LOOKING FOR GAS IN ALL THE TIGHT PLACES

T.L. Davis
Colorado School of Mines

ABSTRACT: Multicomponent seismic data are used to illustrate that sweet spots of high permeability can be identified in a tight gas sand play in western Colorado. These sweet spots coincide with low clay content, high secondary porosity and natural fractures. In addition, the same technology can be used to investigate seal integrity in the petroleum system.

1. Introduction

Multicomponent seismic data can aid in the exploration and development of tight gas. At Rulison Field, Colorado, the Vp/Vs seismic attribute from multicomponent seismic data provided a direct indication of reservoir quality and seal capacity of the petroleum system.

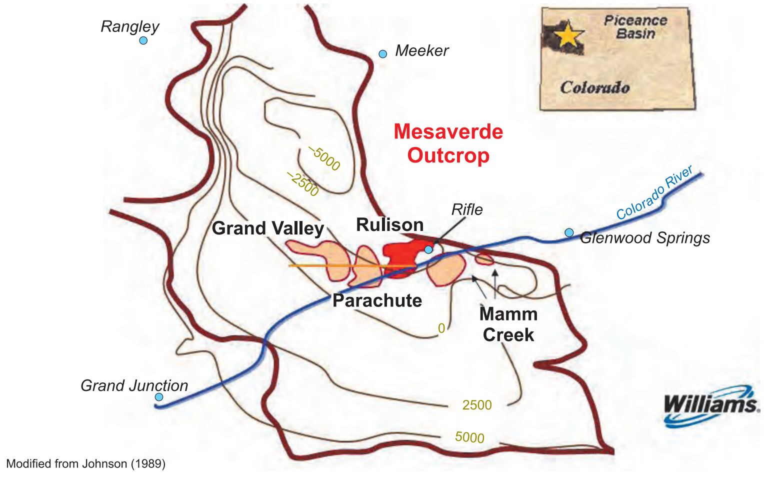

Fig. 1. Location map of Rulison Field, Colorado

Rulison Field produces out of Cretaceous Mesaverde tight gas sandstones, coals and shales (fig. 1 and 2). The pay section spans a 1 700 to 2 400 ft (500 to 700 m) thick interval that is overpressured. Matrix permeabilities in the sandstones range from 5 to 80 microdarcies. The reservoir interval consists of 60% shale and 40% sandstone. The sealing mechanism for the gas has been a subject of debate for years. Multicomponent seismic data, in conjunction with clay diagenesis studies, supports the concept that potassium feldspar dissolution created storage capacity in the reservoir, while faults and fractures facilitated the mobilization of diagenetic clays and silica which further influenced reservoir quality and seal development in the petroleum system.

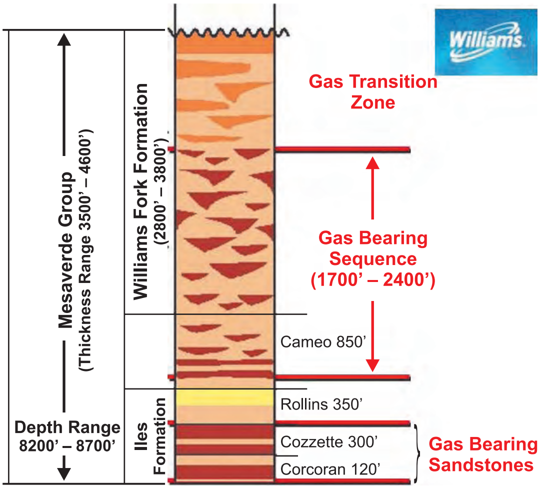

Fig. 2. Generalized stratigraphic column of the Cretaceous Mesaverde Group

2. Clay diagenesis

Stroker [1] found an absence of potassium rich feldspar near the top of the main pay interval. He noted that the main change occurs from 5 400 ft (1 636 m) to 6 000 ft (1 818 m) depth. There is little or no potassium feldspar left in the system below 6 000 ft (1 818 m). Secondary porosity, derived from feldspar dissolution, occurs in the main pay interval. Feldspar dissolution created an abundance of diagenetic clays. These clays have the potential to adversely affect reservoir quality. They are difficult to detect with logs but may be detectable based on the determination of high resolution Vp/Vs ratio methods from multicomponent seismic data.

The clays were transformed from smectite to illite. There are two types of illite present. One is a pervasive mixed layer, pore lining illite. Another is a fibrous illite precipitated during a relatively young fluid mobilization phase formed 7 to 10 million years later than the smectite-illite transformation. The mechanism for overpressuring is related to gas formation in underlying the Cameo Interval. Overpressuring caused mobilization of clay rich fluids.

Diagenetic fluids mobilized along fracture systems in subsurface-precipitated fibrous illite near the UMV shale forming the top seal to the basin-centered gas accumulation at Rulison Field. Fibrous illite is the dominant pore filling at approximately 5 400 ft (1 636 m). The pressure profile changes abruptly with this transition where the feldspars drop out of the system. Above this level there is a dominance of fibrous illite in the rock and feldspars, whose presence equates to the top seal.

Reservoir quality sandstones in the main pay interval contain the least amount of illite. The clay content affects how the rock will fracture naturally and hydraulically. Vp/Vs attributes derived from the inversion of multicomponent seismic data assist in determining clay content in these rocks. Figure 3 indicates the influence of clay content on Vp/Vs.

