PTTC Focused Technology Workshop

"Exploration & Evaluation of Fractured Reservoirs"

October 6, 2004; Columbus, OH

Workshop Summary

Dr. Ron Nelson, a well-known and recognized expert in the field of fractured reservoirs, returned to the Appalachian basin to present a one-day version, designed specifically for PTTC, of his workshop on exploration and evaluation of fractured reservoirs.

The workshop was well-attended and well-received, particularly for a workshop that was added on to the end of a three-day meeting. Seventy persons pre-registered and paid or registered and paid at the door. All registrants were in their seats prior to the announced start of the workshop, so Dr. Nelson actually began his lecture 10 or 12 minutes early.

Dr. Nelson is a speaker who really cares about a workshop that he teaches. He expressed concerns with the shape of the room, the AV equipment, the ability to reduce the lights, the light coming in from the long windows on one side of the room, and the preparation of the workshop notebooks. He wants everything to be a good as possible.

The object of the workshop was to offer a one-day sampler of: the kinds of natural fracture systems; fracture morphology; calculating fracture porosity and permeability; how fracture/matrix interaction affects book reserves; mechanical predictions, i.e., where on a structure one will expect to find more fractures; fracture reservoir classifications; and reservoir heterogeneity, resulting in winners and dogs.

In addition to the workshop notebook, Dr. Nelson directed attendees to two websites: www.dh.com, where one can search on "Ron Nelson" to find 450 slides in Pdf and Power Point; and www.brokenN.com, where Dr. Nelson offers other helpful hints based on his long experience throughout the world.

The workshop began with an explanation of a generalized fracture reservoir work flow diagram, and the steps in creating a static conceptual model in a fractured reservoir. One of the initial cautions offered to participants was to avoid "fracture denial." Too many times, geologists and engineers deny the presence of fractures in their reservoirs, for a variety of reasons, but mainly because they are hard to model. But, the giant carbonate reservoirs in the middle East are all fractured. Eventually, these will undergo EOR, and when water is injected, where will it go?

Sometimes we assume that all reservoir heterogeneity is due to stratigraphy or facies changes. Often it is too late when we realize the control of fractures on heterogeneity. We also tend to underestimate the drainage area of a well, and the elliptical nature of the drainage area around wells in fractured reservoirs. This results in offsetting good wells too closely with wells that are not as good.

Some geologists think that fractures are random, or fail to see them at all. In truth, fractures are highly ordered, and one can read a lot from them, once one knows how. Fracture orientations faithfully record the state of stress at the time of their formation.

Natural fractures can be classified as tectonic, regional, contractional and surface-related and induced. Tectonic fractures can be either fault-related or fold-related. Fractures related to faults increase in number closer to the fault, are more concentrated on the hanging walls, and have a predictable dip, if you know the dip on the fault. The key is, how broad is the zone of more intense deformation near the fault? In a play like the Trenton-Black River, faults and associated fractures provide permeability and porosity and serve as pathways for the movement of diagenetic fluids and hydrocarbons. What is not always known is the extent of the fractured zone around each fault.

“Not all positions along a fault are created equal.” Dr. Nelson cautioned that if you space your wells equally along a fault, you are doomed to failure. Some Trenton-Black River faults have reversed their direction over time. Deeper formations associated with fault inversion, i.e., the Beekmantown-Knox below the Trenton-Black River, may contain more fractures, and higher porosity.

It is important to distinguish between the “process zone” and the “damage zone” bordering a fault. The process zone is a zone of intense deformation, several 100's of feet wide. The damage zone is the result of intense deformation related to fault slip, and is usually only a few 10's of feet wide. The goal is to get close to it, but not too close. Pre-slip fracturing forms the process zone; the fault propagates through it at a later stage of deformation, but not necessarily in the center of the zone.

Fault surfaces are neither straight nor smooth. The topography of a fault surface can be mapped using 3D seismic. Knowing the location of bends in a fault can allow you to predict the location of intense fracture zones. Open fractures are expected on the outside of a bend in a fault; fractures on the inside of a bend are expected to be under compression and thus, more closed. Even in cross section, faults exhibit “outside” and “inside” corners, with the same effect - extension and more open fractures on the outside and compression and more closed fractures on the inside.

