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Observing Fines Releases and Expanding Minerals with an Environmental - Variable Pressure - Field Emission Scanning Electron Microscope (E-VP-FESEM): Fresh Water Hydration and Wetting/Flooding Experiments on Cardium Formation Arenites, Wackes and Mudstones.

Krause[1], Federico F., DeBuhr[1], Chris L., Rojas[1], Camilo A., Wiseman[2], Andrew C., Watson[3], Ron L. and Meyer[1], Rodolfo O.

1. Department of Geoscience, University of Calgary; 2. Lightstream Resources; 3. Morichal Energy Corporation

Widespread drilling of horizontal wells into the halo of existing Cardium Formation reservoirs necessitates improvements in our understanding of the rock quality of the formation. For this purpose we are conducting studies of the Cardium Formation along the southwest and western margins of the Pembina Field with the Tight Oil Consortium (TOC) and the Instrumentation Facility for Analytical Electron Microscopy (IFFAEM) at the University of Calgary.

As is well established, Cardium Formation petroleum fields in west-central Alberta can be characterized effectively in ascending order with 6 lithofacies: 1. Dark grey, bioturbated, very thinly and thinly bedded, silty mudstones; 2. Bioturbated, very thinly and thinly bedded, silty and, very fine- and fine-grained wackes; 3. Laminated and thinly interbedded shales and very fine- and fine-grained sandstones; 4. Medium to thick bedded, very fine- and fine-grained sandstones; 5. Chert pebble conglomerate; 6. Pebbly mudstones and very thinly and thinly bedded, very fine- and fine-grained wackes. Petrologically the fine-grained rocks are lithic- and sublihic- arenites, wackes and mudstones, whereas the conglomerates are dominated by chert.

In the instance of the Pembina Field the productive halo of the reservoir comprises mainly rocks of lithofacies 2, 3, 4 and to a much lesser extent rocks of lithofacies 5. Net pay thicknesses determined from logs (density porosity and resistivity) and core analyses range from 0 to 14 m. Cutoffs are placed at 6% sandstone density porosity and 20 Ωm resistivity. Observations from producing horizontal wells along the northwest margin of the field indicate that optimum production is obtained from rock intervals with 4-6m of net pay and wells >1800m long with ≥ 20 fractures/interval. Importantly base fluids used during fracking have a strong influence on the first year of oil production of a well. Slickwater completed wells have been observed to outperform wells where other fluids were used for fracking. On the other hand fresh water floods have been used for repressurization purposes over most of the Pembina field for the past 60 years. While waterflooding has achieved the intended purpose, rapid oil production declines have been observed in many areas of the field when flood water contacts a producing well.

Too examine the effects of water-rock interactions in the Cardium Formation two types of experiments with fresh water were run in the chamber of the E-VP-FESEM using a Peltier stage, namely, active wetting and passive hydration tests. Samples for these tests were obtained from cores that were cold cut. During active wetting experiments water is allowed to condense on rock surfaces. In this instance the rock is imaged continuously and water condensation is observed to advance actively on the rock surface. Following complete immersion and while imaging continuously, water is allowed to retreat actively by evaporation. Alternatively, in the passive hydration experiments, the sample chamber of the microscope is saturated with water vapour, but below the threshold of condensation. Under this condition the rock sample is left to absorb the water for a defined period of time and imaged at the start and completion of the experiment, or at specified intervals during the experiment.

Throughout active saturation experiments on samples of Cardium Formation lithofacies 1-4 the continuous release and separation of fines from the rock surface is observed. Notably all kinds of minerals grains, individually and in clusters, are seen to be displaced and move with the advancing water. In areas that contain masses of swelling clays these materials will bulk up, expand and extrude from the sample. During active desaturation, water retreats and particles will reaccumulate on the rock surfaces, in some instances in the pores from which they originate. Materials that swelled and expanded during saturation will shrink, diminish and return to conditions similar to those at the start of the experiment.

Passive hydration experiments are not as dramatic as the active saturation experiments. During passive hydration, swelling minerals will expand and progressively alter the rock surface and any visible pores. In the latter case, pore sizes shrink and the porous system is modified by dislocation of mineral materials. Both pore bodies and throats sizes are reduced.

The experiments described herein clearly document the release and movement of fines and the reduction of both pore bodies and throats sizes with the expansion of clay minerals. Both processes are deemed to occur at reservoir scale in the subsurface (*e.g.* during waterflooding), as well as during the processing of core samples during core analyses when fresh water is used.