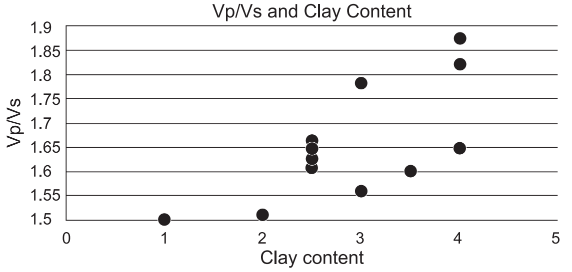

Fig. 3. Vp/Vs as a function of percentage clay content. Each division represents 10% clay content by volume

Figure 4 shows a vertical Vp/Vs slice through the reservoir interval derived from inversion of the P-P and P-S volumes. Zones of abnormally low Vp/Vs correspond to high quality reservoir intervals, and the zone of high Vp/Vs below the UMV marker coincides with the top seal in the reservoir (fig. 5). Notice that the Vp/Vs of the top seal changes spatially in proportion to seal capacity.

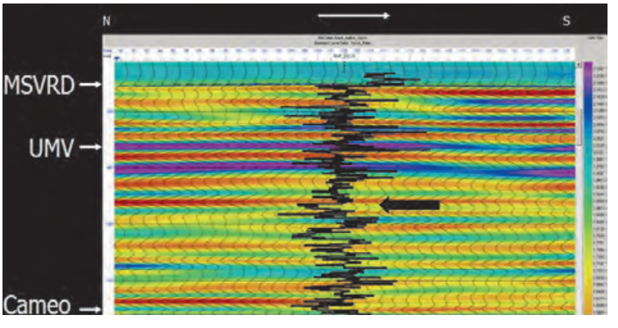

Fig. 4. A vertical slice through the high resolution Vp/Vs volume

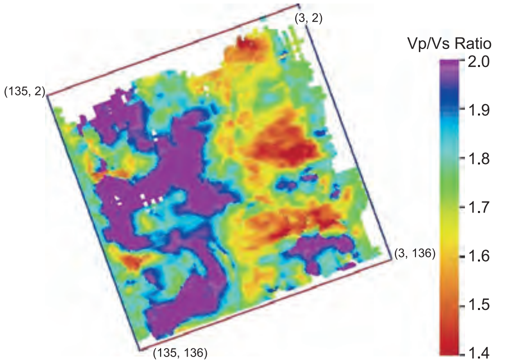

Fig. 5. Vp/Vs of an interval below the UMV marker at approximately 5 400 ft (1 636 m) indicating greater effective seal integrity on the west and southeast side of the study area

High EUR wells are associated with better quality reservoir and the presence of an effective top seal (fig. 6). There is an association between basement-controlled faults, fracture zones, high thermal gradients, and diagenesis. The smectite/illite transformation introduces silica into the system as well as illite. Silicification makes the rocks brittle and prone to fracturing. Faults and fractures create conduits for diagenetic fluids to mobilize under overpressure conditions. These fluids give rise to porosity creation, silicification, clay plugging and the formation of seals in the petroleum system. The understanding of diagenesis is a critical component in the exploration and development of tight gas reservoirs.

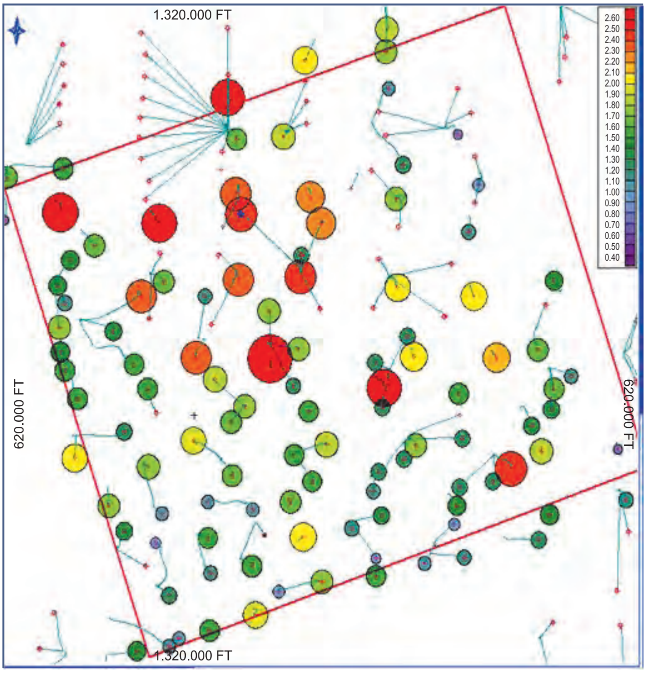

Fig. 6. EUR in BCF

Because of the complexity of reservoir prediction in tight gas resources, we need technology to help us predict reservoir quality ahead of the drill bit. Specifically, we need to quantify the mechanical properties of tight gas reservoirs to optimize hydraulic fracture stimulations. We also need to monitor the effectiveness of these stimulations on reservoir sweep to avoid bypassing reserves and completing into zones that are already depleted. Multicomponent seismology is a technology for finding gas in all the tight places.

3. Conclusions

Multicomponent seismology can aid tight gas exploration and development through identifying high permeability sweet spots. In addition, high resolution Vp/Vs determination can enable the location of better quality reservoir and detection of seal integrity.

4. Acknowledgements

The authors thank the sponsors of the Reservoir Characterization Project for their support.

Reference

[1] Stroker T. – K-Ar dating of authigenic illites: Integrating the diagenetic history of the fluvial Williams Fork Formation, Piceance Basin, Colorado. 2009, MS Thesis, Colorado School of Mines. Barcelona, Spain, 14-17 June 2010