How do you calculate fault zone pore zone volume and oil reserves? Dr. Nelson went though several examples, changing some of the parameters to demonstrate the effect on the final oil volume.

Following lunch, Dr. Nelson began his discussion of fold-related fractures, beginning with where extension and shear fractures are fold on a fold, and the orientation of type I and II fractures on the fold. Fault-related fractures are relatively restricted, measured in 100's of feet, whereas fold-related fractures are the most productive. Everywhere we have folds we have very pervasive fractures at various scales, from thin section scale to those observed on satellite photos.

This analogy was presented: a fractured reservoir is the rush hour going to work. Assume that all roads, of any size, are fractures. When you leave your house you may begin with a narrow alley or street, which leads to a wider access road which takes you to the expressway. Each different road is wider, each one allows you to go faster. Therefore, it is necessary to consider the little fractures as well as the larger fractures. Like getting from your house to the freeway, the little fractures lead to larger fractures; all contribute to well performance.

Dr. Nelson then moved on to regional fractures, those fractures that are developed over large areas with little change in orientation, no evidence of offset along the plane, and are perpendicular to bedding. Examples are the well-developed fracture sets in the Devonian shales in the Appalachian and Michigan basins and fractures, commonly called cleats, in coal beds. Some of these fractures extend through all of the beds, whereas some are restricted to certain beds. Numerous examples of shales and sandstones were shown, including the non-systematic “fanning out” of fracture orientation tangential to the mountain front in New York and Pennsylvania.

The question was raised: how many of these regional fractures are related to “unroofing?” Out west, when you move away from a canyon surface, these fractures maintain the same orientation. It seems that we have different mind sets in different parts of the country. For example, in the Appalachian basin, there is a mind set that says you cannot drill horizontal wells in these rocks. To this Dr. Nelson replied, “Get yourself a new driller.”

Contractional fractures are fractures of varying origin, either tensile or extension, associated with a bulk volume reduction throughout the rock. Dessication, syneresis, thermal gradients and mineral phase changes are processes that can generate contractional fractures. “Chicken-wire” polygonal fractures in the Devonian shales are an example. However, Dr. Nelson cautioned not to confuse these fractures with those seen in old cores. Old cores commonly have polygonal fractures on the outside that formed as the cores dried.

Chicken-wire fractures can significantly increase permeability and production.

Following the afternoon break, Dr. Nelson discussed surface-related fractures and fracture morphology types, including open fractures, deformed fractures, mineral-filled fractures and vuggy fractures in carbonates.

Dr. Nelson confided to me that of all the workshops he teaches, he gets the most feedback from the PTTC workshops. He believes that PTTC workshops are attended by geologists and engineers who are interested in “getting stuff done.”

Evaluation Forms

Nearly everyone who attended (57 of 63) submitted an evaluation form (attached). In general, participants gave the workshop high marks, although there may have been some confusion. Usually we ask registrants to rank from highest (5) to lowest (1). However, in this case, the local host reversed the scoring system, and in some cases where 4's and 5's were given, we were led to believe, by other comments on the form, that the participant thought he or she was awarding a high score, not a low score.

Registrants appeared to learn about the workshop from three main sources: direct mailings, e-mails and from our website. Others learned of it from their Eastern Section AAPG announcement. Among the respondents, workshops appear to be the most helpful tech transfer method, followed by reports/case studies, the internet, tech assistance and newsletters.

Respondents suggested a variety of additional workshop topics: sequence stratigraphy, data, gravity and magnetics, hydrothermal reservoirs, case studies, emerging plays, fractured reservoir simulation, seismic attributes in fractured reservoirs, regional structure and tectonics, HTD development, diagenesis, integrated exploration tools, CO_2 sequestration, enhanced oil recovery, horizontal well drilling and design, production methods, evaluation and stimulation of horizontal well bores, PC mapping techniques, water flooding a fractured reservoir, depositional environments, basin-centered gas vs conventional plays, and drilling fractured reservoirs.

Attendance List

The final attendance list is attached. Of the 63 attendees, 38 were from industry, 17 from government and 8 from academia. Apparently many of the attendees were geologists who were not as interested as engineers in picking up their certificate for PDHs when they submitted their evaluation sheets. Twenty of the certificates were returned to me with the evaluation forms.

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