed facies and channel geometry descriptions, 3D channel dimension analysis, paleocurrent data and well-logs that were used to build regional cross-sections that identify regional stratigraphy. Thirty-one lithofacies were distinguished and grouped into six assemblages: (1) high-sinuosity, meandering fluvial, (2) isolated, low-sinuosity anastomosed fluvial, (3) tidally influenced fluvial, (4) estuarine, (5) regressive marine shoreline, and (6) transgressive marine shoreline barrier systems. The fluvial facies tend to be laterally extensive with variations in channel type throughout the basin while marine and tidal facies show lateral discontinuity in the northwestern sections of the Basin. Remote measurement of actual channel dimensions provides insight into potential controls on fracture development in various facies. Initial observations suggest that the anastomosed fluvial and marine shoreline facies have the most fractures with varying intensity in the facies. Future work will build on the array of detailed facies, sequence-stratigraphic context and fluvial channel dimensions to understand relationships between facies, fractures, and production from tight-gas sandstones.
References


1. Abstract

The Piceance basin, Northwest Colorado, is home to one of the most important basin-centered light-gas accumulations in North America. A wide range of geologic controls are responsible for variation in gas production from the heterogeneous, low permeability reservoirs here, but these controls are not well understood. Outcrop-to-subsurface stratigraphic correlation and detailed analysis of facies can elucidate potential stratigraphic controls on geographic nd stratigraphic zones with better gas production. The objectives of this project are to: (1) characterize the specific types of fluvial and marine facies in the middle and upper Williams Fork Formation, (2) delineate the regional distribution of, and transitions between these depositional facies, (3) determine mechanical properties in these facies that affect fractures and (4) disentangle potential relationships between depositional and mechanical properties of the facies that may control gas production. Here, we present the first phase of the project including preliminary regional sequence-stratigraphic framework for the middle and upper Williams Fork Formation. The database focuses on outcrop data and consists of 8 new detailed (10cm scale) measured sections, 5 published sections, 6 outcrop gamma-ray profiles, detailed facies and channel geometry descriptions, 3D channel dimension analysis, paleocurrent data and well-logs that were used to build regional cross-sections that identify regional stratigraphy. Twenty-nine lithofacies were distinguished and grouped into six assemblages: (1) high-sinusity, meandering fluvial, (2) isolated, low-sinusity anastomosed fluvial, (3) tidally influenced fluvial, (4) estuarine, (5) regressive marine shoreline, and (6) transgressive marine shoreline barrier systems. The fluvial facies tend to be laterally extensive with variations in channel type throughout the basin while marine and tidal facies show lateral discontinuity in the northeastern sections of the Basin. Remote measurement of actual channel dimensions provides insight into potential controls on fracture development in various facies. Initial observations suggest that the anastomosed fluvial and marine shoreline facies have the most fractures with varying intensity in the facies. Future work will build on the array of detailed facies, sequence-stratigraphic context and fluvial channel dimensions to understand relationships between facies, fractures, and production from tight-gas sandstones.

2. Scientific Questions

1. What was the basin-scale configuration and connection of depositional systems within a sequence-stratigraphic framework? And, what were the type of depositional systems and their orientation?

2. Do the region-scale sedimentation trends help predict higher-than-average permeability zones?

3. Can sedimentation patterns be used to define trends in potential mechanical units that affect fracture development? If so, in which units and their distribution in the basin?

3. Geologic Background

Figure 1: Map showing major structural elements of the Piceance Basin, Northwest Colorado. Basin axes are shown in red and green. (Modified from Sanger, 2010)

Figure 2: Stratigraphic columns of the middle and upper Williams Fork Formation showing net-to-gross facies, channel geometry, and system tracts. (Modified from West and Van Wagoner, 2001)

Figure 3: Regional stratigraphy of northeastern Colorado and southern Wyoming during the Precambrian and Mesozoic. The basement (light grey) is highlighted. (Modified from Cobban et al., 2006)

Figure 4: Shale fracture count model for the middle and upper Williams Fork Formation in the Piceance Basin. (Modified from Wetton et al., 2005)

4. Methods

1. Define key lithofacies, their porosity/permeability characteristics and sequence-stratigraphic context

2. Assign potential mechanical properties to lithofacies based on fracture types, spacing and abundance within each facies

3. Identify actual channel dimensions using remote data and geological interpretation programs

4. Petrological analysis of core samples to identify sequence-stratigraphic surfaces and sediment provenance.

5. Construct an outcrop-based, basin-scale stratigraphic framework based on outcrop and well log data.

5. Preliminary Datasets

Outcrop Dataset

* 6 Outcrop measured sections
* 4 Outcrop Gamma Ray profiles
* 30 Facies
* 6 Associations
* Paleocurrent data
* 8 additional outcrop profile sections identified

