AAPG HEDBERG CONFERENCE
"Applications of Reservoir Fluid Geochemistry"
June 8-11, 2010 - Vail, Colorado

Relationship between a Reservoir Plumbing System and Drilling Gas Geochemistry

Alfred Lacazette[1], Don L. Hall[2]
[1]EQT Production Company, Pittsburgh, PA, ALacazette@EQT.com
[2]Fluid Inclusion Technologies, Inc., Broken Arrow, OK, dlhall@fittulsa.com

The ***Mallory 145 Multi-Well Project*** (MAL-145) is a detailed study of the natural and induced plumbing system of an important sequence of gas producing formations in southern West Virginia. This contribution will examine how vertical and lateral seals and permeable fracture zones affect reservoir geochemistry at MAL-145.

The target strata at MAL-145 are the 1800 foot-thick, sequence of gas shales, tight gas sandstones, and siltstones that comprise the Upper Devonian section. The project was designed to comprehensively determine the natural and induced reservoir plumbing system in three dimensions and to simultaneously test, develop and cross-validate new reservoir characterization technologies. A vertical pilot hole and four horizontal wells were drilled on air. The horizontal wells are directly above each other at 300-550 foot depth intervals. The data that has been and will be collected at MAL-145 will represent one of the most extraordinarily detailed data sets ever collected in a fractured reservoir.

Logging. Continuous, direct quadrupole mass spectrometer (DQMS) gas logs of the produced drilling air were collected in all of the wells. The vertical pilot hole was loaded with brine after drilling and a complete suite of conventional logs was collected including triple-combo, crossed-dipole sonic (XMAC), pulsed neutron (FLEX), and acoustic and electric borehole images (STAR). An optical televiewer log was collected in the pilot hole prior to loading it and in the top three of the horizontal wells. Open hole production logs were run in the upper horizontal wells. Post-frac production logs will be collected.

Frac tracing. All of the horizontal wellbores were fraced with nitrogen. A unique chemical tracer was added to the frac gas in each well to test for interference. Radioactive tracers were used to determine frac initiation points and near-wellbore frac geometry.

Microseismic data. Fracs in three of the wells were observed with a 16 element subsurface microseismic array in one of the horizontal wells and with a surface microseismic array comprised of 300 vertical-component stations and 60 full-waveform stations. The surface data will be processed using a new semblance-based method intended to image the movement of the pressure wave through the reservoir.

Pressure monitoring. Mini-frac pore-pressure measurements were collected in three of the horizontals which were shut-in for pressure monitoring during fracing of the adjacent wells. A pressure monitoring program with surface and downhole gauges was implemented both in the

MAL-145 wells and in the field. The program includes pressure build ups, gradient surveys, surveillance, and interference testing.

The data collection is still in progress at the time of this writing and analysis is as yet incomplete. Early results indicate a complex reservoir plumbing system that is reflected by the reservoir geochemistry. Four examples are shown below.

