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Improved Amott Experiments Capture Dynamics of Spontaneous Imbibition into Mixed-Wet Carbonate-Rock with Non-Zero Initial Brine Saturation

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Spontaneous imbibition of brine at nonzero initial water saturation is an important mechanism for recovering crude oil from mixed-wet heterogeneous carbonate rock. Many studies focus on studying or modeling spontaneous imbibition of brine into fully oil-saturated (i.e., without connate water) or water-wet porous media. As a result, adequate models describing spontaneous imbibition process into rock with nonzero initial water saturation and mixed-wettability do not exist.

First, we review the experimental variables that are important for spontaneous imbibition in water-wet and mixed-wet rocks in the presence of connate water. We show that the classic Amott experiment, broadly used to evaluate ultimate oil recovery, masks several flaws that hinder the interpretation of recovery dynamics and thus the development physical and predictive recovery models. The key aspects are 1) contribution of the buoyancy-driven oil production; 2) wettability-dependent oil hold-up at the core surface; and 3) inconsistent outer surface wettability of mixed-wet limestone core plugs.

We then modify the classic Amott testing procedure to minimize experimental artifacts in the recovery dynamics. The main modifications include the following: 1) capping the top and bottom faces of core plugs with glass discs to eliminate the axial flow and enforce only 1D radial two-phase flow; 2) continuous shaking throughout the entire experiment to eliminate the oil external-surface hold-up with different core wettability states; 3) degassing of both brine and oil prior to any experiments. We show that the modified Amott experimental procedure obtains smooth and reproducible oil-recovery histories for oil-saturated core plugs with different wettability conditions of limestone rock. Figure 1 compares the cumulative oil recovery versus square root of time in the classic Amott test and with the introduced modifications. Note the smooth oil recoveries compared to the classic procedure.

Finally, we show that the resulting smooth recovery profiles of oil production can be described by a statistical model that fits the data very well. For the first time, we demonstrate that generalized extreme value (GEV) distribution can be applied to model spontaneous brine imbibition into water-wet and mixed-we cores in the presence of connate water. Figure 2 is an example of the GEV scaling of cumulative recovery versus square root of dimensionless time for water-wet core plugs.

The next step in developing our new approach to modeling spontaneous imbibition in the presence of connate water is to elaborate on how the distinctions of the physical processes during oil recovery by spontaneous imbibition are reflected by the GEV statistics. We believe, that our GEV modeling approach will serve as a foundation for the development of a next-generation predictive model of oil-recovery dynamics from mixed-wet carbonates.

Participation

In-Person

References

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