FRACTURE IN DEVONIAN BLACK SHALE OF THE APPALACHIAN BASIN

BOTTOM LINE

Black, organic-rich clay and mud that now comprise the Marcellus Shale were deposited from east to west across the Appalachian basin from New York to West Virginia. As the overburden increased due to deposition of Middle and Upper Devonian clastics and thin carbonates, the Marcellus Shale was pushed downward into the oil window. Early gas generated in this "cooking pot" created a natural hydraulic fracture set with a consistent orientation, and this orientation was controlled by the existing Appalachian basin stress field, not by the orientation of fold axes that developed later in time. Additionally, these fractures were developed early enough that many remain open to this day. Therefore, operators in search of gas in the new Marcellus Play should consider drilling horizontal wells perpendicular to these NE-SW trending fractures, referred to by Terry Engelder in his earlier publications as the J_1 joint set.

PROBLEM ADDRESSED

In many parts of the country, and in many geological basins, shale plays are not only the hot plays of the moment, but also relatively new and poorly understood. Even in the Appalachian basin, where gas has been produced from the Upper Devonian Ohio (Huron) Shale for nearly a century, operators still struggle to produce even as much as 10 percent of the estimated gas in place in the shale reservoirs.

Black shales like the Huron, Rhinestreet and more recently, the Marcellus, are both source and reservoir; most of the gas generated in the organic-rich shales has remained relatively in place, although some has migrated into adjacent Lower to Upper Devonian sandstone and siltstone reservoirs. Furthermore, the gas in these shale plays is predominantly adsorbed on fracture walls or in the matrix of the shale, although a minor amount of free gas is known to exist within the fractures themselves. When the shale is penetrated by the drill bit, the decrease in reservoir pressure around the borehole allows the adsorbed gas to change phase to free gas which flows into the well. Unfortunately, due to the nature of the shale reservoir, this phase change is limited to the reservoir very close to the wellbore, and in fractures that extend into the shale reservoirs. Therefore, gas locked into the shale matrix between fractures is only produced over a number of years, often many decades, resulting in long-term, nearly flat decline curves.

The challenge then, not only in the older Huron play but in the new Marcellus play as well, is to develop new drilling and completion methods to unlock more of the gas trapped in the tight shale matrix away from fractures, and/or to drain more of the fracture network. Horizontal drilling is one method that can be used to intersect more of these nearly vertical fracture sets, but first one much be able to predict the orientation of fracture sets in the subsurface, and to predict which of the fracture sets may be open. To do this, one must first understand when and how the different fracture sets were created.

TECHNOLOGY OVERVIEW

Professor Terry Engelder (Department of Geosciences, The Penn State University) presented a two-day workshop based on decades of field and laboratory research in New York and Pennsylvania. The first day was devoted to an overview of the mechanical considerations during burial of the rocks in the Catskill delta sequence, and the mechanical considerations during the later tectonic deformation of these same rocks. Fracture sets developed during the burial of the deltaic deposits would be controlled by the orientation of the basin-wide stress field. Fracture sets developed during later tectonic deformation would be controlled by the orientation of the faults and fold axes.

Presentation on the second day focused on the nature of the fractures in the various black shales, and the exploration and production from the black shales. The discussion on the second day became with observations of fractures made from surface studies, and then descended into the subsurface where these same shales would have been placed in an overpressured, more thermally mature environment where the generation of natural gas led to natural hydraulic fracturing of the shale.

The approach taken by the instructor was to provide participants with an introduction to rock mechanics, stress and strain relationships, and pore pressure, consolidation and compaction disequilibrium. Regional tectonics, elasticity versus rock strength and elementary rock mechanics also were covered on day one, much to the discomfort, apparently, of many of the attendees.

The second day, when fracture sets were shown in outcrop photos and the distinction between J_1 and later J_2 sets, with different orientations, was emphasized, attendees appeared to become more involved in the discussion sessions that followed each one hour lecture.

By the end of the workshop, attendees should have gained an understanding of the thickness and extent of the Marcellus Shale; the distribution and amount of organic material in the Marcellus; where in the basin the Marcellus had descended into the oil window, thus generating early oil that was cracked to gas; and the area of the basin in which the earliest, gas-driven, natural hydraulic fracturing process had created a joint set with a consistent orientation that is still open.

CONNECTIONS

Based on a workshop sponsored by PTTC's Appalachian Region in Morgantown, WV on January 8 and 9, 2008.

Speakers:

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SUMMARY OF EVALUATION FORMS

Although 172 individuals pre-registered and registration was cut off, 188 people actually attended the workshop. Apparently, some refused to be turned away just because they did not bother to register before the deadline. Of this number, 166 were from industry and 20 from state and federal government and universities.

More than 140 attendees returned an evaluation sheet. Most of them were industry members; only 12 indicated they were from government of academia.

Prior to the workshop we e-mailed a 5-page announcement to the members of our e-mail distribution network and posted the workshop on our website. The workshop also was posted on the PTTC national website and was a front-page story on the national website of the AAPG. In spite of this broad adverting campaign, we still printed and mailed flyers to our mailing list of 1500 people. So, we were interested in how attendees actually heard about the workshop. Specifically, did we waste time and money to prepare, print and mail flyers?

Of those who responded to this question, 78 received and e-mail announcement and another 10 find the workshop posted on the internet, although whose homepage (PTTC? AAPG?) was not specified. Twelve apparently heard it by word of mouth. However, 41 indicated that they received a flyer and registered using the form on the flyer.

Although the vast majority (85-90%) of attendees was pleased with the workshop content, facility and speakers, they still offered many negative comments. Many of these dealt with the heating/cooling problem experienced the two days (too cold; then too hot) and the inadequate lunch (we ran out do to the large number of unexpected, unregistered walk in's). Most of the others repeatedly said that the content was too theoretical and not practical enough. Opinions of the speaker himself varied considerably.

Nearly 30 topics were mentioned for future workshops. Approximately one third were shale-play related. It was interesting to note that several references were made for the need to develop workshops related to CO2 sequestration and using CO2 to produce more oil or gas from coal beds. These topics will be covered in our upcoming February 12th workshop.