RESERVOIR-DRILLING FLUID DESIGN IN FISSILE SHALE FORMATION

Wenwu He, Stephens Mike, and Charles Svoboda, MI-SWACO
Bill Dannels, BEPCO,L.P.

ABSTRACT

Fissile shale has strong potential to cause severe wellbore instabilities, especially in high angle and horizontal wellbores. It is highly laminated and splits easily into thin layers along its bedding planes. With the high concentrations of clay minerals, this type of rock usually has high cation exchange capacity. Dispersion may not be strong, even in water, but the rock may become highly broken mainly along bedding planes once it has been contacted with fluids.

Finding suitable drilling fluids to stabilize reactive fissile shale formations is an area of active research in M-I SWACO. Detailed characterization of the rocks and formations is the first step of this process. The direct observations of interaction between the formation rocks and fluids are conducted to determine which fluid causes the least rock instability. Morrow formation instability had caused serious drilling problems on a previous high-angle well attempt in New Mexico that had been drilled with a KCl water based drilling fluid. An oil-based fluid designed to stabilize the Morrow formation resulted in successful drilling.

INTRODUCTION

The petrological, mechanical, and chemical properties of rocks have profound effects on the design of reservoir drilling fluid. While mud weight could cause the stress imbalance on the rock surrounding the borehole and thus lead to wellbore breakouts, the interaction between drilling fluid and the rocks also causes severe mechanical instabilities in the boreholes. Finding a suitable drilling fluid which causes the least mechanical and chemical change in the wellbore rocks is essential in improving the success of drilling and completion processes. It becomes increasingly important for the drilling in very reactive shale formation. Fissile shale belongs to this type of reactive rock which has strong potential to cause severe wellbore instabilities.

The effects of reactive fissle shale on drilling fluid design is an area of active research in MI-SWACO. Detailed characterization of the rocks and formations is the first step of this process. The direct observations of interaction between the formation rocks and fluids are conducted to determine which fluid minimizes rock instability. The purpose of this paper is to illustrate the application of these technologies to Morrow shale formation.

MORROW FISSILE SHALE IN NEW MEXICO

The instability of the Morrow shale formation during drilling had been the major obstacle to a Morrow gas exploration and development project in a drilling area of New Mexico. The Morrow shale is highly laminated and easily splits into thin, approximately parallel layers mainly along closely spaced bedding planes (Fig. 1 and 2). It has predominant clay-sized materials (Fig.2). Except the splitting along the bedding plane, fractures crossing the bedding planes also exist in the rocks (Fig. 2). A combination of weak bedding planes and crossed fractures forms good fluid channels and the interactions between rocks and fluids could lead to serious wellbore breakouts.

Most of the shale consists of clay minerals (Table 1). Smectite is 21-23%, kaolinite ~10%, illite ~20%, and chlorite ~10%. Quartz is relatively low, 29-35%. In addition, these rocks contain small amount of pyrite, siderite, feldspar etc. With high concentrations of clay minerals, these rocks have high Cation Exchange Capacity (CEC), which ranges from 18 to 21.

INTERACTIONS OF MORROW SHALE AND FLUIDS

The Morrow fissile shale has very weak dispersion in water base fluids (Table 2). The recovery rate for all of the tested drilling fluids are above 97%. Even in water, the recovery is ~95%.

But the weak dispersion does not suggest that the fissile shale is stable during contact with drilling fluids. The stability of these rocks was evaluated by the direct observations of the interactions of rock and fluids. The interactions between rocks and fluids are recorded at the elapsed test time and evaluated according to the kinetic rate and frequency of production of new fractures, enlargement and extension of pre-existing fractures, opening of closly-spaced bedding planes, and the effects of fracturing and bedding-plane opening on rocks at both the macroscopic and microscopic scales. The test procedures are:

1. Saw the rock sample into pieces between 1 and 2 inch (approximately cubic shape) if the sample conditions permit. Make sure to minimize the possibility of fracturing samples and at least one face to be approximately perpendicular to the bedding planes
2. Place each piece of rock in an optically clear square container and add the fluids into the containers.
3. Observe and record photographically the changes in the rocks
4. Examine the thin section of the tested samples by microscopy

Test fluids include:

(1) 6% KCl Brine
(2) 12 PPG K-Formate Brine
(3) West Texas Brine (A 10 ppg NaCl brine and dilute back to 9.5 ppg with seawater)
(4) Diesel
(5) Water

Significant differences regarding the fracturing of the rocks were observed in these tests (Figs. 3 -12). No significant change was observed for the sample in Diesel, but in water, the pre-existing fractures were extended and widened and new fractures both along and crossing bedding planes were produced. Part of the samples fell apart due to fracturing. Sample in 12 PPG K-Formate Brine was also very stable and only a slight change was observed. Both 6% KCl Brine and West Texas Brine showed some effects on fracturing and shale stability. If we assumed the stability of Morrow shale in Diesel is 100% and in water is 0, its relative stability in different tested fluids is summarized in Table 3.

CONCLUSIONS FROM LAB TESTING

The effects of drilling-fluid chemistry on well-bore stability can be evaluated by directly observing the development of fractures in rocks which are exposed to drilling fluids. These observations include the kinetic rate and frequency of production of new fractures, enlargement and extension of pre-existing fractures, opening of rocks along bedding planes, and the effects of fracturing and bedding-plane opening on rock integrity. An oil-based drilling fluid was designed according to this technology to stabilize the Morrow shale formation in New Mexico. This fluid was used to drill a near-horizontal well in the Morrow Formation near the well that had experienced serious wellbore instability with the KCl water based mud.

FIELD RESULTS

The objective of the drilling project was to kick off and drill 2,550’ of 6-1/8” lateral hole transversing 200’ of potential pays in the Middle Morrow formation using the oil base mud recommended from the lab studies. The final mud weight and lateral direction were determined by rock stresses identified in the recently developed geomechanical model. Onsite drilling engineering consultants were on location to calculate ECDs, swab and surge pressures and assist in maintaining those parameters within the pre-determined mud weight window. A rig was contracted in April 2006 to re-enter a recently drilled Morrow well in the Big Eddy Unit. Using a 13.0 ppg VERSAPRO oil base mud with additions of sized calcium carbonate, the well was successfully kicked off at 12,267’ TVD, the curve built at 30°/100’, an 87° inclination hole drilled to a total measured depth of 14,705’ (12,555’ TVD) at 40° azimuth, and the entire open hole cased with a 4-1/2” slotted liner.

ACKNOWLEDGMENTS

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REFERENCES

1. Gomez, S. and He, W., Laboratory method to evaluate fracture development in hard shale formation exposed to drilling fluids, AADE-06-DF-HO-38, AADE Drilling Fluids Technical Conference, 2006
2. Lee, J., Overview of shale stability testing, *Drilling and Completion Fluids* (May/June, 1994) 15.

Table 1
XRD analysis results for Marrow shale in Big Eddy, New Mexico

	# 1 (%)	#2 (%)	#3 (%)	#4 (%)	#5 (%)	#6 (%)
Smectite	23	23	25	21	23	23
Kaolinite	10	10	10	10	10	10
Illite	20	20	20	20	20	25
Chlorite	10	10	10	10	10	10
Pyrite	1	1	2	2	2	2
Siderite		2	1	1		
Calcite		1				
Feldspar	1	1	1	1	1	1
Quartz	35	32	31	35	34	29
CEC, meg/100gr	18	18	20	21	18	18

Table 2
Dispersion test results of Morrow shale in Big Eddy, New Mexico

Drilling fluid	Recovery (%), Sample 1	Recovery (%), Sample 2
KCl/Glydril	97.95	97.95
KCl w/o Glydril	97.20	97.15
Freshwater Mud	97.75	97.95
ULTRADRIL	98.85	98.80
VERSADRIL	98.30	98.15
VERSACLEAN	97.95	98.50
Dipro	98.5	99.25
Formix	99.55	99.35
Water	94.50	95.00