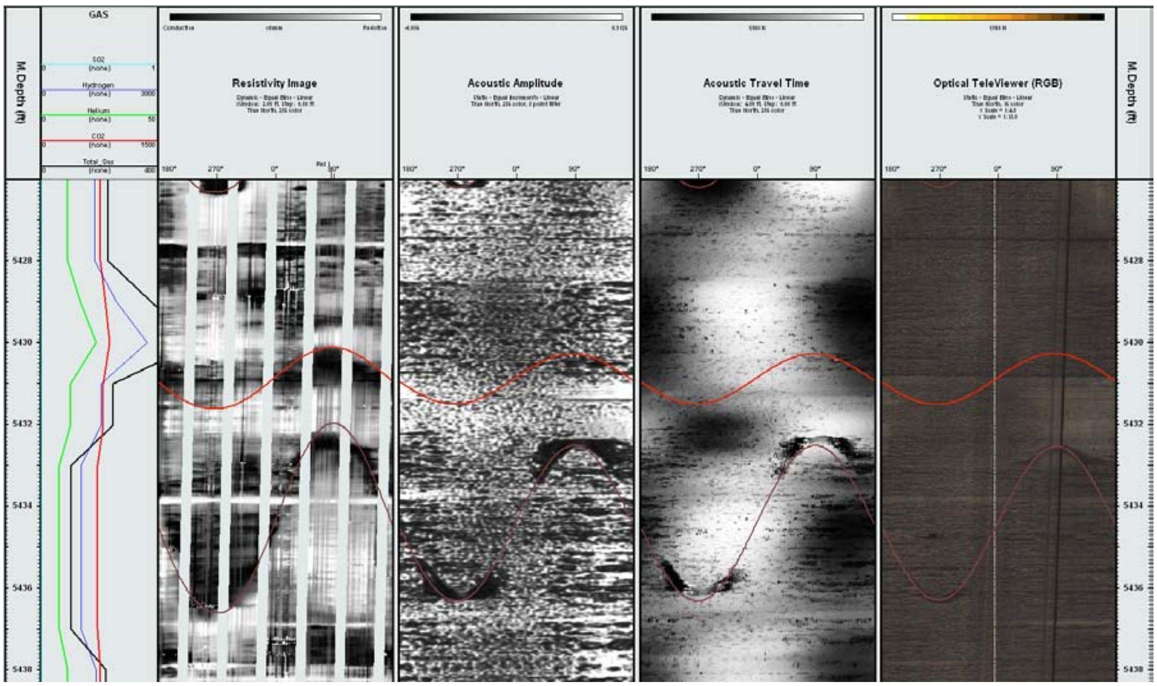

Figure 1: Chemical signature of gas coming out of a natural fracture during drilling of the vertical pilot hole. DQMS profile while drilling with air at left, electrical image, acoustic amplitude image, acoustic travel-time image, and optical televiewer image successively to right. Natural fractures are marked with sinusoids. The red sinusoid represents a minor fault, the brown a joint. Note that the DQMS data are in driller's depth and the images are in log depths, consequently, the slight offset. Three of the air-drilled MAL145 horizontal wells were imaged with optical televiewers. The borehole images show that productive fractures can be detected from drilling gas geochemistry.