Subsurface Dataset

* Over 6000 wells
* Over 200 wells with digital data
* Lower Williams Fork Formation sequence-stratigraphic framework

Figure 1: Outcrop measured sections from middle and upper Williams Fork Formation in northwestern Colorado. Geologic profiles and measured gamma-ray profiles and facies associations identified. (Modified from Sanger, 2010; Cobban et al., 2006)

Figure 2: Regional stratigraphy of northeastern Colorado and southern Wyoming during the Precambrian and Mesozoic. The basement (light grey) is highlighted. (Modified from Cobban et al., 2006)

Figure 3: Map showing major structural elements of the Piceance Basin, Northwest Colorado. Basin axes are shown in red and green. (Modified from Sanger, 2010)

Figure 4: Shale fracture count model for the middle and upper Williams Fork Formation in the Piceance Basin. (Modified from Wetton et al., 2005)

Figure 5: Gas producing well from the Rio Blanco County, Piceance Basin, Colorado. Normalized digital Gamma Ray data is displayed with Gas finding to display the contrast between sandstones, shales, and coal of the lower Williams Fork. (Modified from Wetton et al., 2005)

Figure 6: Map of the Piceance Basin. Wavebands Outcrops are displayed in green and magenta gas fields are identified in red. Trended measured outcrop profiles and stratigraphic locations of measured profiles are identified. (Modified from Proctor, 2013; Cole and Currey, 2013)
9. Actual Channel Dimensions - Workflow

Using a mapping software, such as GlobalMapper, and high resolution DEM and aerial photos it is possible to pick out individual channel bodies or channel complexes. This allows us to determine the apparent channel dimensions, much like in the field. When combined with elevation data, the channel boundaries can be placed into a structural software package and the actual channel dimensions can be determined.

Bringing the apparent channel dimensions and elevation data into a structural modeling program such as Move allows us to determine the actual channel dimensions before erosion. By applying the palaeocurrents measured in the field it is possible to project the channels onto a section that is perpendicular to flow. This projection allows us to determine the actual channel dimensions instead of the apparent dimensions that are normally measured in the field.

10. Conclusions

*Detailed lithofacies analysis aids identification of high frequency flooding surfaces that enhance correlation.

*Study supports the suggestion that the Williams Fork Formation changes from meandering fluvial systems to anastomosed systems.

*Fluvial facies are laterally extensive with variations in channel types while marine and tidal facies show lateral discontinuity in the northwestern sections of the Piceance Basin.

*Thinning in the middle and upper Williams Fork possible due to uplift of the Uinta Mountains and movement on the Uncompahgre Uplift.

*Initial observations suggest the anastomosed fluvial, meandering fluvial and marine shoreline facies have the most fractures with varying intensity in the facies.

*Determining actual channel dimensions gives us a better understanding of the size of reservoirs and their extent in the subsurface.

11. Future Work

*Continue measuring stratigraphic profile sections, along with obtaining outcrop gamma-ray (GR) data, in the northwest, southwest, and southeast margins of the Piceance Basin.

*6-9 new sections

*Continue to combine stratigraphic profiles with GR to recognize key sedimentary packages and bounding surfaces from outcrop to correlate into the basin using PETRA.

*Obtain fracture measurements in the field including: fracture type, spacing, and orientation.

* Petrographic analysis from Core to determine Provenance and reservoir heterogeneity.

*Obtain channel dimensions throughout the Piceance Basin using remote software workflow presented above.

*Combine depositional isopach maps and production data to determine relationships between depositional zones and facies to production maps to determine if zones we believe to be productive are extensive throughout the basin.

*Combine depositional isopach maps and and fracture occurrence maps to determine mechanical properties that control gas production.

12. References


Hettinger, N.D. & Kirschbaum, M.A., 2002, Stratigraphy of the Upper Cretaceous Mancos Shale (upper part) and Mesaverde Group in the southern part of the Uinta and Piceance Basins, Utah and Colorado, United States Geological Survey, Geologic Investigations Series I-276, 2 plates


13. Acknowledgements

RPSEA for funding this project. Williams and Bill Reed Corporation for providing well data. John Webb from the Discovery Group for providing core data and sharing his knowledge of the Piceance Basin. Michael Dee for his help in developing a workflow to determine actual channel dimensions. The Colorado School of Mines Geology and Geological Engineering Dept. and the Graduate Student Association for awarding travel grants for presenting at this conference. My advice, Dr. Aschoff, for taking me on as a student and helping me become a better geologist. Special thanks to my field assistants Jim Amsley, Elizabeth Kirby, and Ted Lee. Lastly, my friends and family for providing me with such a great support system.