Table 3
Relative stability of Morrow shale in Big Eddy, New Mexico

Fluids	Fluid effect	Stability
Diesel	No evident effect	100%
12 PPG K-Formate Brine	No evident effect	95%
West Texas Brine	Fracturing mainly along bedding planes	80%
6% KCl Brine	Extending and widening pre-existing fractures Producing new fractures mainly along bedding planes	50%
Water	Extending and widening pre-existing fractures Producing new fractures both along and crossing bedding planes Falling apart	0

Figure 1 - Fissile Shale in Big Eddy, New Mexico

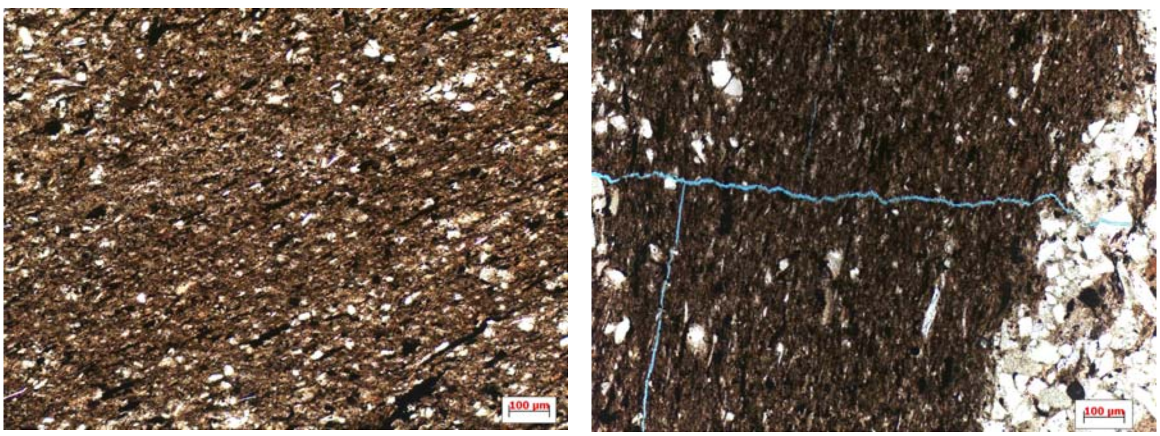

Figure 2 - Thin Section Images of Morrow Shale in New Mexico

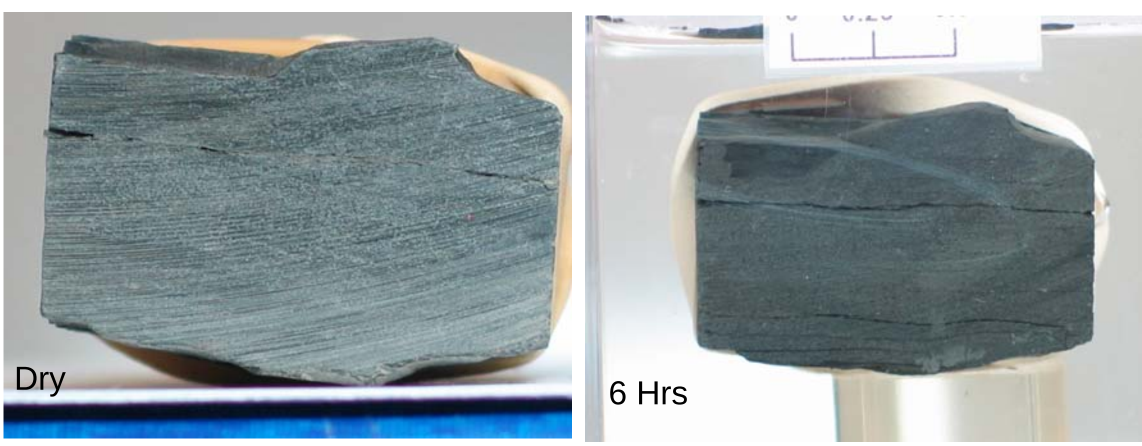

Figure 3 - Morrow shale exposed to 6% KCl Brine. The picture on the left side represents the dry rock and on the right side represents the rock after exposed to drilling fluids for 6 hours in this figure and the following.