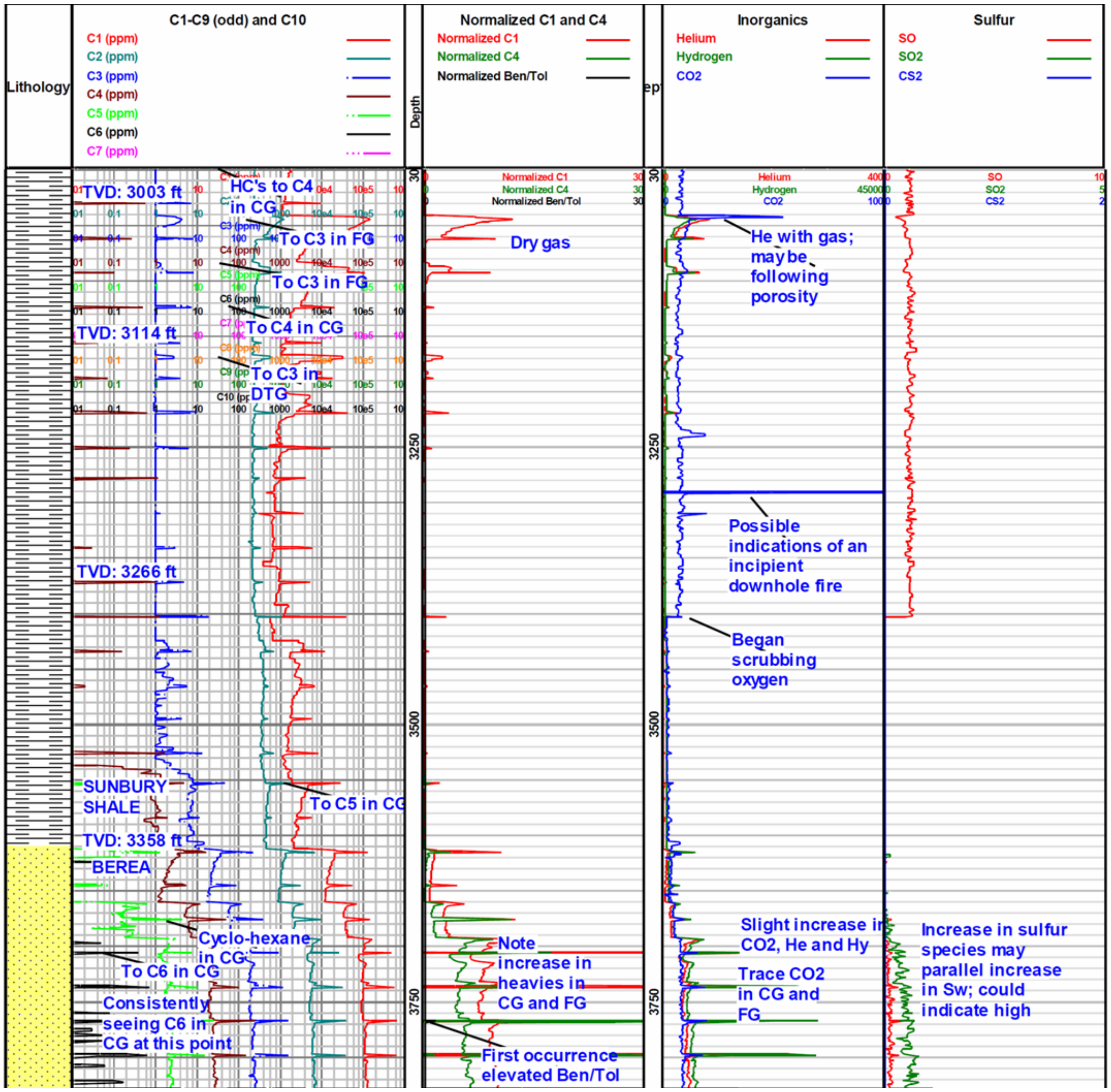

Figure 2: DQMS data from shallow portion of Berea lateral in the curve. Note dry gas in shale, in comparison to increased hydrocarbon wetness in Berea. Of note here are thin CO_2 anomalies that may indicate incipient downhole fires, particularly at about 3290 ft MD, shortly after which oxygen scrubbing began. Increase in sulfate and incipient increase in water soluble species may indicate increased water saturation in the Berea, and possibly presence of mature gas. This is explored further in the next diagram.

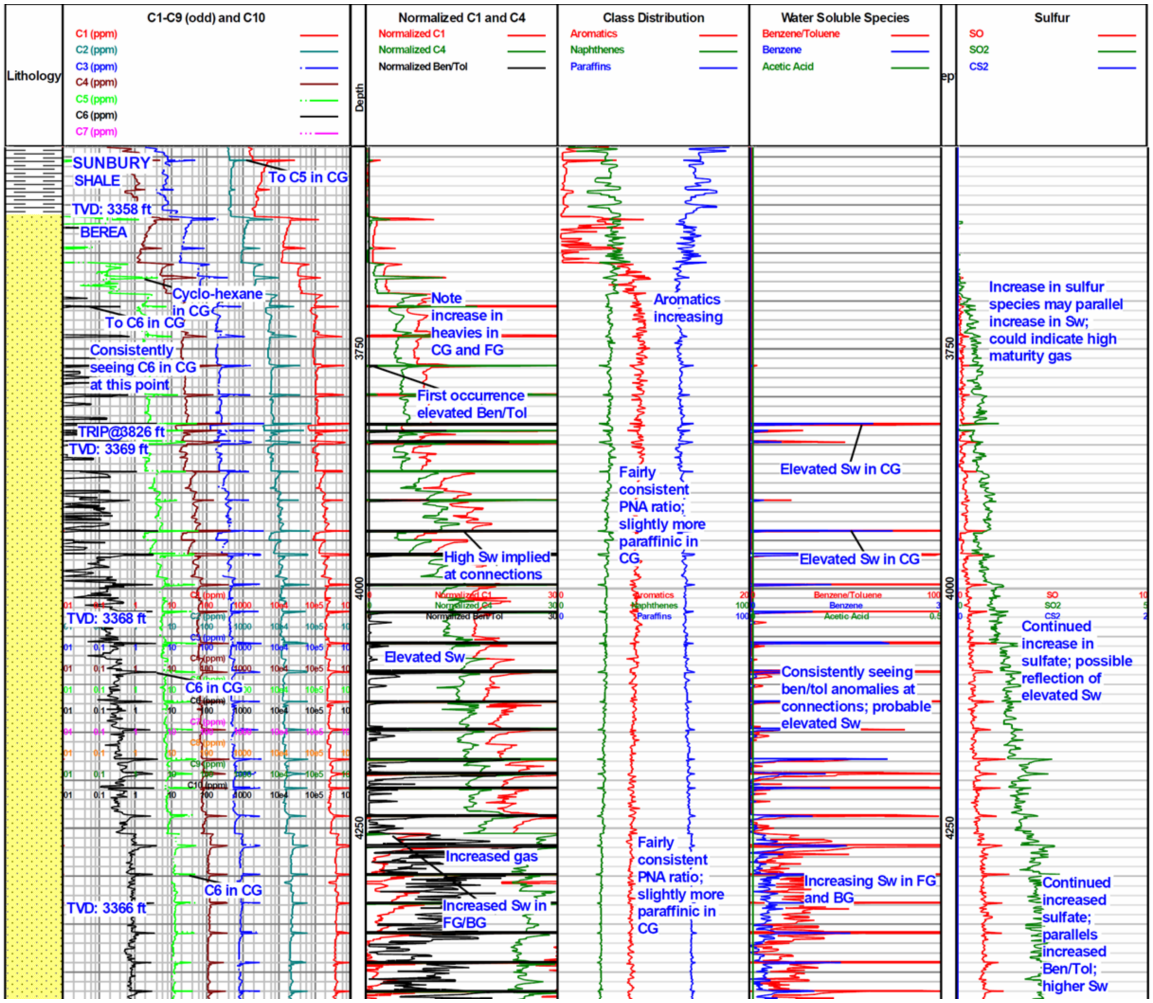

Figure 3: DQMS data from top of Berea lateral as the well is landed in the Berea. Note progressive increase in apparent water saturation (normalized ben/tol, other aromatic indicators not shown, and sulfate) and dramatic change in the paraffin-naphthene-aromatic ratio indicating a distinctive chemistry in the Berea.

