Title: “Evaluation of the Impact of Reservoir Heterogeneity and Mixing on Low Salinity Waterflooding”

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Abstract:
The impact of heterogeneity induced mixing between the injected low salinity water and the high salinity connate water is investigated in secondary low salinity waterflooding (LSW). Although LSW has proved to be a promising EOR process in laboratory experiments and field trials, its efficiency can be altered due to mixing with in situ higher salinity connate water. This mixing is caused by molecular diffusion and dispersion and it has been suggested that it may be exacerbated by heterogeneity.

We have investigated the impact of 1) conformance caused by layering in the sandstone and 2) mixing caused by water-saturated shale layers adjacent to the reservoir sand on recovery. The study used a commercial reservoir simulator in which LSW is modelled by varying relative permeability as a function of salinity. Prior to evaluating the impact of mixing on oil recovery by LSW it was essential to a) validate the formulation used to model diffusion (longitudinally and transversely) in the numerical simulator and b) ensure that our simulations were dominated by physical rather than numerical dispersion. This was achieved by performing grid refinement studies of single phase flow for longitudinal diffusion and transverse diffusion.

For the longitudinal diffusion investigation, a single phase 1D model was used with low salinity water displacing high salinity water. It was found that physical dispersion can only be modelled for when the grid Peclet number is less than 60, for higher values numerical dispersion dominates over physical values. This threshold Peclet number varies with the number of grid blocks, e.g. the optimum number of grid blocks was found to be 10 for (Pe <12) compared with 1000 grid blocks (Pe = 60).

For the transverse diffusion investigation, a single phase 2D model was used with two layers having two producers and two injectors. In the top layer, low salinity water is injected at the model’s edge and producing it at the other edge. While for the bottom layer, high salinity water is injected at model’s edge and producing it at the other edge. It was found that the discretization of at least 2 grid blocks per each layer is essential to capture the physical transverse mixing between layers.

For two phase flow, the transverse dispersion number (NTD) originally proposed by Lake and Hirasaki (1981) is shown to be a very robust way to measure the impact of mixing on the performance of LSW. Generally, for any (NTD > 1), diffusion dominates the flow and thus the efficiency of LSW is reduced.

In the absence of shales, it was shown that that mixing improves incremental oil recovery especially as the high permeability layer adjacent to low permeability layer is thinner. This is because the salt in high salinity connate water bank in the low permeability layer is diluted as a result of diffusion of the salt into the low salinity water in the higher permeability layer.

However in the presence of shaly zones filled with high salinity connate water, it was found that molecular diffusion reduces the effectiveness of LS. This performance reduction is more noticeable as the thickness of the sand layers between the shales decreases.
**Short Bio:**

2002-2006: Bachelor of Science in Petroleum Engineering, KFUPM, Saudi Arabia  
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