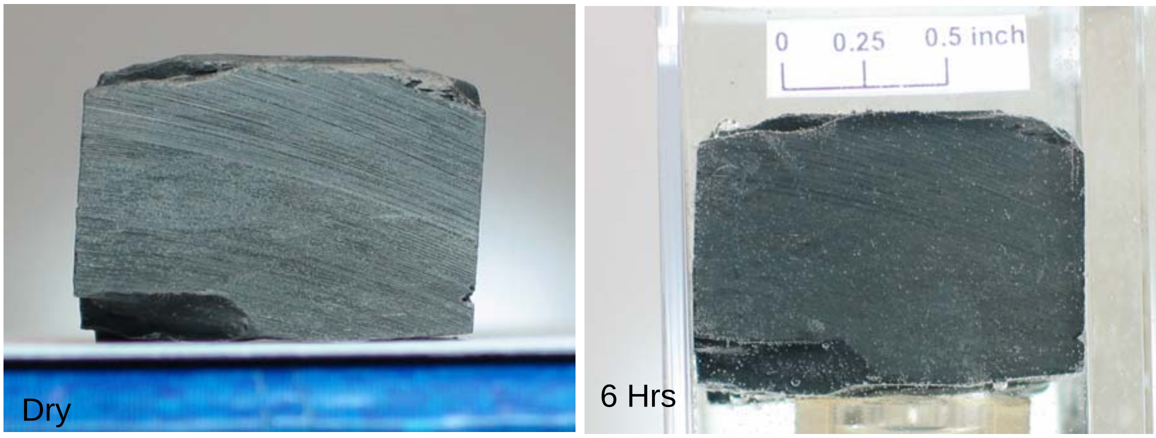

Figure 4 - Morrow Shale Exposed to 12 PPG K-Formate Brine

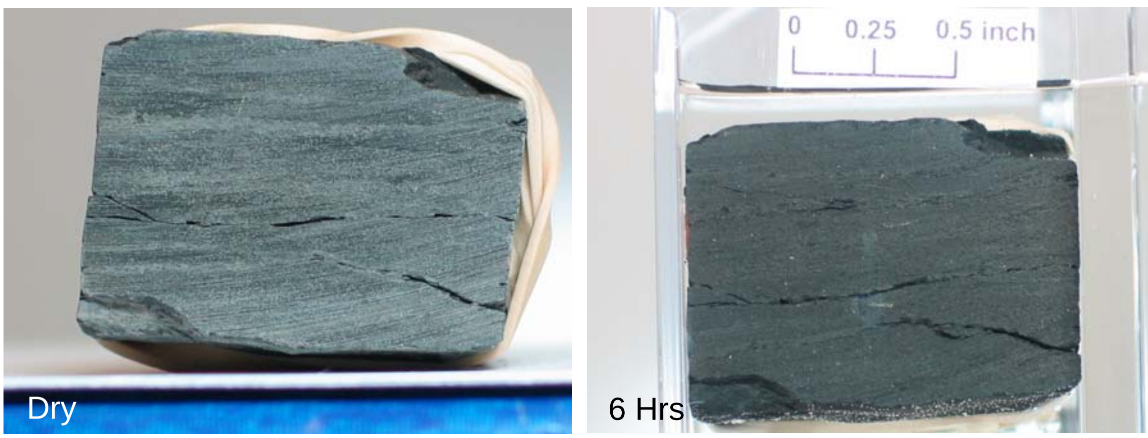

Figure 5 - Morrow Shale Exposed to West Texas Brine