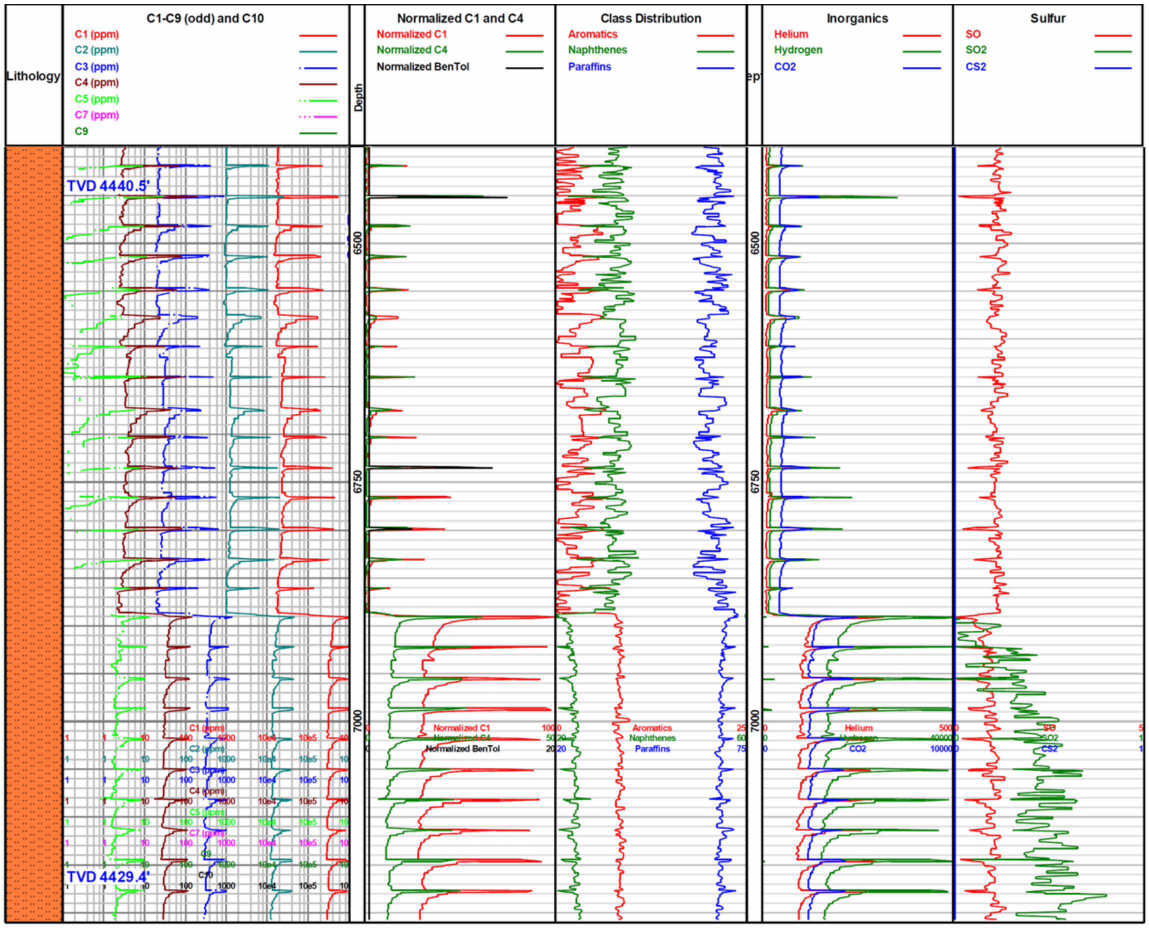

Figure 4: DQMS data indicating lateral compartmentalization in horizontal well in the Lower Huron siltstone. A strong increase in gas at approximately 6890 ft MD (4432 ft TVD) is accompanied by a decrease in hydrocarbon wetness (i.e., relative proportion of heavier hydrocarbon components, an increase in aromatics, with respect to paraffins and naphthenes (cylics), an increase in methane and hydrogen with respect to helium, and an increase in sulfate. These chemical variations define a clear compartment boundary at this depth, and suggest increased water saturation in the deeper section (e.g., sulfate). Note that increases in the ratio of benzene to toluene in connection gases in the shallower section also imply movement of water and gas into the borehole during connections. This shallower gas contains greater abundance of heavier hydrocarbon components allowing the benzene/toluene ratio to be used.