Wettability and Prediction of Oil Recovery from Reservoirs Developed with Modern Drilling and Completion Fluids

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Given the extreme ecological sensitivity of the Arctic region, new environmentally friendly synthetic oil-base muds (SBM) are likely to be used for drilling wells. Oil company experience using SBM has shown that it can change the wettability of cores, causing great uncertainty in estimates of secondary recovery. For example, the uncertainty in waterflood residual oil saturation due to invasion of SBM has been found to be in excess of 20% PV, which significantly impacts the economics of waterflooding. It is vital that the recovery from different schemes be evaluated accurately so that the Arctic reserves are developed efficiently. Low-invasion coring, which is used to minimize alteration of core properties, is not always viable due to drilling considerations or if the formation is very permeable.

This research will improve our fundamental understanding of the factors that cause SBM to change the wettability of cores. Wetting changes due to SBM components will be tested on smooth mineral surfaces and in cores that have previously been exposed to reservoir fluids; cleaning and restoration procedures specific to different oils, surfactants, and mineralogy will be developed. The immediate focus is on finding methods to clean and restore cores to the *in-situ* condition for rocks and fluids that are relevant to arctic reservoirs. However, we expect this research will also serve to guide industry efforts to design muds that are both environmentally friendly and non-damaging with respect to core wettability.

The Department of Energy will provide federal funding of $850,000 for the three-year project. The New Mexico Institute of Mining and Technology will contribute $270,000, and the University of Wyoming will contribute at $150,000.

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OBJECTIVES

The objectives of this project are (1) to improve understanding of the wettability alteration of mixed-wet rocks that results from contact with the components of synthetic oil-based drilling and completion fluids formulated to meet the needs of arctic drilling; (2) to investigate cleaning methods to reverse the wettability alteration of mixed-wet cores caused by contact with these SBM components; and (3) to develop new approaches to restoration of wetting that will permit the use of cores drilled with SBM formulations for valid studies of reservoir properties.

SCOPE OF WORK

There is an ever-expanding universe of synthetic oil-based mud (SBM) formulations. This project will primarily target the components of SBMs likely to be applied in the context of drilling and completing wells in an arctic environment. Identification of such muds and their components will be the first step. For wettability testing, crude oils representing a range of chemical and wetting properties will be identified together with a set of lithologies. Baseline studies will include both surface and core tests of wettability alteration with the selected oils in each lithology. Surface studies will then be focused on examination of the effects of mud components on surfaces before and after contact with oil to identify the components and concentration ranges where wettability alteration is significant. Finally, cleaning and restoration schemes will be tested on smooth surfaces and the most promising will become the basis for proof of concept testing in cores.

TASKS TO BE PERFORMED

Task 1 Baseline surface studies

Task 1 will begin with identification of materials to be included in the initial rounds of surface testing. SBM formulations that meet the needs of arctic conditions will be identified in discussions with mud producers and drilling experts. Crude oils representative of different chemical classes will be selected from the existing crude oil library and/or new samples provided by oil companies interested in this project.

Baseline testing will include chemical characterization of the oil samples (including possible asphaltene destabilization by SBM base oils) and interfacial tension observations of surfactants as a function of concentration and of fluids selected. The next level of baseline testing is to observe COBR interactions between oil, brine, and clean mineral surfaces in the absence of contaminants. In successive steps, the surface active SBM components will be tested for wetting alteration on clean and on oil-treated surfaces, removal of contaminants from these surfaces will be examined, and finally, the possibility of wetting restoration will be tested. At each step, representative and/or promising systems will be selected for core testing. *New Mexico Tech is primarily responsible for Task 1.*

Task 2 Mixed-wet cores

Rock samples will be selected and characterized by measurements of porosity, absolute permeability, and mineralogy of the rock samples. COBR interactions will be explored in combinations of different oils and core types in the absence of contamination, using the rate of imbibition to assess core wetting. *The University of Wyoming is primarily responsible for Task 2.*

Task 3 Contamination, cleaning, and restoration

Based on the results of baseline testing and generation of mixed-wet conditions in cores, systems will be selected for studies to investigate the extent of wettability alteration in cores exposed to varying levels (corresponding to low levels that might be present in a filtrate and to high levels more representative of the conditions experienced by cuttings) of SBM surface active materials. In subsequent tests, contaminated cores will be cleaned using the results of Task 1 to select cleaning solvents and sequences. Finally, in the most successfully cleaned cores, restoration of wettability will be attempted using the same brines and oils originally used to generate mixed-wet conditions. *Task 3 will be the join responsibility of New Mexico Tech (selection of test variables, evaluation of results) and the University of Wyoming (core testing and evaluation).*

Task 4. Reporting

Reports on technical progress will be prepared semiannually. A final report will be prepared at the conclusion of the three-year project. Significant findings will be offered for presentation at appropriate professional meetings and submitted for journal publication. Collaborators will arrange an organizational meeting of researchers with representatives from DOE and industry to discuss candidate crude oils, rocks, base oils, and surfactants for this study. Other opportunities for technology transfer, including web-based information sharing, will be pursued actively.

Project Schedule