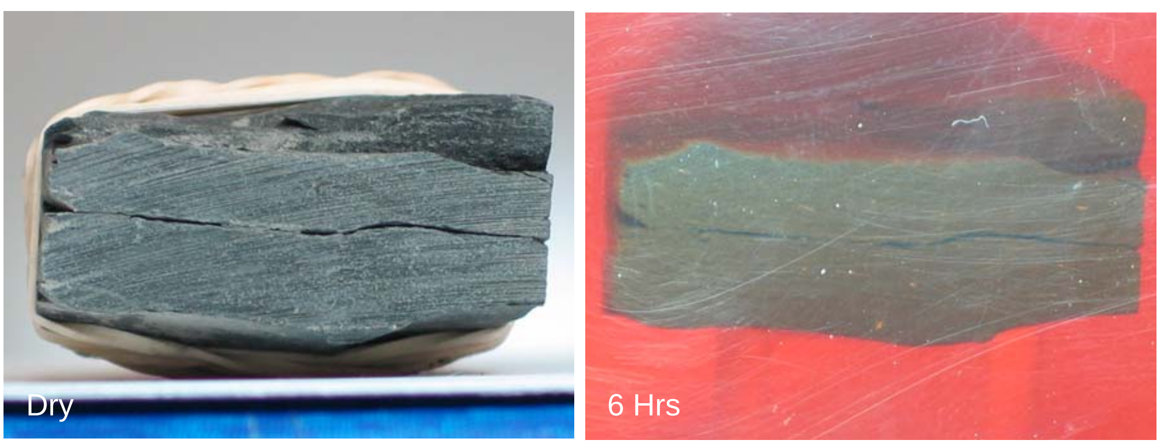

Figure 6 - Morrow Shale Exposed to Diesel

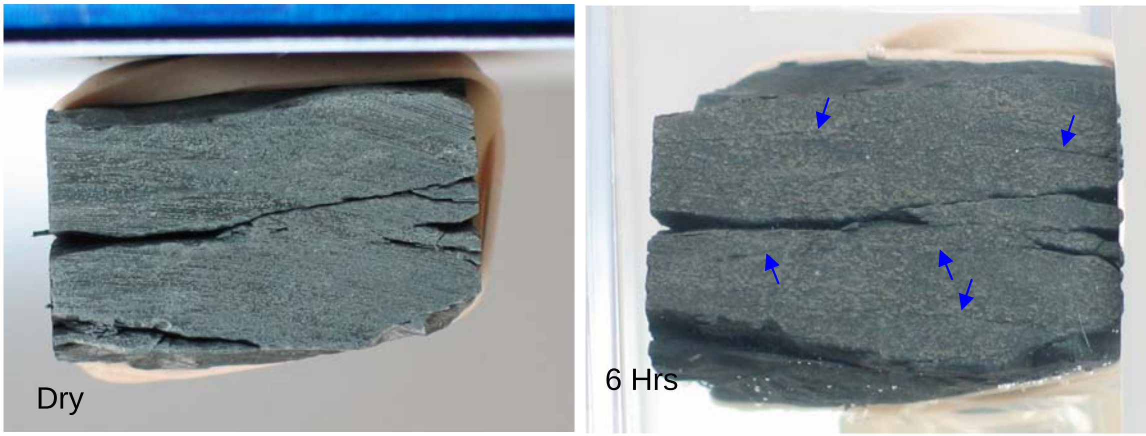

Figure 7 - Morrow shale exposed to water. Arrow indicate fractures.

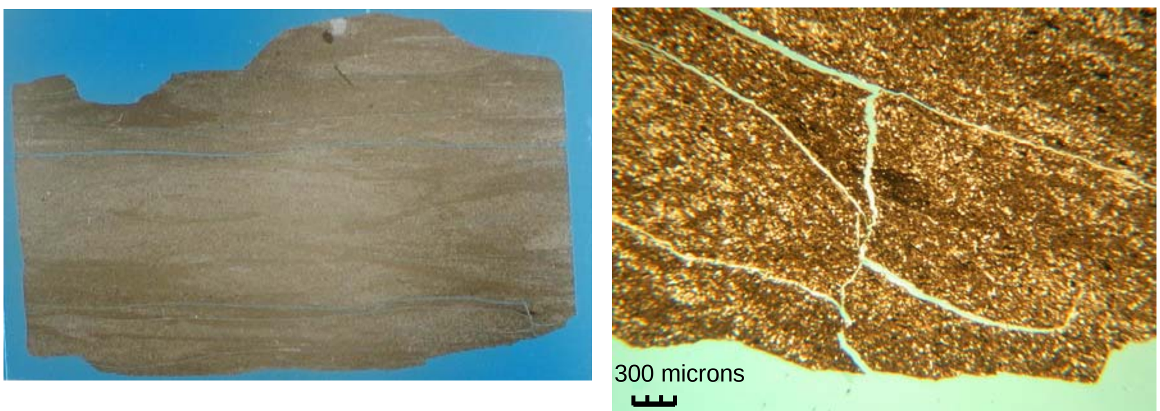

Figure 8 - Morrow shale exposed to 6% KCl Brine after 6 hours. The picture on the left side represents the whole thin section of the tested sample and on the right side represents part of the thin section which was observed through microscopy in this figure and the following.

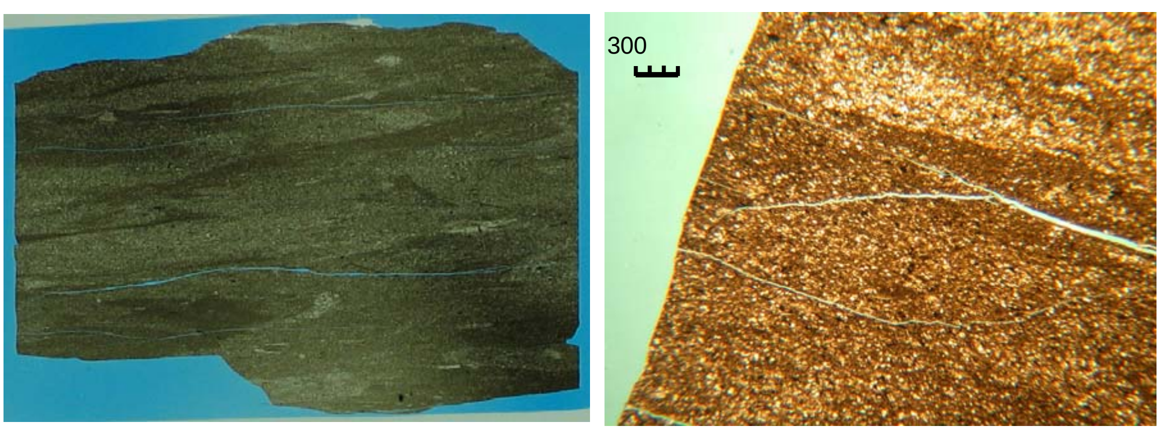

Figure 9 - Morrow Shale Exposed to 12 PPG K-Formate Brine After 6 Hours

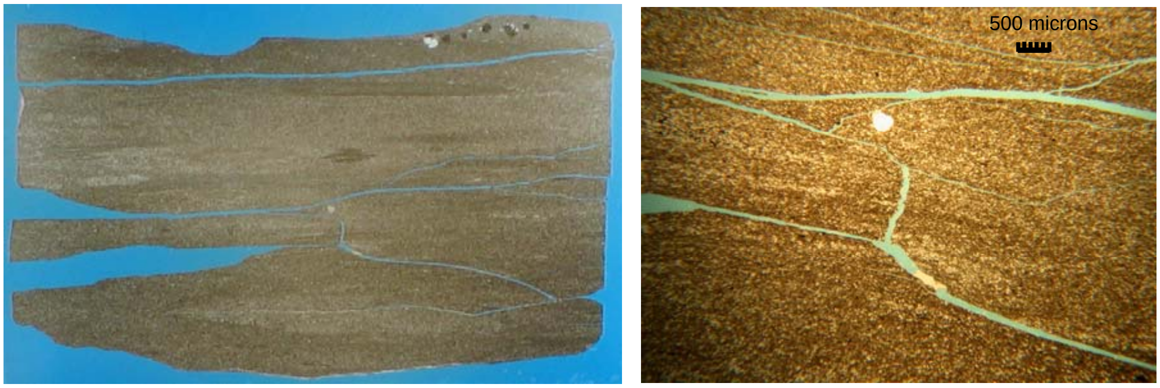

Figure 10 - Morrow Shale Exposed to West Texas Brine After 6 Hours

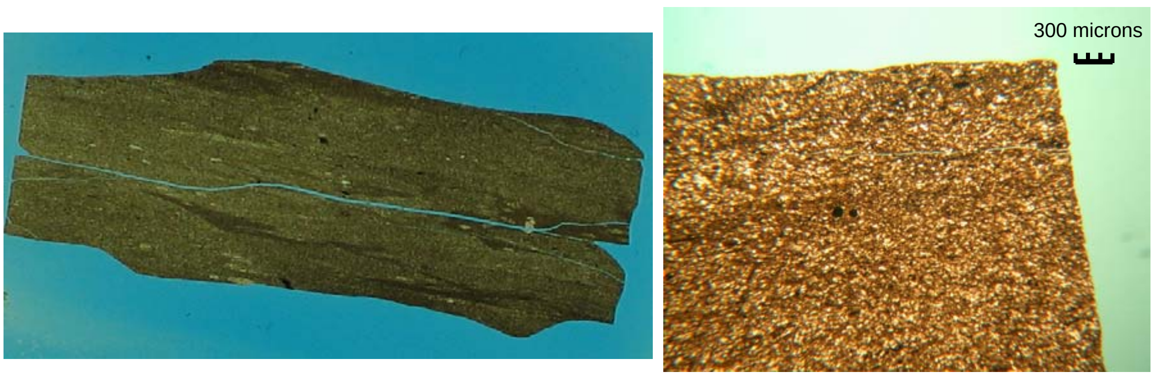

Figure 11 - Morrow Shale Exposed to Diesel After 6 Hours

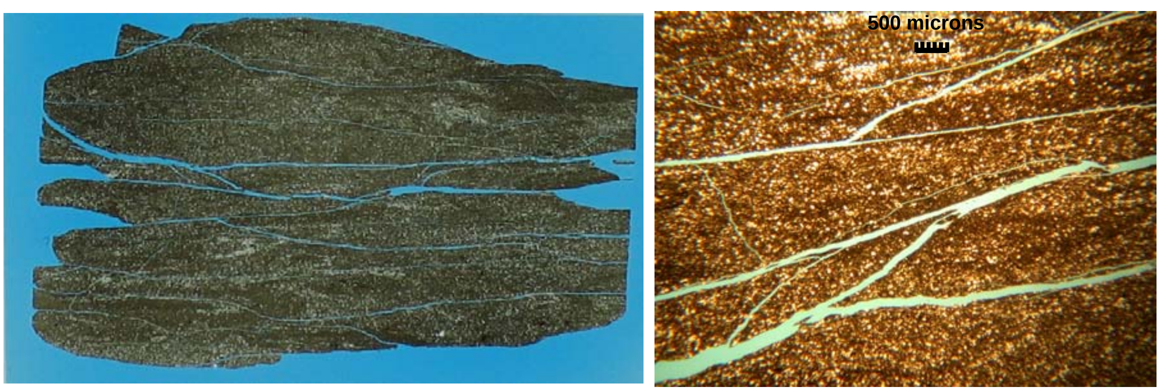

Figure 12 - Morrow Shale Exposed to Water After 6 Hours